i. PREFACE

The original High Speed Craft (HSC) Human Factors Engineering (HFE) Design Guide was published in 2008 and won the Seawork International Innovation Showcase award for the Vessel Design & Construction category. Subsequently it has gone on to become a standard reference for HSC design and procurement around the world.

In the seven years since it's release the development of science and technology relating to HSC design and operation has continued at a rapid pace. Therefore it has been possible to develop a supplement to the original Guide to disseminate current best-practice to enhance HSC performance and safety.

The aim of the Guide is to be a practical reference for Designers to use as they develop new HSC and retro-fit systems in existing / legacy HSC. We welcome feedback on the original Guide, and this supplement, so as to continue its future development to support the HSC Community.

Acknowledgments:

- The UK MOD for sponsoring the development of the Design Guide, particularly Tony Springall; Naval Advisory Group, DE&S.
- The US Navy and the US Coast Guard for supporting the development of the Guide
- The ABCD Working Group for Human Performance at Sea for supporting the development of the Guide.
- Tim Thompson (T-Design) for illustrative support.
- Bill Sheppard for his Foreword section on support for the Guide and the HSC community.

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ii. FOREWORD

In their **High Speed Craft Human Factors Engineering Design Guide,** Messers Dobbins, Rowley and Campbell have addressed a very complex design challenge which may be unique in the engineering disciplines. No other vehicle-operator systems on land, sea, air, or in space, experience the range of motions, loads, and environments which are routine on small craft, moving at high speed, in a seaway.

The need for more comprehensive development processes for small craft is at hand. Requirements for coastal patrolling, port and harbor security, anti-piracy, and maritime counterterrorism operations are all increasing. Many of these critically important missions can only be done effectively from small craft platforms. These craft are often highly specialized and must be optimized by careful design and integration efforts.

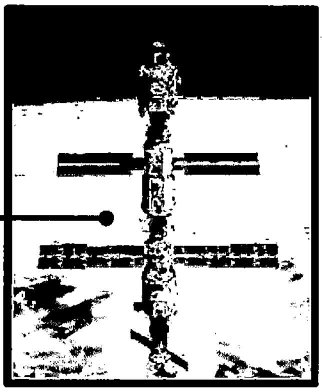
Many advances from aerospace, defense, and information technology sectors have found their way into today's high-speed craft. Composite materials, gas turbine and high speed diesel power plants, flat panel displays, and CAD/CAM models are now routine in small craft developments. Many new hull forms are available which further extend small craft performance. All of these advances have enabled craft to achieve higher speeds, ranges, and payloads, but many of these changes impose unique operational constraints and compromises. Similar issues with aircraft and spacecraft result in them receiving "placards" which limit their operational envelopes. Synergy between high-speed craft and aerospace systems, engineering, and operational "cultures" will continue. As an example, protective aircraft canopies have become fixtures on some offshore raceboats.

The need for 6 Degrees-of-Freedom craft motion analysis early in the design process is highlighted. Impressive shock data is presented from RIB craft, operated under "normal" conditions; similar vehicle shock loadings would only be found in auto crashes and aircraft ejections. Important work remains for the future—fully effective models for predicting the risk of motion-induced injury to the whole human body, suitable for the high-speed craft environment, remain elusive.

Today's design task is increasingly complex; the goal should be a platform where human considerations are fully integrated with performance requirements, with crews able to operate the craft with good function, efficiency, and safety. The Design Guideline is a rational, comprehensive, and much needed approach to this end.

Bill Sheppard:

- US Navy SEAL Officer (Rtd.)
- NASA Astronaut:
  - Space Shuttle missions; STS-27 1988, STS-41 1990, STS-52 1992.
  - International Space Station, Commander of Expedition 1; 2000-2001.
- Technical Advisor to US SOCOM; 2008-2011



iii. CONTENTS

iv. ABBREVIATIONS

%ILE	Percentile
3D	Three Dimensions
6DOF	6 Degrees Of Freedom
AR	Augmented Reality
C2	Command & Control
CAD	Computer Aided Design
CADMID	Concept, Assessment, Development, Manufacturing, In-service, Disposal
CAM	Computer Aided Manufacture
CB	Combat Boat
CCG	Canadian Coast Guard
CHIEF	Comprehensive Human Integration Evaluation Framework
CONOPS	CONcept of OPerationS
COTS	Commercial Off The Shelf
DE&S	Defence Equipment & Support
DHM	Digital Human Model
DOD	Department Of Defense
DEFSTAN	Defence Standard
DYNAV	DYnamic NAVigation
EAV	Exposure Action Value
EHFA	Early Human Factors Analysis
ELV	Exposure Limit Value
EU	European Union
FRC	Fast Rescue Craft
HCD	Human Centred Design
HF	Human Factors
HFE	Human Factors Engineering
HFI	Human Factors Integration
HFIP	Human Factors Integration Plan
HIC	Head Injury Criterion
HP	Host Platform
HRL	Human Readiness Level
HSI	Human Systems Integration
HSC	High Speed Craft
H-SURV	Health SURVeillance
ICI	Impact Count Index

IMO	International Maritime Organisation
INCOSE	INternational Council On Systems Engineering
ITEAP	Integrated Test, Evaluation and Acceptance Plan
JCS	Joint Cognitive System
JIP	Joint Industry Project
JSP	Joint Services Publication
KTS	KnoTS
L&R	Launch & Recovery
LAURA	LAUnch and Recovery of Any small craft
LCG	Longitudinal Centre of Gravity
MAIB	Marine Accident Investigation Branch
MAS	Maritime Autonomous Systems
MCA	Maritime & Coastguard Agency
MGN	Marine Guidance Note
MIF	Motion Induced Fatigue
MII	Motion Induced Interruptions
MOTS	Modified Off The Shelf
MSI	Motion Sickness Incidence
MOD	Ministry Of Defence
NPS	Naval Postgraduate School
PAD	Physical Agents Directive
PAX	Passenger
PPE	Personal Protective Equipment
RACI	Risk of Acute and Chronic Injury
RAIDO	Risks, Assumptions, Issues, Dependencies and Opportunities
RIB	Rigid Inflatable Boat
RINA	Royal Institution of Naval Architects
RNLI	Royal National Lifeboat Institution
RS	Repeated Shock
RYA	Royal Yachting Association
S4I	Standardisation for Interoperability
SA	Situation Awareness
SAR	Search And Rescue
SE	Systems Engineering
SME	Subject Matter Expert
SOP	Standard Operating Procedure

SQEP	Suitably Qualified and Experienced Person
SRD	System Requirements Document
SRL	System Readiness Level
SSRS	Swedish Sea Rescue Society
STAS	Short Term Air Supply
SWL	Safe Working Load
T&E	Test and Evaluation
TA	Task Analysis
TNA	Training Needs Analysis
TRL	Technology Readiness Level
UIM	Union Internationale Motonautique
UK	United Kingdom
URD	User Requirements Document
US	United States
USCG	United States Coast Guard
USV	Unmanned Surface Vessel
VDV	Vibration Dose Value
WBV	Whole Body Vibration

v. INTENDED AUDIENCE

NAVAL ARCHITECTS & DESIGNERS

This Guide is designed so that it may be used as a resource for the Naval Architecture (NA) and Design community. It is envisaged that it may be used as a (quick) reference that NAs can utilise in their every-day activities allowing them to rapidly gain a basic understanding of the Human Factors (HF) issues, potential design solutions, and where to source further, more detailed information when required.

ACADEMIA

This Guide is designed so that it may be used as a resource for the academic Naval Architecture and Design community. It is envisaged that it could form the basis of a module / course, or be used as reference material within individual lectures. The information on the HSC design process should allow students to obtain a greater understanding of how HF are integrated into the design of the craft.

PROCUREMENT AGENCIES

This Guide is designed so that it may be used as a resource for the HSC procurement / acquisition community. It is envisaged that the guideline may be referenced in tender documentation, therefore reducing the amount of detailed HF requirements that need to be included in the documentation. System suppliers may then be asked to document where and why they have not followed the advice within the document (i.e. compliance with the SRD). The guideline also provides advice on how to include objective HF requirements within the Specification and T&E processes and therefore assist in the procurement / acquisition acceptance process.

REGULATORY BODIES

This Guide is designed so that it may be used as a resource for Regulatory Bodies (e.g. UK Maritime & Coast Guard Agency). It is envisaged that such bodies may use the guide as reference material when providing advice to HSC designers, manufacturers, and operators.

HUMAN FACTORS SUBJECT MATTER EXPERTS

This Guide is designed so that it may be used as a resource for the Human Factors SME community. It is envisaged that it may be used as reference and guidance material for HF SMEs who are not familiar with the specific requirements of HSC design and operation. The information on the HSC design process should allow them to obtain a greater understanding of the constraints and compromises involved in the design of HSC.

vi. THE USE OF THE GUIDE:

THIS GUIDE DOES NOT:

Provide detailed anthropometric data on which to base a HSC design. This is to ensure that the dimensions are not taken out of context, and because different nations have differing operator sizes. The designer should refer to the appropriate countries most up-to-date source of anthropometric data. Examples of anthropometric data sources are given within the appropriate Sections.

DISCLAIMER

DOCUMENT RELEASE CONDITIONS

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COMMENTS & FEEDBACK

The authors welcome comments and feedback on this guide and where appropriate will endeavour to incorporate these into future updates of the Guide. These can be addressed to:

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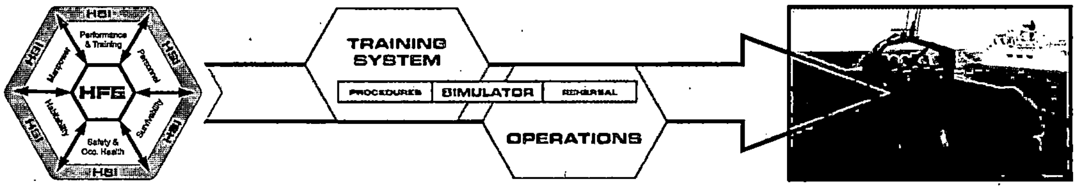
1. HUMAN FACTORS INTEGRATION (HFI)

SUMMARY

Human Factors Integration (HFI) and Human Systems Integration (HSI) are an integral part of the Systems Engineering process that delivers safe and effective systems. The importance of HFI / HSI is recognised by official organisations and is a requirement of the UK MOD (JSP 912) the US DOD (DOD 5000) and the USCG (COMDTINST M5000.10). Human Factors Engineering (HFE) is one of the HFI / HSI domains, but does not stand in isolation from the other domains. Rather, all of the domains are interrelated and feed into the development of optimised solutions. An example being the link between HFE and training, where operational effectiveness requires systems to support training (e.g. simulation) as well as the operations.



1.1: INTRODUCTION

The human is the most important aspect of maritime operations. This is recognised by the International Maritime Organisation (IMO) who adopted the Human Element resolution in 1997[1]. In the same way the military recognise that *'Humans are more important than hardware'*[2]. Human Factors Integration (HFI), also known as Human Systems Integration (HSI), are an integral part of the Systems Engineering (SE) process that delivers safe and effective systems. The importance of HFI / HSI is recognised by official organisations and is a requirements of the UK MOD (JSP 912[3]), the US DOD (DOD 5000) and the U.S. Coast Guard (COMDTINST M5000.10). Human Factors Engineering (HFE) is one of the HFI / HSI domains, but does not stand in isolation from the other domains. A more detailed comparison of the similarities between the UK MOD HFI initiative and the US HSI initiative is provided in Appendix 1.

The HFI / HSI process share the following common domains:

- Human Factors Engineering (HFE)
- Manpower
- Personnel
- Training

In addition to these common domains, the two initiatives address other aspects of the human integration into systems including:

- Safety
- Health Hazards
- Occupational Health
- Survivability
- Habitability

Although all of the domains need to be addressed to develop an optimised system / solution, this guide focuses on the HFE aspects. It should be noted that many aspects of the domains are interrelated and feed into the HFE Domain. This is graphically illustrated below in Figure 1.1.

[1] http://www.imo.org/OurWork/HumanElement/Pages/Default.aspx

[2] http://www.socom.mil/Pages/SOFTruths.aspx

[3] MOD JSP 912 Human Factors Integration for Defence Systems. Part 1: Directive (Pt 1 V1.2 Feb 15)

MOD JSP 912 Human Factors Integration for Defence Systems. Part 2: Guidance (Pt 2 V1.2 Feb 15).

Figure 1.1: The Human Systems Integration (HSI) Domains linking to HFE.

The link between HFE and the other domains can be straightforward to demonstrate, e.g. training. In addition to designing the HFE aspects of a HSC, the training system to support operations must also be considered at the same time. Within the maritime sector this will include the use of simulation where specific HFE aspects will need to be addressed. Figure 1.2, below, illustrates this process with additional information being provided in Section 1.9.

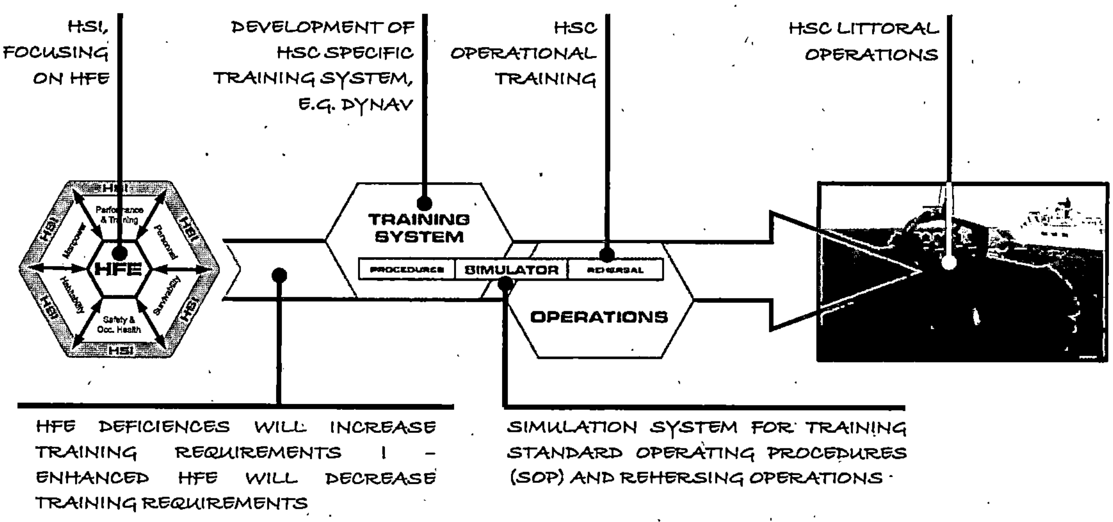


Figure 1.2: An illustration of the link between HSI - HFE - Training and Operations.

Naval Architects and Designers are required to comply with Classification Society rules. Human Factors are being included with Classification Society rules, the following is an example from Lloyd's Register[4] regarding HFI;

*"One of the most important elements in ensuring any system or platform operates safely and efficiently **is the human element. It is critical that human factors are considered in the concept phase of a project** and that the standards and assessment criteria are carefully selected. Although some aspects of **human factors integration are implicit** within classification, many aspects must be undertaken as a consultancy type role. Care must be taken to ensure that these two elements integrate: a clear understanding of what class does and does not require for human factors is essential."*

[4] Lloyd's Register; Naval Ship Safety Assurance and the Role of Classification: Guidance for Navies and Shipbuilders, 2013

Subsequently, UK National guidance from the Maritime & Coastguard Agency (MCA) provides more detailed HFI / HFE design guidance[5]. The follow points are required by MGN 436 and are covered in more detail in Chapter 2 (Digital Human Models);

- **Correct Posture**
  - Facing in the direction of travel
  - Neutral spinal alignment – not twisted
  - Hand holds and support for postural stability
  - Shock mitigation requirement
- **Enhanced crew training and competency for high speeds and poor sea conditions**

The design and assessment of a HSC should follow a recognised Systems Engineering (SE) process, such as that described in the INCOSE[6] Systems Engineering Handbook. The link between SE and HSI / HFE has been described[7] and demonstrates the use of tools such as Digital Human Models (re: Chapter 2), and the need for a greater emphasis of HF within Classification Society rules and the subsequent assessment of HF requirements by Surveyors[8].

1.2: SYSTEM DESIGN, PROCUREMENT & OPERATION

For an organization to develop and maintain the capability to operate HSC effectively requires not only the craft, but also the infrastructure to support it. The ISO System Lifecycle Standard[9] describes the phases of the process as being:

[5] MCA MGN 436. Whole-Body Vibration: Guidance on Mitigating Against the Effects of Shocks and Impacts on Small Vessels.

[6] International Council On Systems Engineering

[7] Dobbins, T., McKesson, C. and Stark, J. (2012) Embedding Human Systems Integration within Marine Systems Engineering. Conference Proceedings; RINA Systems Engineering in Ship & Offshore Design Conference, London. March, 2012.

[8] Walker, O. (2011) The human element competency required for design appraisal. *Conference Proceedings; Human Factors in Ship Design And Operation, RINA, London.* November 2011.

[9] ISO 15288:2015 Systems and Software Engineering – Systems Life Cycle Processes

For the UK MOD, this process is described as the CADMID cycle; Concept, Assessment, Development, Manufacture, In-service and Disposal.

An essential element of the **C**oncept phase is the initiation of the Human Factors Integration Plan (HFIP).

1.3: HUMAN FACTORS INTEGRATION PLAN

A Human Factors Integration Plan (HFIP), also known as the HSI Plan, is recommended for all projects with an HF element, this is particularly to agree and secure HF support and resources. Human Factors Integration (HFI), or HSI is the process by which the product or equipment and users are brought together and may be defined as:

> *"A SYSTEMATIC PROCESS FOR IDENTIFYING, MONITORING AND SOLVING HUMAN RELATED ISSUES TO ENSURE AN OPTIMUM DESIGN, DEVELOPMENT AND INTEGRATION OF THE SYSTEMS HUMAN AND TECHNOLOGICAL COMPONENTS".*

The HFIP is the vehicle for ensuring that the human related issues associated with the design, development and integration of a system are identified, analysed and sufficiently addressed. The HFIP will detail how the various engineering disciplines responsible for delivery of HFI work together to address the issues. The users and other system elements need to be integrated, optimising safety and efficiency as well as considered throughout the systems life-cycle. The process of balancing the systems human and technology needs, is known as Human Centred Design (HCD), an internationally recognised process[10]. An example of the HCD process is shown below in Figure 1.3.

[10] ISO 9241-2010: Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems.

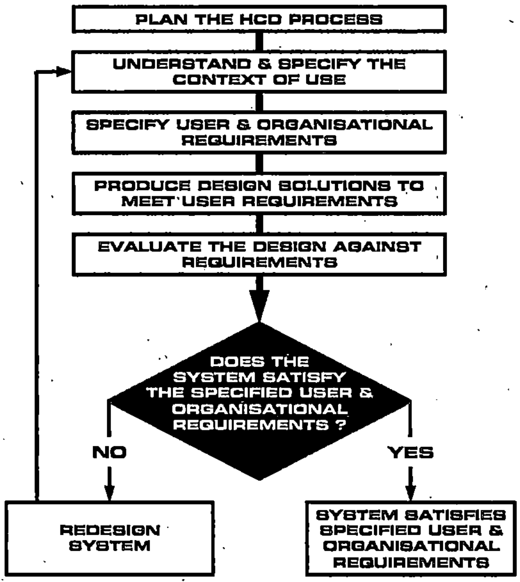


Figure 1.3: The Human Centred Design (HCD) Process

The HFIP should draw upon the project scope and depth of analysis required (which will vary from project to project) as well as review of the HFI issues contained in an Early Human Factors Analysis (See Section 1.4). The HFIP is tailored to each project, i.e. small projects will have a short plan, compared to larger, longer projects which will be more comprehensive. The HFIP will also be iterative as the project progresses. Typically an HFIP will contain:

- **Introduction:**
  - Project outline and scope
  - Key objectives and HF requirements
- **Approach:**
  - Document previous lessons, both identified and learnt
  - Document HF Methods to be used
  - Produce HF project risk register,
  - Engage stakeholders
  - Define / describe users (inc. anthropometry, education level, etc.)
  - Produce Task Analysis
  - Define Functions
  - Conduct Workload Analysis
  - Define User Interface requirement
  - Define Test & Evaluation plan
  - Integration with associated project documentation
  - Key Deliverables
  - Acceptance Criteria
- **Work Programme**
  - Define the HFIP timeline and resources required to fulfill the strategy
  - Define HF milestones (e.g. Design Reviews) and integrate with other project tasks, milestones and deliverables.
- **Management**
  - HF personnel
  - Stakeholders
  - Subcontractors
  - Subcontractor management
  - Customer(s)
- **Early Human Factors Analysis (refer to Section 1.4 below)**

This list is not exhaustive and is adjusted to suit the requirements of the project.

1.4: EARLY HUMAN FACTORS ANALYSIS

An Early Human Factors Analysis (EHFA) is undertaken at the start of all projects. Following the development of the HFIP, the purpose of the EHFA is to identify and record essential and important HF issues (considering all HFI / HSI domains) and risks, and support the production and initiation of the HFIP. This information is documented within an HFI Issues Log, also known as the HFI RAIDO[11].

The EHFA is undertaken by an HF SME in collaboration with other SMEs (e.g. systems engineers, ILS engineers, safety engineers and end user representatives). The analysis highlights the need for further studies to support the HFIP and how it will influence the design of the system and it's through-life support. The EHFA will:

[11] RAIDO; Risks, Assumptions, Issues, Dependencies and Opportunities

- Collate and review available information
- Generate HF requirements
- Develop plans to address HF issues within the overall project
- Ensure user issues are appropriately logged in all project documents.

1.5: LINK TO THE HSC SPECIFICATION PROCESS

The HSC Specification Process is outlined within Section 7 of the HSC HFE Design Guide[12]. It is essential that the HFE features are specified in an objective format, and the assessment methodology is included in the User Requirements Document (URD), Systems Requirements Document (SRD) and the T&E Assessment Plan (TEAP). The approach to the specification, design and assessment activities will be defined in the HFIP – including the EHFA. Also, within the URD, SRD and TEAP documents the full range of HSI / HFI domains, e.g. Training (see Section 1.9 below) must be considered.

The contractual specification for the HSC is where attention needs to be focused if good HFE is to be effectively integrated within the system. For the design team to invest the appropriate time and resources to the HFE aspects of the system, the requirements ***MUST*** written down or they won't be included. Also, if the requirement isn't written in an objective / quantitative format it will always be just someone's (a non-HF SME ?) interpretation / opinion, and potentially a contractually compliant – but poor solution, will be delivered. Similarly, if the specification can't be measured than it can't be assessed within the system Test & Evaluation (T&E) phase – and rejected if non-compliant. Therefore it is essential to commit resources to the HFE aspects of the specification production process if the crew and passengers are to receive an effective system that is both safe and supports their operational performance.

1.6: ASSESSING HF ACCEPTANCE

The design review process is an inherent paper of the system development process. Technology Readiness Levels (TRLs), developed by NASA[13], are a recognized method of assessing the development progress of the technical components and systems. To ensure that the HF aspects of the system are developed at an equivalent pace, Human Readiness Levels (HRL) have more recently been developed[14] and provide a review mechanism to help ensure that the HF aspects are developed at the correct rate. A comparison of the TRL and HRL scales is shown below in Table 1.1.

It should be noted that in this context TRLs and HRLs are a tool for the management of the development programme. They are to help identify whether aspects of the programme are on track, and where deficiencies are identified, decisions taken to ensure that all aspects of the programme progress at the correct rate. Figure 1.4 illustrates how the TRL may exceed the HRL and therefore additional resources be invested in the HF programme, or the technology programme slowed until the HRL matches the TRL.

Subsequently, System Readiness Levels (SRL) may be used as part of the assessment the total system. Within the MOD HFI process SRLs are aligned with the CADMID cycle (re: Section 1.2).

[12] High Speed Craft Human Factors Engineering Design Guide. ABCD-TR-08-01 v1.0

[13] Mankins, J. (1995) Technology Readiness Levels, A White Paper. Advanced Concepts Office, Office of Space Access and Technology, NASA.

[14] Philips, E. (2010) The development and Initial Evaluation of the Human Readiness Levels Framework. US NPS Thesis.

TECHNOLOGY READINESS LEVEL (TRL)		HUMAN READINESS LEVEL (HRL)
Actual system proven through successful mission operations	9	User interface successfully used in operations across the operational envelope
Actual system completed and qualified through test and demonstration	8	User interface of actual system complete and qualified across the operational envelope through operational testing
System prototype demonstration in operational environment	7	User interface prototype validated in operational environment
System / subsystem model or prototype demonstration in relevant environment	6	User interface prototype modified to incorporate lessons learned to provide optimal human performance, workload, situation awareness, usability, reach, fit, trainability and safety
Component and / or breadboard validation in relevant environment	5	User interface prototype validated in mission relevant simulation
Component and / or breadboard validation in laboratory	4	User interface prototype validated in part-task simulation
Analytical & experimental critical function and / characteristic proof of concept	3	Prototype of user interface developed
Technology concept and/or application formulated	2	Basic HF/E principles & standards applied to system design
Basic principles observed & reported	1	Basic HF/E principles observed & reported

Table 1.1: The Technology and Human Readiness Levels (TRL & HRL) descriptions. Note; the example HRL specifically relates to the user interface, wider HSI aspects are also considered using the HRL scale.

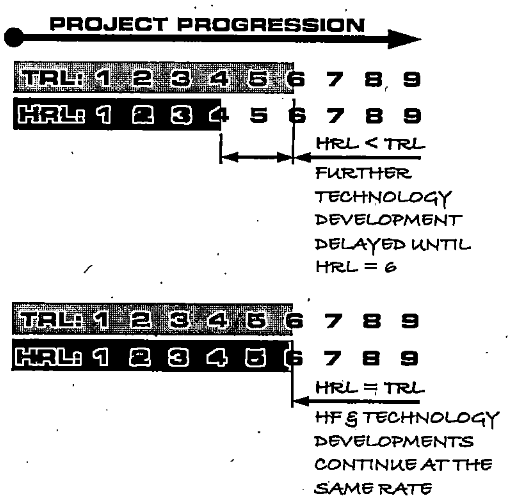


Figure 1.4: An example of TRL and HRL assessment and management at review milestones

1.7: HFI/HSI MANAGEMENT WITHIN THE PROCUREMENT / ACQUISITION PROCESS

There are many HFI / HSI process description that Procurement / Acquisition organisations are required to use, e.g. UK MOD JSP 912, US DOD 5000 and USCG COMDINST M5000.10. The guidance provided can be daunting for any organization, particularly those responsible for HSC where resources are limited compared to the capability the HSC deliver. Therefore practical tools are required to support the HFI / HSI process.

To support the implementation of HSI, and focus on total system performance within the maritime acquisition process, the USCG developed a simplified framework known as

CHIEF – **C**omprehensive **H**uman **I**ntegration **E**valuation **F**ramework. **CHIEF** was developed at the US Naval Postgraduate School[15] and builds upon the concept of Human Readiness Levels (HRL)[16]. **CHIEF** has been developed for the evaluation of USCG maritime acquisition programs. An essential lesson learnt in the development of the **CHIEF** framework is the need for HF SME's / SQEP to be involved from the start of the acquisition program.

CHIEF focuses on delivering a simple framework for evaluating HSI during acquisition. It utilises summary visualisation to illustrate to Project Mangers how the program's HF aspects are affecting the performance of the total system. This allows program personnel to ensure that human and technological elements (supported by HRLs and TRLs) of the system are being integrated to deliver the required capability. An example of a **CHIEF** HSI Performance Summary is shown below in Figure 1.5.

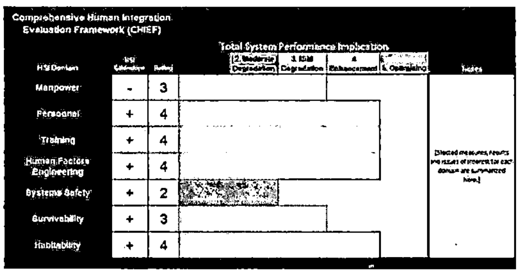


Figure 1.5: An example Comprehensive Human Integration Evaluation Framework (CHIEF) HSI Performance Summary with notional ratings shown for illustration only.

In the same way that HRLs allow project managers to understand how the system development is progressing in terms of the HF requirements, **CHIEF** also uses the concept of the 'HSI Glide Slope'. This illustrates whether system-specific HSI knowledge is being developed at the required rate to deliver the required system performance. (TRL & HRL = 9) on time. The ability to rapidly understand if the programme is on-track allows the Project Manager to make resource decisions, thus making corrections to the programme early and not having to deal with HF-related deficiencies at the end of the programme, which are difficult and expensive. The HSI Glide Slope definitions are shown below in Table 1.2 and a graphical representation of the Glide Slope concept, related to system maturity and performance, is shown in Figure 1.6. The illustration demonstrates how the ahead-of-schedule, positive (+), Glide Slope will increase the likelihood of delivering the required system performance, whilst the behind-schedule, negative (-), Glide Slope will result in degraded performance and compromised safety.

RATING	DEFINITION
On / above HSI Glide Slope (+)	The quantity and / or quality of contributing evidence on HSI activities is sufficient or more than expected for the given domain, in the current acquisition phase.
Below HSI Glide Slope (-)	The quantity and/or quality of contributing evidence on HSI activities is less than expected for the given domain, in the current acquisition phase

Table 1.2: HSI Glide Slope Definitions

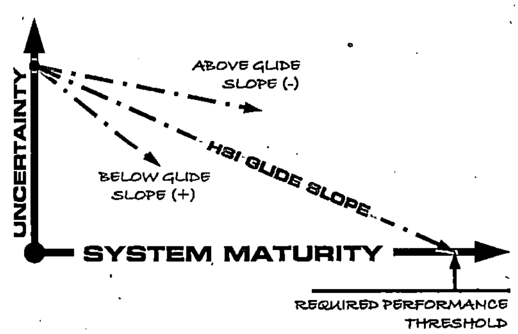


Figure 1.6: Illustration of Planned HSI Glide Slope Compared to Glide Slopes Ahead of, and Behind Schedule, to Achieve the Required System Maturity and Performance.

[15] O'Neil, M. (2104) Development of a Human Systems Integration Framework For Coast Guard Acquisition. US NPS Thesis.

O'Neil, M., Shattuck, L. and Sciarini, L. (2015) A framework for assessing and communicating human systems integration efficacy across the system lifecycle. Conference Proceedings; 6th International AHFE Conference 2015, Las Vegas, USA.

[16] Philips, E. (2010) The development and Initial Evaluation of the Human Readiness Levels Framework. US NPS Thesis.

Similarly, the HSI Glide Slope can also illustrate project risk and scheduling requirements which are essential for successful acquisition / procurement programmes. This illustration is shown below in Figure 1.7.

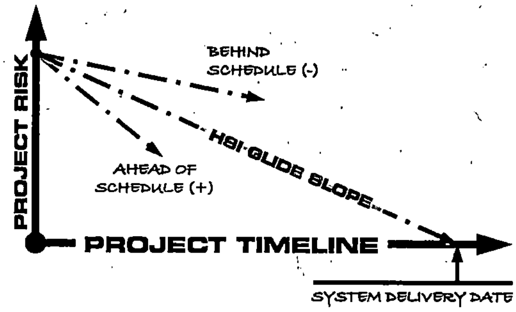


Figure 1.7: Illustration of Planned HSI Glide Slope Related to Project Technical and Schedule Risk.

Therefore where Procurement / Acquisition organisations need to implement HSI, tools such as **CHIEF** provide a framework for understanding how the HFI / HSI domains affect HSC system performance in supporting the maritime community to enhance both performance and safety.

1.8: THE INTEGRATED HSC DESIGN PROCESS

The HSC HFE Design Guide[8] describes how the Naval Architect's design process is integrated with the HF aspects necessary to deliver a fit-for-purpose HSC. The process, reproduced below in Figure 1.8, from the original HSC HFE Design Guide, is included as an aide memoir and to support the material provided within this Supplement.

1.9: LINK TO TRAINING

The early consideration of all of the HSI / HFI domains within the HFIP and EHFA provides the links to domains such as Training. Within the HFIP and EHFA there will be work packages to produce the detailed Task Analysis (TA) and Training needs Analysis (TNA), both of which will have a direct influence on the HFE system design aspects – and vice versa. The design of the training system, based on the TNA, is likely to include part-task procedural trainers, simulators, and craft specifically modified for training. All of these system components have HFE design requirements that must be considered at the appropriate time in the design process.

Some organisations, e.g. UK MOD, have policies (JSP 822[17]) that define how training systems should be developed and operated. The role of JSP 822 is to;

Provide recommended guidance to meet the Quality Standard to encourage a coherent approach across Defence and be a source of 'good practice' to optimise training across Defence.

Therefore the integration between policies such as JSP 912 (HFI) and JSP 822 (Systems Approach to Training) provide the basis for delivering an effective through-life system to deliver both safe and effective operations.

Anecdotal reports from experienced HSC operators have highlighted that:

USER INTERFACES WITH BETTER HFE WILL GENERALLY REQUIRE LESS TRAINING - OR - AN INTERFACE WITH POOR HFE WILL ALMOST CERTAINLY REQUIRE ADDITIONAL TRAINING TO REACH THE SAME LEVEL OF PERFORMANCE

POOR ERGONOMICS HAS CAUSED SIGNIFICANT SKILL FADE WHICH INCREASES THE CONTINUAL TRAINING, AND RE-TRAINING REQUIREMENT, JUST TO MAINTAIN THE MINIMUM LEVEL OF CAPABILITY

The use of HSI review tools such as **CHIEF** (re: Section 1.7), during the defined programme design reviews (re: Figure 1.8) means that the training requirements for the system will be continually addressed and refined during the development of the system. Thus both enhanced performance and reducing training requirements can be developed simultaneously.

[17] UK MOD, JSP 822; The Governance and Management of Defence Training & Education

NOTE:

This is a simplified design process for the purposes of illustrating Human Factors Integration (HFI) / Human Systems Integration (HSI).

HF LEGEND:

A: Motions

B: Sight

C: Sound

D: Environment

E: Health & Safety

F: Man-Machine Interface

G: Habitability

H: Maintainability

I: Design Review

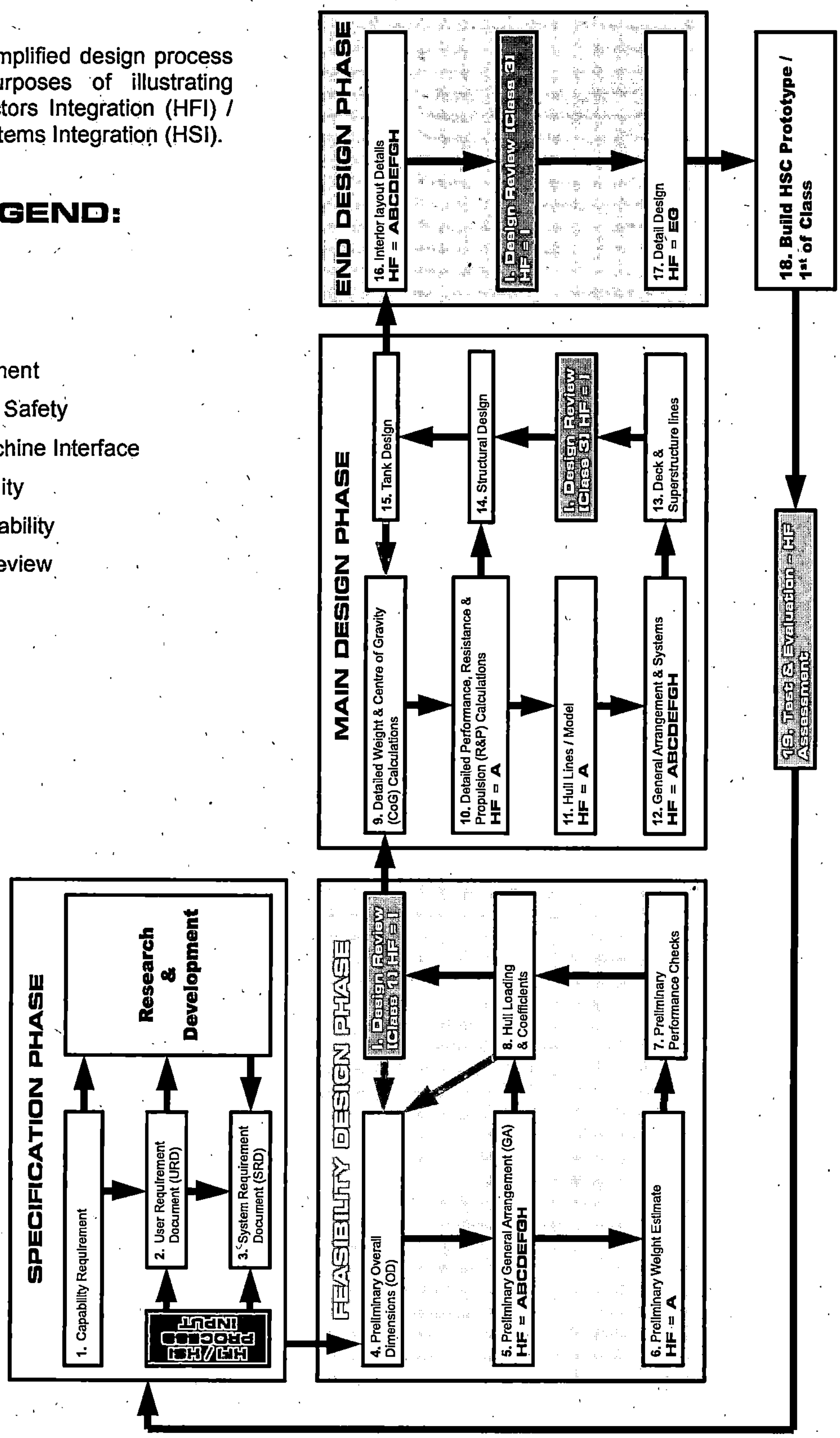
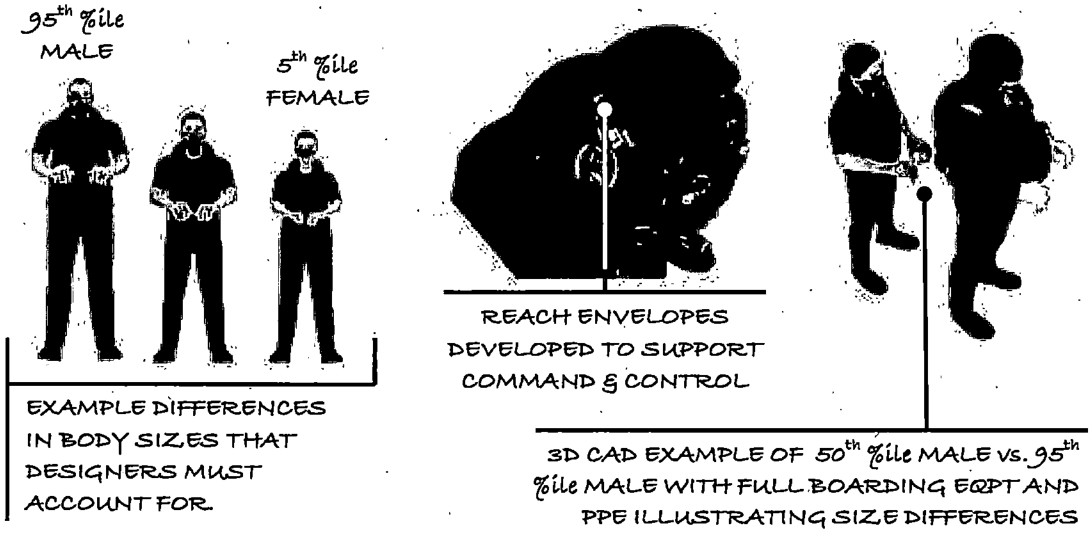


Figure 1.8: The Integrated High Speed Craft Design Process; Ref. High Speed Craft Human Factors Engineering Design Guide. ABCD-TR-08-01

2. DIGITAL HUMAN MODELS SUPPORTING HFI & HFE

SUMMARY

*Digital Human Models (DHM) are a support tool for Human Factors Engineering (HFE) within the Human Factors Integration (HFI) and Human Systems Integration (HSI) processes. Not only do they fill the space that Designers may otherwise need to leave empty within their craft but they allow for the correct posture, reach and vision envelopes to be established within the design during the start of the design process. It is only by being able to visualise how much space the humans take up, along with the clearance they need to moving around the craft and getting access to spaces, that it is possible to design the craft around the people – **NOT** – force the humans to have to cope and adapt to poor designs once they come into service.*



2.1: INTRODUCTION

The introduction of Computer Aided Design (CAD) to the design process revolutionised the ability of Designers to visualise their concepts in 3D before a mock-up was produced. Human Factors Integration (HFI) / Human Systems Integration (HSI) requires that the crew and passengers are considered to be an integral part of the system design process. With Human Factors Engineering (HFE) being a part of the HFI / HSI process it is essential that the human is effectively represented with the Designers CAD concepts. In the past Digital Human Models (DHMs) have not been included within CAD software programs, or where they are available they have been very simple and basic. To ensure the proposed design works, the DHM needs to have the appropriate anthropometric dimensions, e.g. 95th percentile (95th%ile), 50th percentile (50th%ile), and 5th percentile (5th%ile), for both males and females – refer to Section 3. Subsequently the DHM needs to be dressed in the appropriate clothing, Personal Protective Equipment (PPE) and operational equipment – all of which impacts on the size of the individual, their mobility / dexterity and the subsequent space requirements.

The Human Systems Integration (HSI) / Human Factors Integration (HFI) process includes Human Factors Engineering (HFE) / ergonomics. All vessels are designed using 3D Computer Aided Design (CAD) programs such as Rhino, Solidworks, etc. Typically designers have not included the human within these CAD models and so the resulting vessels have often had poor space allocation and working conditions for the human once the vessel is built.

2.2: THE DESIGN PROCESS

The HSC design process is described within Section 8 of the HSC HFE Design Guide[1].

It is difficult to leave empty space within a design for the humans to eventually occupy. No matter how hard the designer tries, someone will fill in the space with a structure, fixture, equipment etc. By having representative DHMs of the correct size this space envelope can be 'filled' with an appropriately sized human, and the designers / engineers will recognise that the space is **NOT** available for systems and equipment.

The use of DHMs is not new, but until now it has been relatively rare in the marine sector. Some DHMs have been used by designers but these typically have not been representative of the true size of the vessel occupants, both anthropometrically or accounting for the size and bulk of the Personal Protective Equipment (PPE) and operational equipment.

The following DHMs illustrate a number of the issues that designers must consider when developing their vessels. They must remember that the size of the human occupants are fixed and therefore the craft must be designed around the people – and therefore they cannot expect the humans to cope with poor designs with the inherent risk of reduced performance and risk of injury.

THE CRAFT MUST BE DESIGNED AROUND THE HUMAN - NOT - THE HUMAN BEING FORCED TO FIT THE BOAT - WHICH ALWAYS RESULTS IN DEGRADED PERFORMANCE AND AN INCREASED RISK OF INJURY.

Although some designers may not consider the human crew and Passengers (PAXs) to be the main design drivers, they are a principal design feature and constraint. The design **MUST** be tailored around the human and therefore the design sequence always starts with the human. This sequence is illustrated in Figure 2.1:

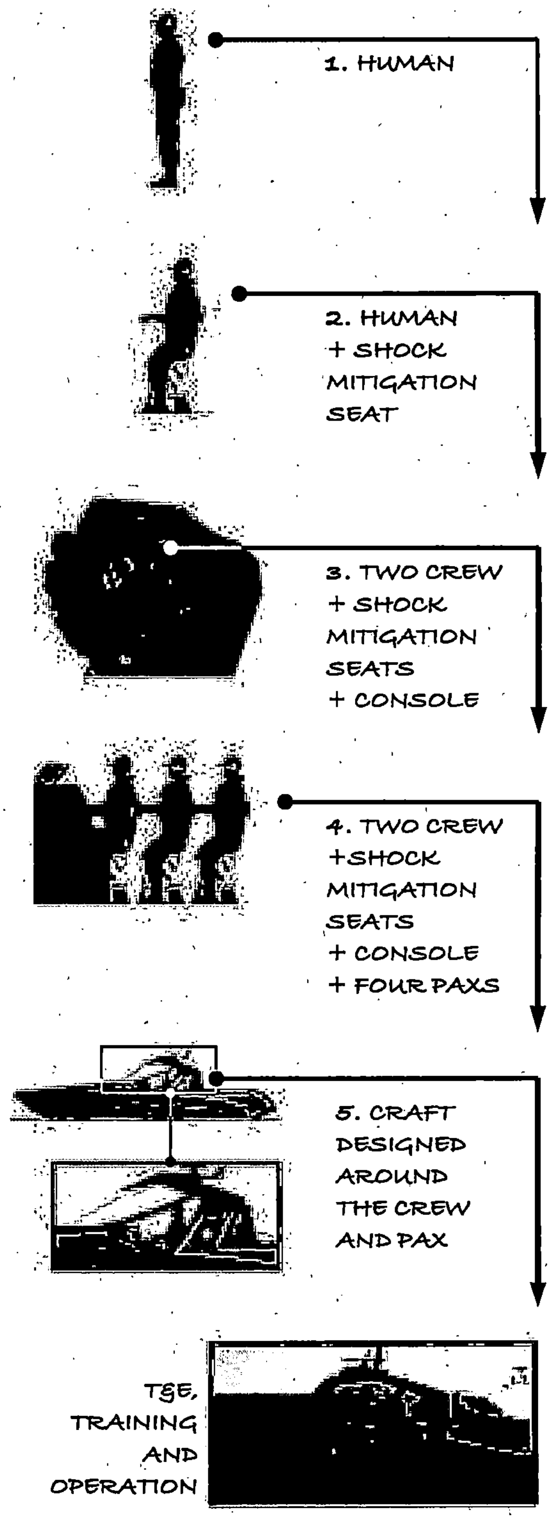
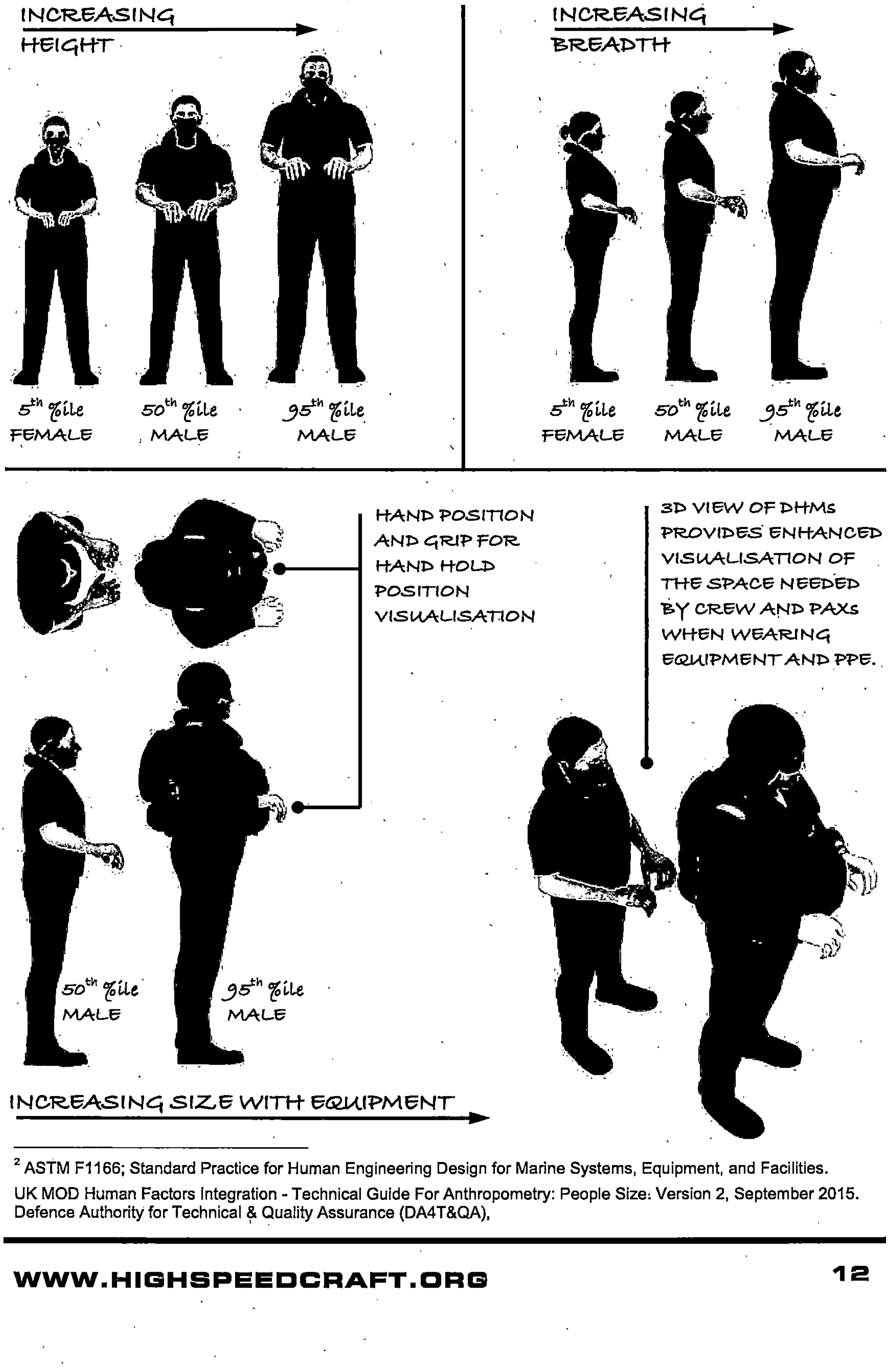


Figure 2.1: The Human Centred HSC Design Sequence

[1] High Speed Craft Human Factors Engineering Design Guide. ABCD-TR-08-01 v1.0

2.3: THE SIZE ISSUE

Humans come in a range of sizes that the designer must account for. Anthropometric guidance and databases[2] provide body size data that is used to ensure the boat features fit the human operator. The following illustrations provide an insight to the difference in sizes that Designers need to account for. These illustrations are based on the UK MOD anthropometry survey and provide the correct relative sizes.



[2] ASTM F1166; Standard Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities.
UK MOD Human Factors Integration - Technical Guide For Anthropometry: People Size: Version 2, September 2015. Defence Authority for Technical & Quality Assurance (DA4T&QA).

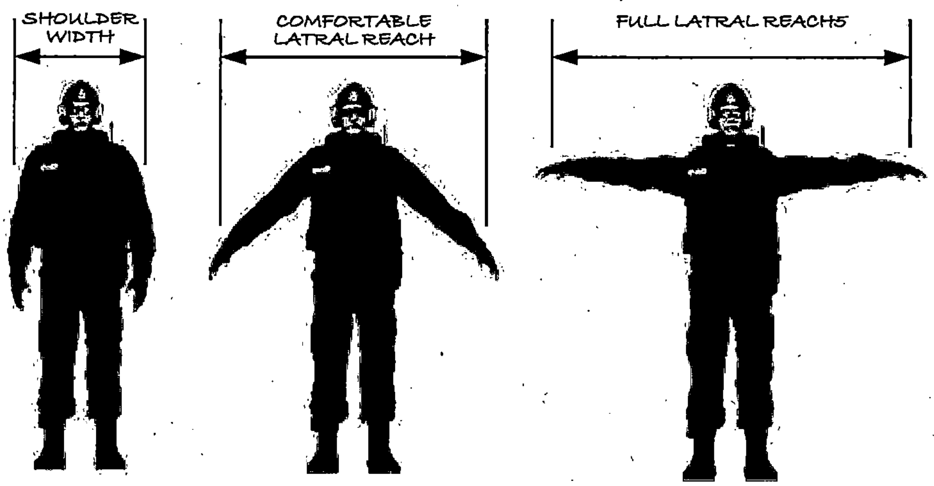
CAUTION: THE MYTH OF THE 5^{TH} & 95^{TH} %ILE HUMAN

95^{th} %ile males or 5^{th} %ile females do **NOT** exist. Humans are made up of a range of %ile dimensions. For example, an individual with a 95^{th} percentile standing height, may have 75^{th} percentile buttock to knee length. Percentiles relate to a specific attribute (e.g. standing height, shoulder (bideltoid) breadth, etc.) and therefore the appropriate %ile dimension(s) should be used for specific design requirements. It is essential that designers understand that in some areas they need to consider **BIG** dimensions, e.g. for access and clearance, whilst in other areas they need to consider **SMALL** dimensions, e.g. reaching controls from fixed seats.

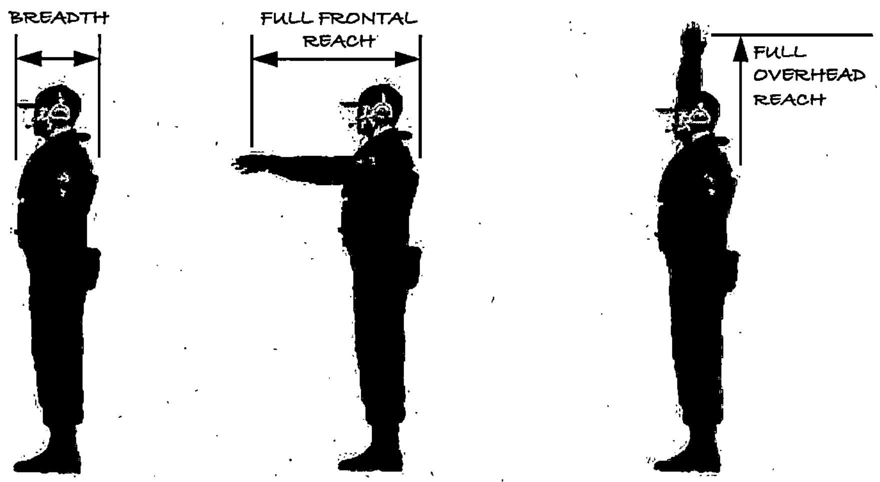
2.4: POSTURE RELATED SIZE REQUIREMENTS

The Designer, in addition to understanding the anthropometrical requirements of the crew and passengers, must account for all of the postures that the craft occupants will and may adopt during the operation of the craft. Examples of these postures and their sizes are illustrated below. The DHM is shown wearing typical maritime clothing and Personal Protective Equipment (PPE). On small fast craft there is often little consideration given to ingress, egress, escape & evacuation and restrictive access to areas of storage and maintenance. In the examples shown below in Sections 2.4.1 and 2.4.2 the shoulder width and breadth dimensions should be used in the design of access areas.

2.4.1: FRONT VIEW

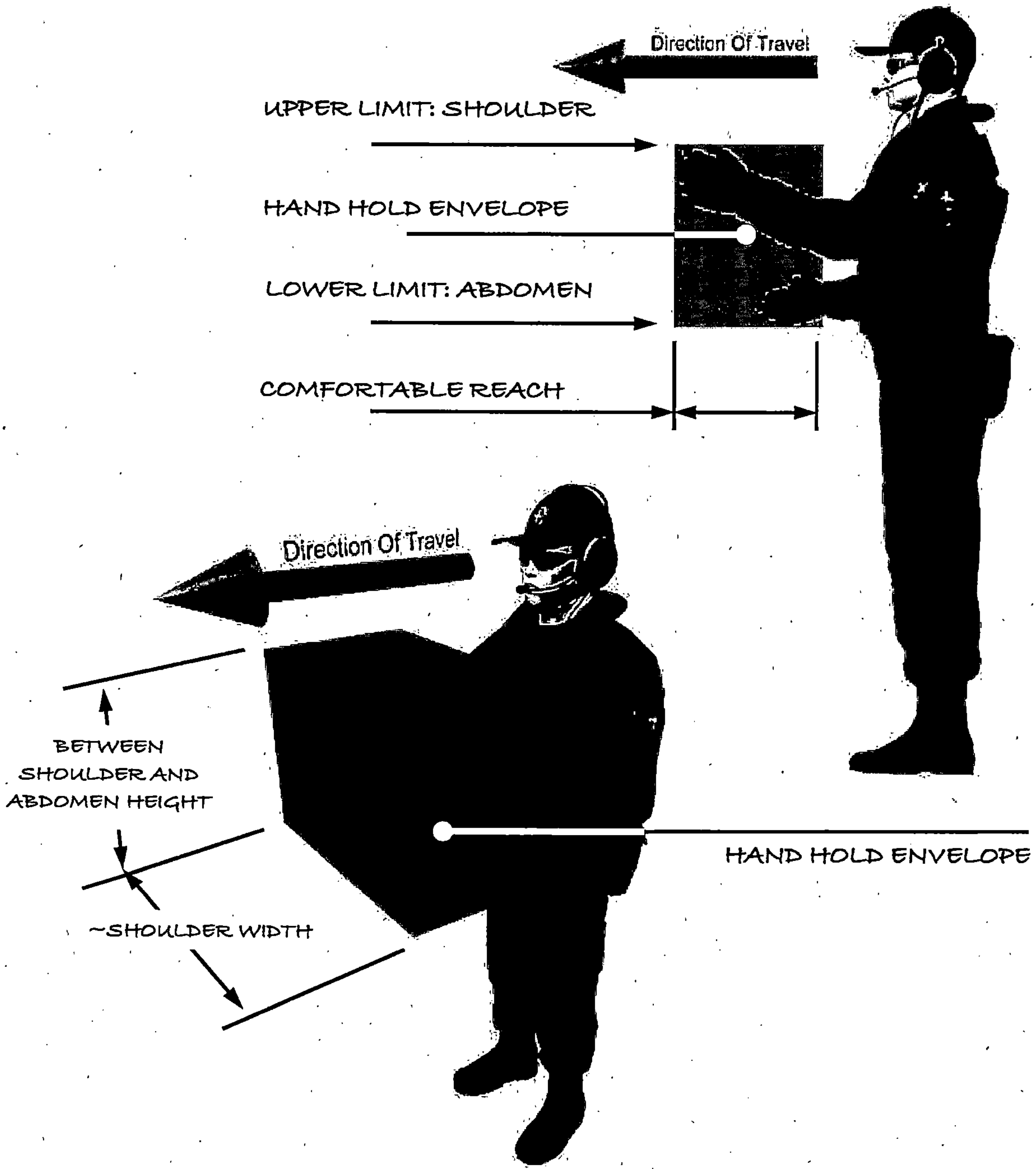


2.4.2: SIDE VIEW



2.4.3: HANDHOLD REACH ENVELOPE

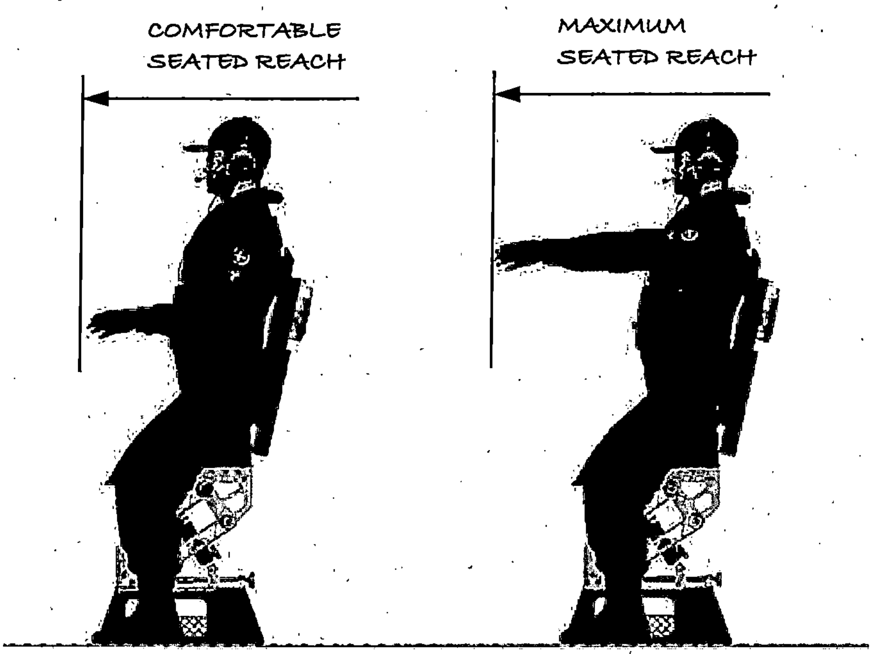
Fast craft are renown for exposing their occupants to high levels of RS and WBV. To cope with this motion the crew and passengers need to maintain their postural stability. One aspect of this is the location of handholds. These handholds, as defined in MCA MGN 436[3], should be approximately shoulder width apart and at a comfortable height between the individual's abdomen and shoulder. This handhold envelope is illustrated below. As the craft will be used by a range individuals of different sizes (refer to Section 3), the Designer must position the handholds at a height and width that fits the required size range, and ensure that the individual is facing in the forwards towards the bow of the craft.



[3] MCA MARINE GUIDANCE NOTE (MGN) 436: Whole-Body Vibration: Guidance on Mitigating Against the Effects of Shocks and Impacts on Small Vessels.

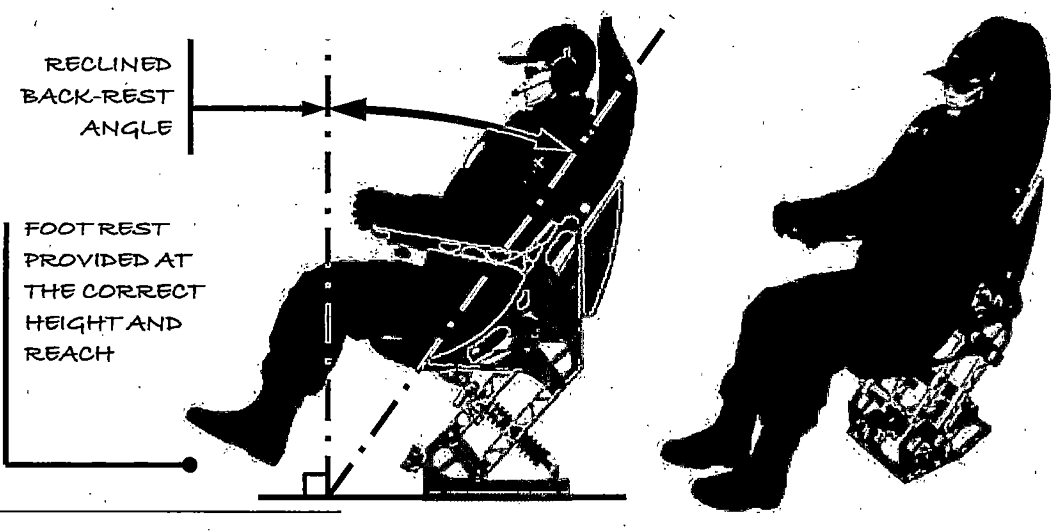
2.4.4: ARM REACH ON STRADDLE SEAT

Straddle seats are commonly used on small fast craft for both the crew and passengers. Where used the designer must ensure that the seats are positioned to facilitate the correct reach and handhold position to support postural stability and crew C2 activities.



2.4.5: FULL SEAT INTEGRATION

Where the craft uses full seats, i.e. the occupant is isolated from the deck, postural stability is typically provided by the provision of arm rests and handholds mounted on seat. Options for this type of seat, to facilitate effective Command & Control (C2) by the crew include the use of controls that are mounted on the armrests / hand holds. The reclining angle should be limited to ~50° as a recline angle of 60° does not support optimum vigilance performance[4], and adequate sleep may be achieved where the back-rest angle approaches 40°[5].



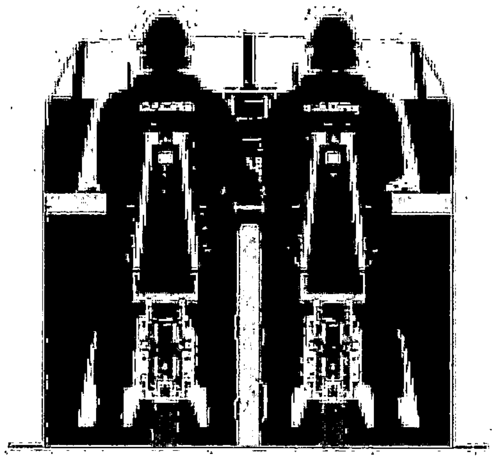
[4] Thody, M., Gregg, V.H. & Edwards, R.J. (2003) Reclined sitting Postures: their effect on human performance of a vigilance task. In, Contemporary Ergonomics. Ed; Lovesay, E.J. Pub. Taylor & Francis, pp 33-39.

[5] Nicholson, A.N. & Stone, B.M. (1987) Influence of back angle on the quality of sleep in seats. Ergonomics. Vol. 30(7). pp 1033-1041.

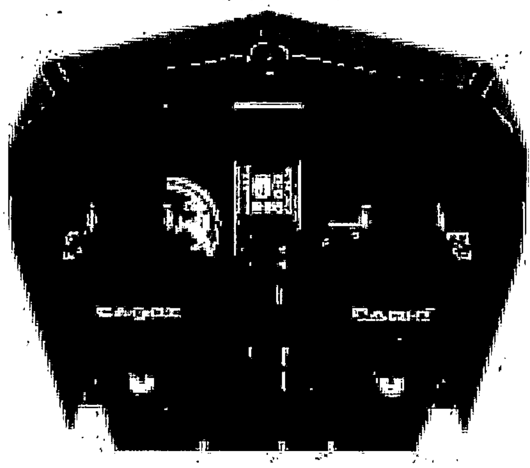
2.4.6: CREW, SIDE-BY-SIDE, AT CONSOLE

Once the correct posture is attained (neutral spinal alignment facing in the direction of travel) on the seat, the console is integrated with the crewmembers to ensure the controls can be reached and the displays viewed without loosing the correct posture. An example of how this may be achieved is shown below.

PORT SIDE VIEW



AFT VIEW



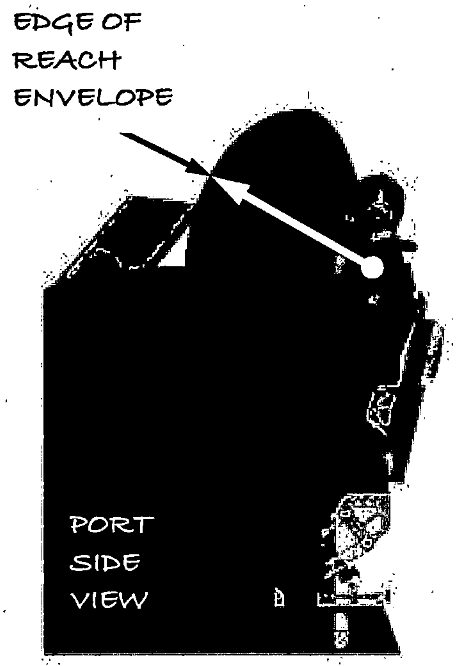
ELEVATED VIEWS FROM AFT ILLUSTRATING UNOBSTRUCTED VIEW OF DISPLAYS, AND CONTROLS WITHIN COMFORTABLE REACH

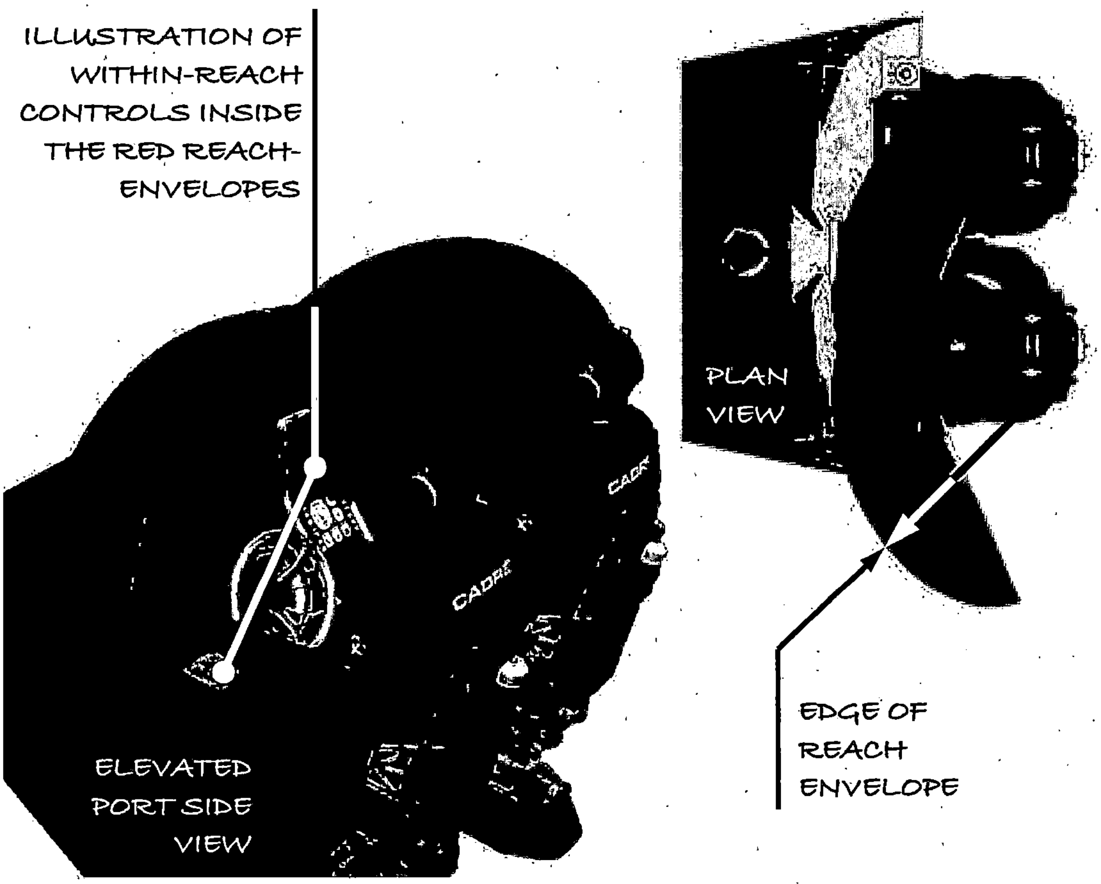
2.4.7: CONSOLE REACH ENVELOPES

To establish whether the crew has effective control over the craft's systems from their seated position reach envelopes are used to visually assess the position of the controls. The reach envelopes having been developed using anthropometric guidance and data[6]. Where frequently-used / important controls lie outside of the reach envelopes they shall be repositioned to be within easy reach, this includes the potential for mounting some controls on the seat.

Additional information on controls is provided in Chapter 3, Section 3.7.

Subsequent formal assessment of the users reach envelopes is undertaken using physical mock-ups (Re: HSC HFE Design Guide, Section I – Design Review)

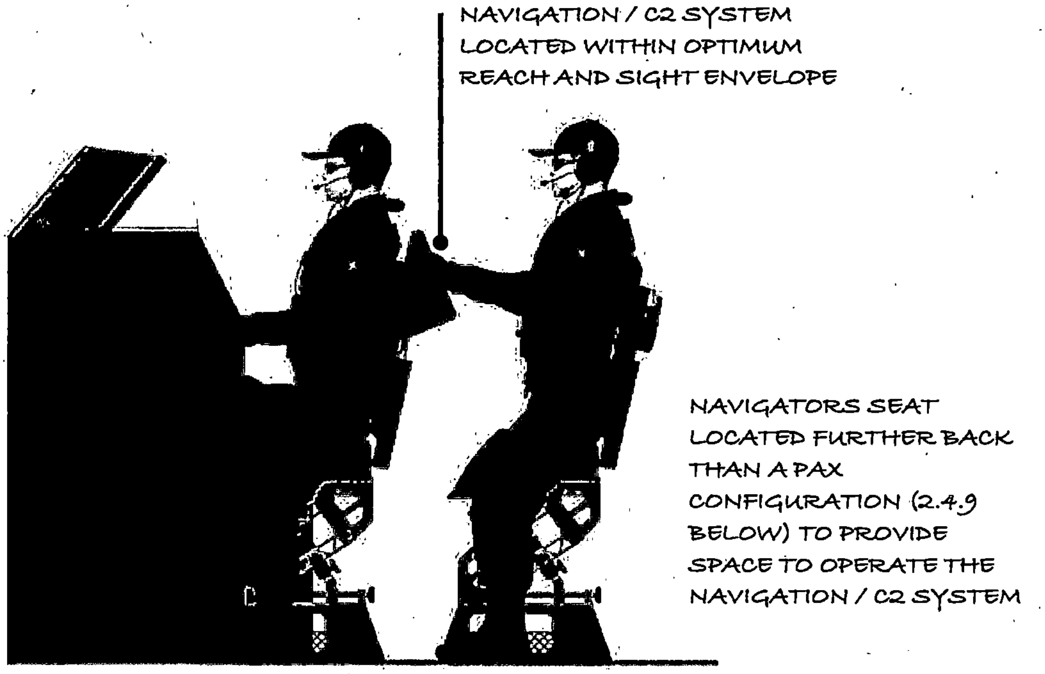




[6] ASTM F1166; Standard Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities.
UK MOD Human Factors Integration - Technical Guide For Anthropometry: People Size. Version 2, September 2015. Defence Authority for Technical & Quality Assurance (DA4T&QA),

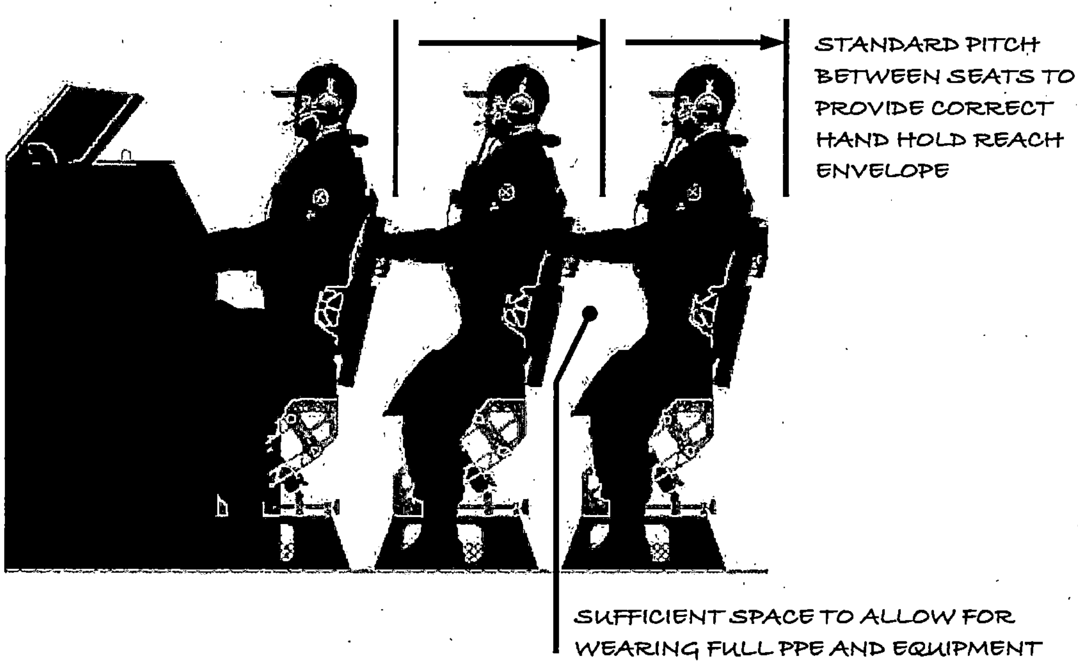
2.4.8: TANDEM DRIVER & NAVIGATOR CONFIGURATION

Small fast craft often use a tandem configuration for the driver and navigator. In addition to the driver having the optimum C2 design, the navigation (and other) system display and controls must be mounted within easy reach and within optimum sight line. See below for an illustration. of the required position for the Navigators system.



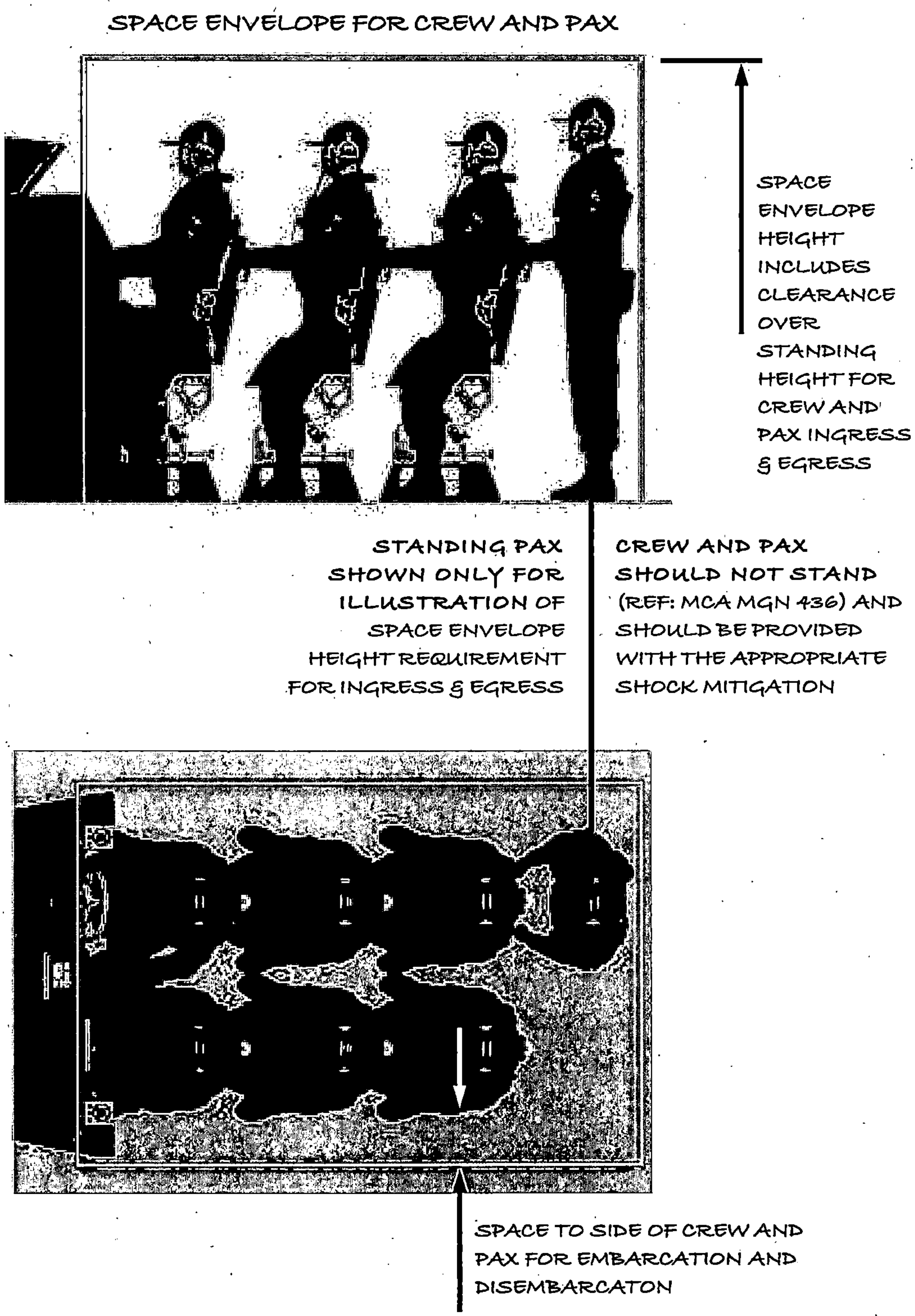
2.4.9: CREW + TANDEM PASSENGERS

Where the passenger seats are arranged in tandem, the spacing between the seats must provide the appropriate space and location of hand holds to support postural stability.

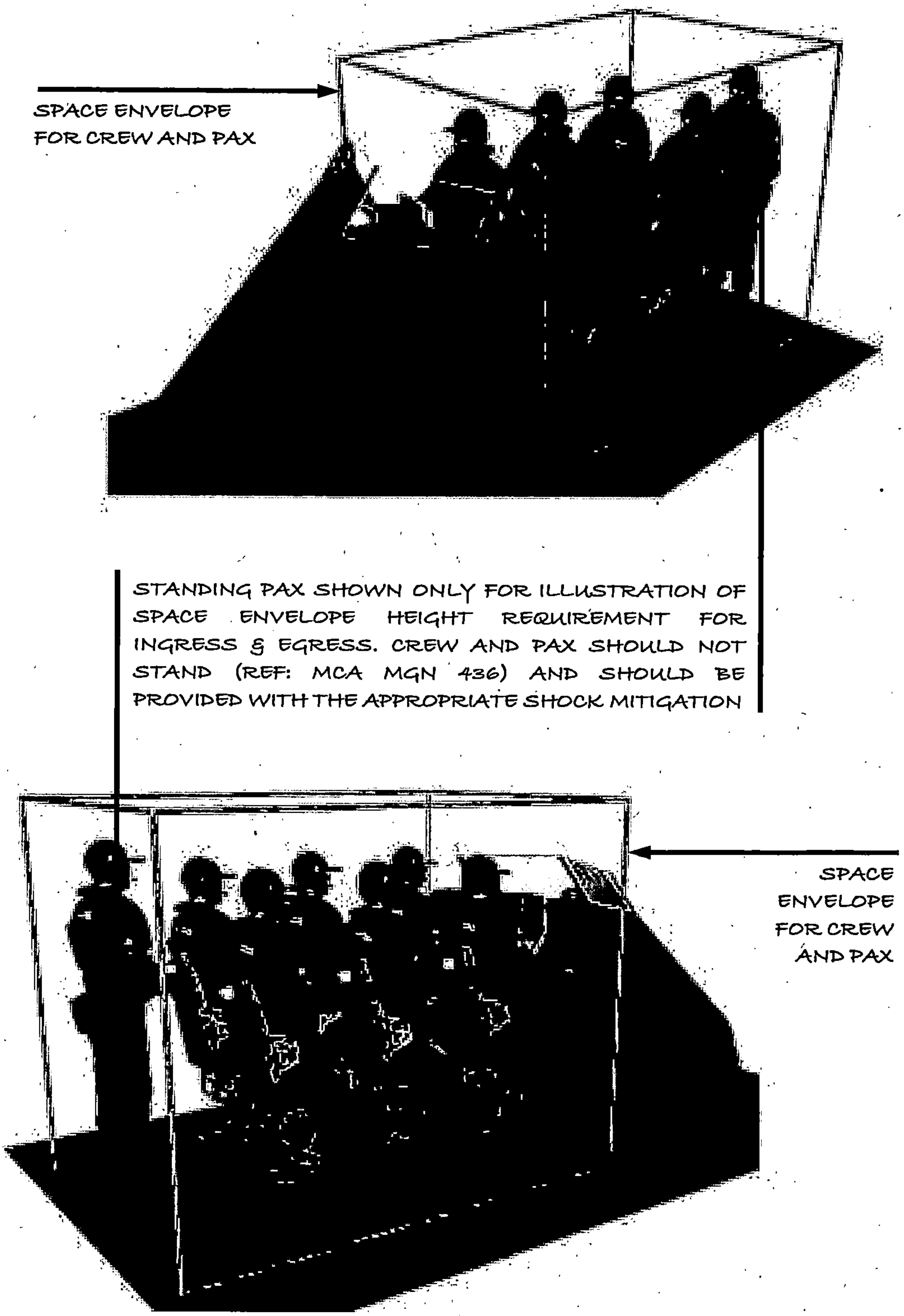


2.4.10: EXAMPLE SPACE ENVELOPE FOR 2 CREW & 4 PAX

The space required by the crew and passengers can be visualised as a volume within which the Designer should not place any structure / features that are not required by the crew and passengers to complete their tasks effectively and safely. An example of such a space envelope is shown below.

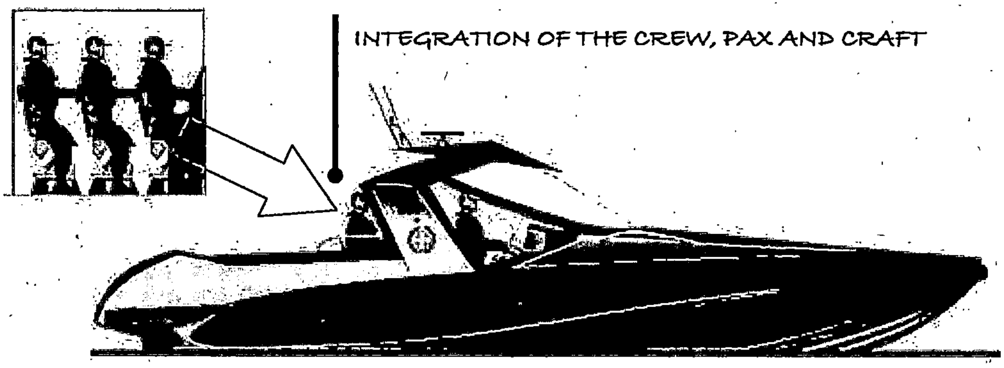


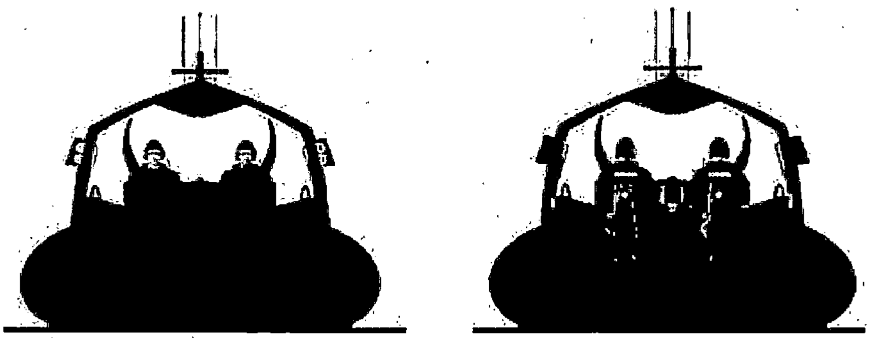
The side and plan views of the crew and passenger space envelopes are shown in 3D below.



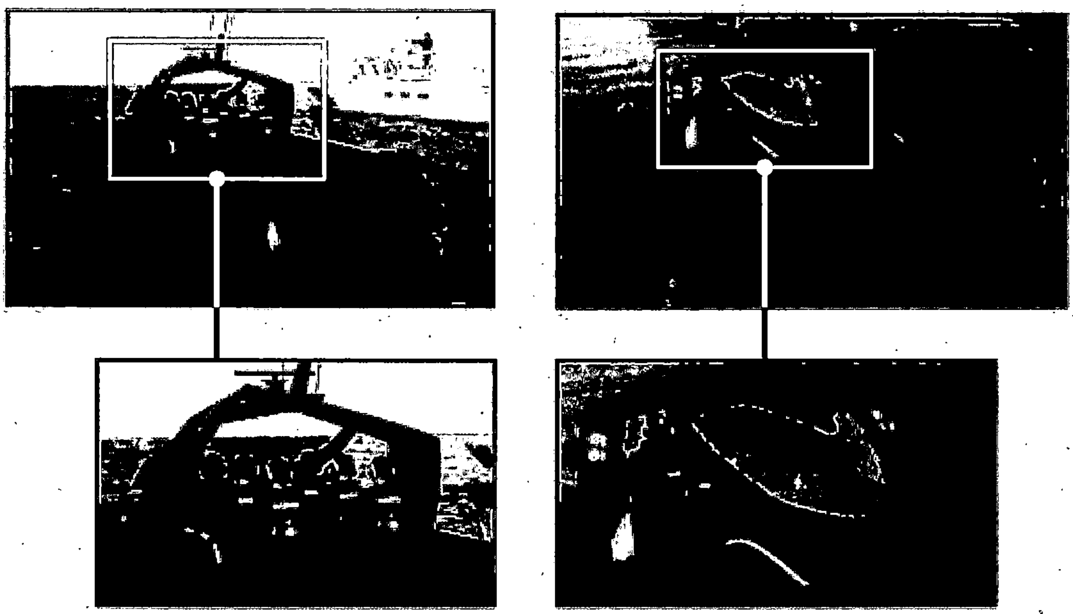
2.4.11: AN EXAMPLE OF CREW, PASSENGER AND CRAFT INTEGRATION

Once the crew and passenger configurations have been finalised, and the space envelope identified, the integration of the craft can be completed. The images below illustrate this process and how CAD is used to visualise this process before developing a mock-up and prototypes are produced.





FRONT VIEW AFT VIEW

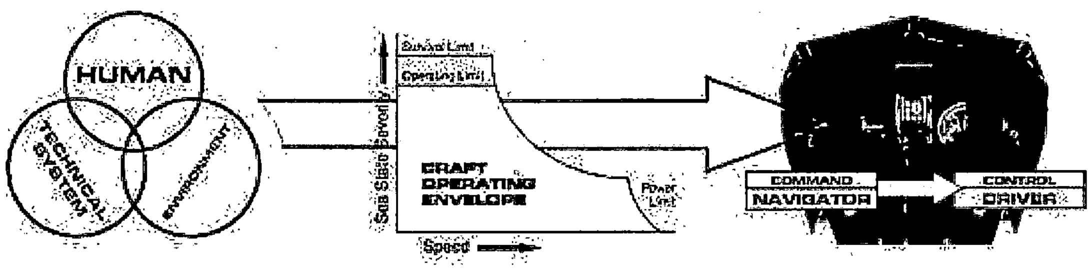


REAR AND FRONT VIEW OF CREW AND PAX WITHIN THE CRAFT ILLUSTRATING THE SPACE ENVELOPE, ROOM FOR ACCESS, AND EXTERNAL VIEW FOR SITUATION AWARENESS

3. COMMAND & CONTROL (C2)

SUMMARY

The Command & Control (C2) of HSC is what delivers operational capability. Without it the craft will have no direction or objective. At high speeds / tempos the time the crew often has little time to make critical decisions, therefore the information they are given must be in the right format and presented at the right time. In addition to short decision making times the crew has to deal with high levels of craft motion which reduces text / information legibility. Therefore it is essential that the C2 information architecture is optimised for edge of the envelope operations.



3.1: INTRODUCTION

The HSC crew do not operate the craft on their own. They are part of a Joint Cognitive System (JCS) where the humans, the technical systems and the environment interact. This JCS relationship is illustrated below in Figure 3.1.

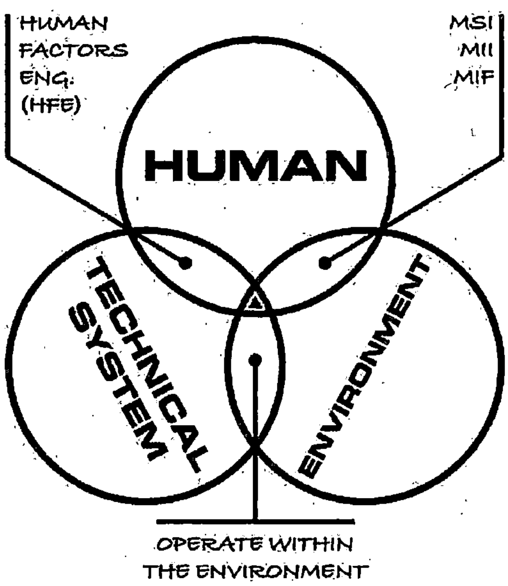


Figure 3.1: The Joint Cognitive System – the integration of the Human, Technology, and the Environment.

The Command & Control (C2) activities lie within the JCS[1], and due to the high-tempo nature of HSC operations, part of the C2 tasks include risk-based decision-making. This decision-making requires information that has to be displayed to the crew.

The harsh motion environment (RS & WBV), means that operational effectiveness is degraded / compromised by poor display information architecture. This may be acceptable for slower-tempo operations – **BUT** - HSC operations are characterised as being undertaken at the Edge of the Operating Envelope. Therefore this is where the design emphasis needs to be focused.

An example of a generic operating envelope[2] is shown in Figure 3.2, with an indication of the edge of the operating envelope. Unfortunately the speed / sea-state graphs do not always effectively illustrate the harsh motion conditions. Figure 3.3 illustrates how

[1] Dobbins, T., Hill, J., Thompson, T., McCartan, S., Brand, T. and, Smoker, A. (2015) Human-Centred, Scalable, Combat System Design For Littoral Operations. RINA Conference Proceedings; Warship 2015: Future Surface Vessels, Bath, UK.

[2] Riley, Michael R., Marshall, Jason T., Empirical Equations for Developing Ride Severity Envelopes for Planing Craft Less Than 55 Feet in Length, Naval Surface Warfare Center Carderock Division Report NSWCCD-83-TM-2013/36, 80-TR-2014/015, September 2013.3.

poor display information architecture degrades operational performance and capability when operating in a harsh motion environment.

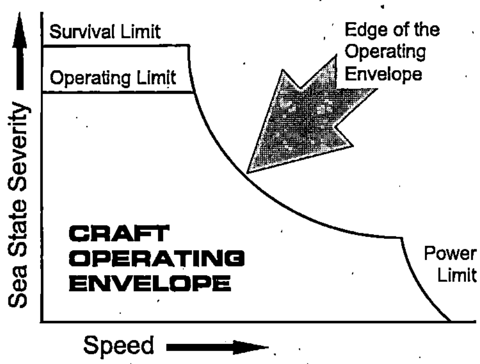


Figure 3.2: Example of a generic HSC operating envelope.

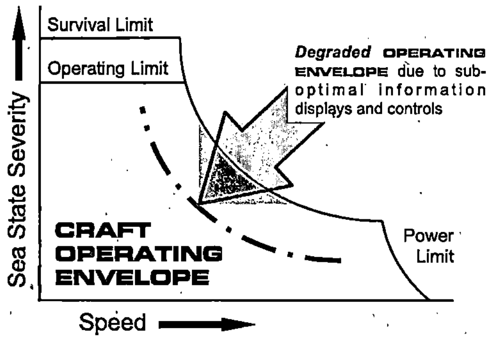
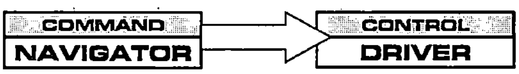


Figure 3.3: Example of how poor information architecture degrades the HSC operational envelope.

3.2: THE NAVIGATOR - DRIVER TEAM

The C2 of the HSC JCS is dependent on the teamwork between the Navigator and Driver.



An outline model of this functionality has been described[3] and is used as a foundation for system and training design. To illustrate the different roles undertaken by the Driver and Navigator, Figure 3.4 illustrates how the Driver focuses on the external view (e.g. the green cross) whilst the Navigator (not shown) concentrates on both the external view and the information displayed by the systems within the cockpit.

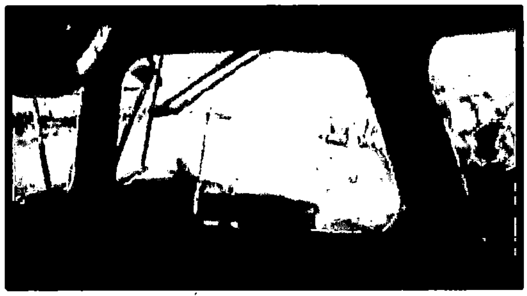


Figure 3.4: Example of the HSC drivers view highlighting their focus on the external view and hazards.
Image: Dahlman, CTU, SWE

Research has shown that driving at high speed cannot be effectively, and safely, undertaken by a single operator[4]. Therefore the Driver and Navigator team use the **DY**namic **NAV**igation (**DYNAV**) methodology to enhance both performance and safety.

3.3: DYNAMIC NAVIGATION (DYNAV)

All HSC operations are underpinned by safe and effective navigation. Due to the high-tempo nature of HSC operations the crews' use the **DYNAV** methodology[5]. The four phases of the methodology (**PLAN→, COMMUNICATE→, EXECUTE→ and CONTROL→**) are illustrated in Figure 5. Examples of how the crews undertake **DYNAV**, and how C2 is practically achieved, are provided in the **DYNAV** Manual[6].

[3] Dobbins, T., Dahlman, J. & Stark, J. (2009) High Speed Craft Command & Control - A Preliminary Model. Conference Proceedings. European Human Factors & Ergonomics Conference. Linkoping, Sweden.

[4] Dahlman, J., Forsman, F., Sjörs, A., Lützöft, M., Falkmer, T. (2008). Eye-Tracking during High-Speed Navigation at Sea. In proceedings of 6'th annual meeting of Society for Human Performance in Extreme Environments, New York, NJ, Sept. 21-22.

[5] Forsman, F., Dahlman, J. and Dobbins, T. Developing a Standard Methodology For Dynamic Navigation in the Littoral Environment. Conference Proceedings; RINA Human Factors in Ship Design Conference, London, November, 2011.

[6] DYNAV Manual, v1. DYNAV.ORG

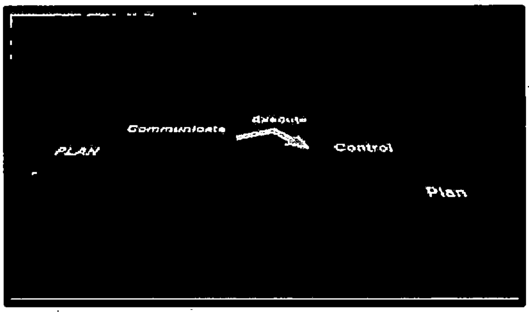


Figure 3.5: The 4 Phases of the DYNAV Methodology

The C2 roles of the Navigator and Driver within the **DYNAV** methodology are described below in Figure 3.6, where the navigator generates course instructions communicates these to the Driver, who subsequently executes them.

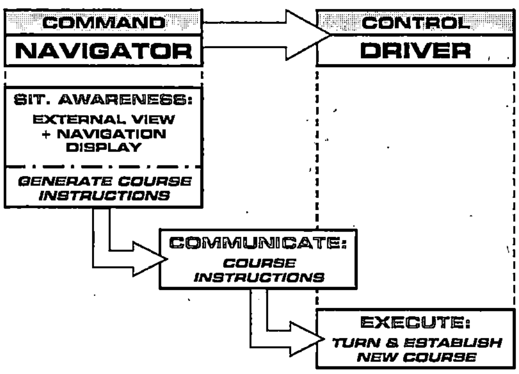


Figure 3.6: The DYNAV C2 Process Between the HSC Navigator and Driver

Due to the need to make rapid decisions when operating at the edge of the operational envelope, it is essential that the display information architecture is optimised to support **DYNAV** in the harsh operating environment[7].

3.4: COMMUNICATION PROTOCOL DEFINES THE INFORMATION DISPLAY REQUIREMENT

The **DYNAV** methodology requires the Navigator to provide the Driver with the following information during the **COMMUNICATE→** Phase:

1. Turn Direction
2. Turn Point
3. Next Course
4. Head Mark
5. Position of Dangers
6. Minimum Depth
7. Movement Space
8. Length and time to next turn point

This may be shortened to a minimum of the following with subsequent details provided after the turn is executed:

1. Turn Point
2. Next course
3. Head Mark
4. Position of Dangers
5. Minimum Depth

Therefore the navigation system display designer must focus on providing these pieces of information in the most intuitive method possible, i.e. minimise the time required to perceive and assimilate the information. Also the navigator must ***NOT*** have to work through a menu system to find / access the information.

As the JCS must work at the edge of the operating envelope, the navigator must be able to read the display, and control the system in the worst-case RS & WBV environment. Thus the operation should not be compromised due the Navigator / Crew not being able to use the displays.

3.5: DISPLAY DESIGN PROCESS

As described above (re: Section 3.1 and Figure 3.3), HSC displays typically do not effectively support the decision making required by the Navigator, e.g. they are unreadable in a RS / WBV environment, and the required information is not intuitively displayed to support the **DYNAV** instructions requirement. Previously, display layouts have been designed around the sensor outputs rather than the tasks of the crew. This process is illustrated in Figure 3.7. When designing to support the crew, a human-centred design (HCD) approach is required. This is illustrated in Figure 3.8.

[7] Dobbins, T., Forsman, F., Hill, J., Brand, T., Dahlman, J., Harris, D., Smoker, A., Stark J. and MacKinnon, S. (2013) Information Architecture for Fast Response Craft – Command & Control & Human Systems Integration. Conference Proceedings; RINA SURV-8 conference, Poole, UK.

Figure 3.7: An Example of Typical Information Display Design Methodology That Does NOT Support the Users Needs.

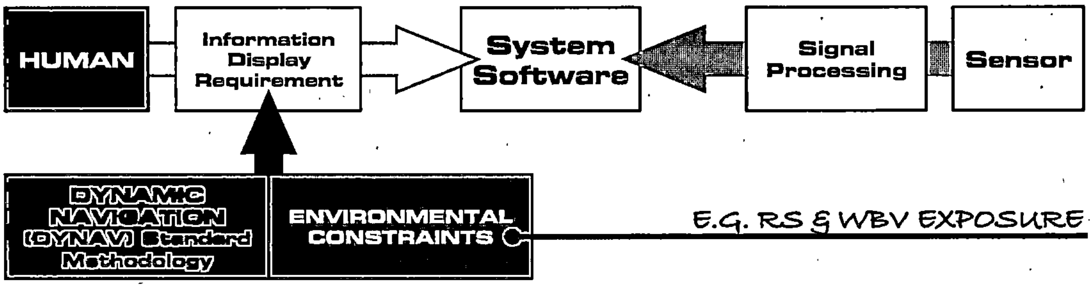


Figure 3.8: An Example of Human Centred Design (HCD) Methodology for a Display to Support HSC Navigation Using the DYNAV Methodology

3.6: DISPLAY LEGIBILITY

Human visual perception means that display text size has to increase the further away the display is from the eye. Similarly, the greater the level of vibration, the larger the text has to be for it to be legible to the operator. An example of the distance between the operator and the cockpit display is shown in Figure 3.9 below (~1m). Note that this is a relatively small console / seating design and therefore the distances can be greater, e.g. 1.5m or more.

Text size recommendations[8] for operating in a WBV environment are provided as **MINIMUM** sizes, and therefore the designers must focus on the use of the system at the edge of the operating envelope (e.g. Figures 3.2 and 3.3), i.e. the worst-case scenario. Therefore text sizes will need to be greater than the minimum. The

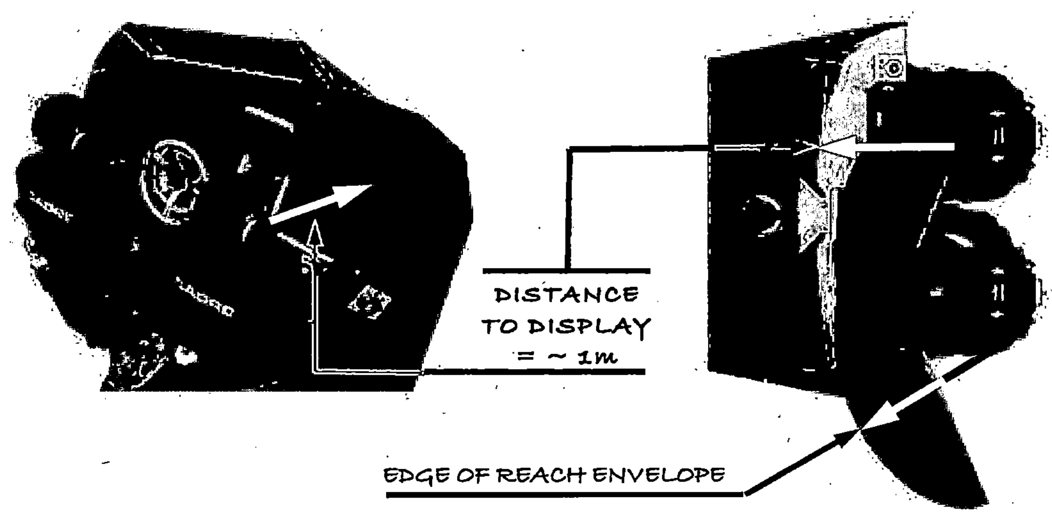


Figure 3.9: Typical example of the distance from the crewmember to the information display

[8] UK MOD DEFSTAN 00-970; Design and Airworthiness Requirements for Service Aircraft

relationship between WBV exposure and text size is illustrated in Figure 3.10 where the graph's lines indicate the ***MINIMUM*** text size for typical display distances from the crewmember of 0.75m, 1.0m and 1.5m. Where crewmembers typically use corrective vision glasses they should be appropriate for use in the high RS / WBV environment.

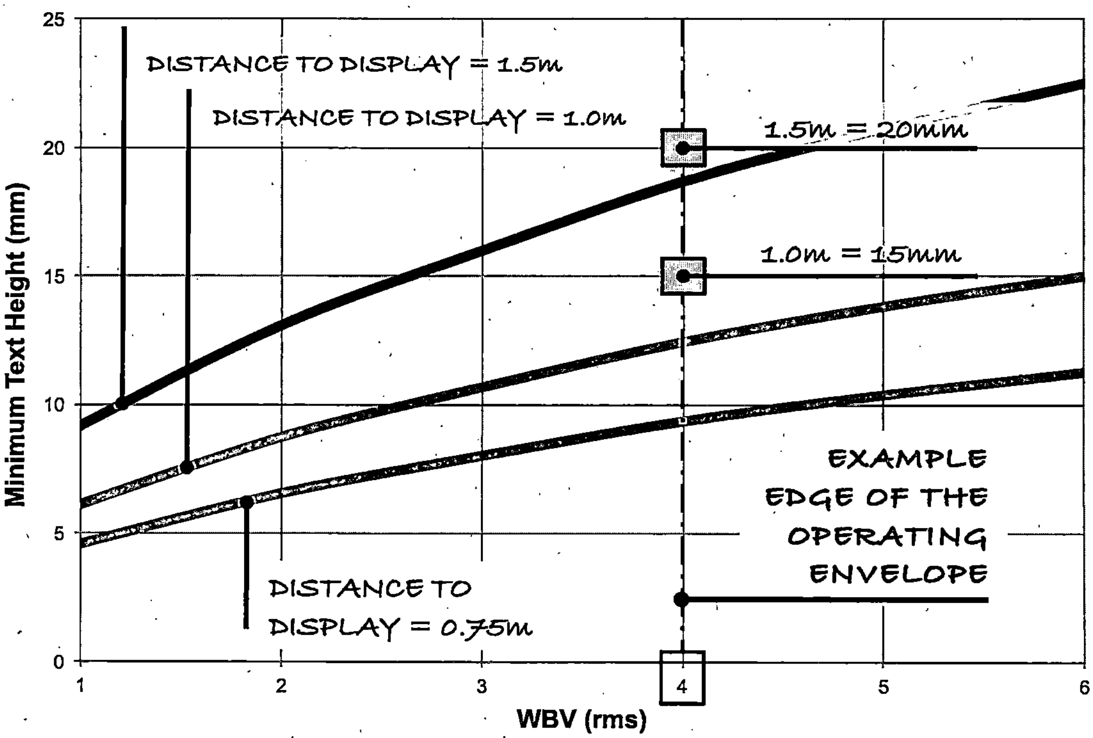


Figure 3.10: Minimum and Recommended Text Height (mm) for Displays Utilised Within a Harsh Repeated Shock (RS) and Whole Body Vibration (WBV) Environment.

From the graph (Figure 3.10), and the need to ensure the effective legibility during worst-case RS / WBV exposure, the following recommendations are made in Table 3.1 below.

Distance to Display (m)	Text Height (mm)
1.0	15
1.5	20

Table 3.1: Recommended text heights for display distances of 1.0m and 1.5m when operating in a vibration environment.

The follow are examples of the typical sizes of text required (re: Table 3.1):

15 mm 20 mm

The designer must also consider viewing the display(s) in a range of conditions:);

- **In strong sunlight / glare**
  - Display brightness
  - Shielding from the sun / strong light sources
- **At night**
  - The use of an alternative colour palette
  - Rapidly dim all displays
- **Using night vision devices**

3.7: DISPLAY ORIENTATION

Navigation displays are commonly designed for use in a landscape orientation. Although this may match the use of the majority of computer and television screens, it may be inappropriate for the majority of HSC **DYNAV** tasks. The Navigator needs to maximise the information they have about what is ahead of them, **NOT** what is to the side. This situation is highlighted when transiting narrow channels and is illustrated below in Figure 3.11.

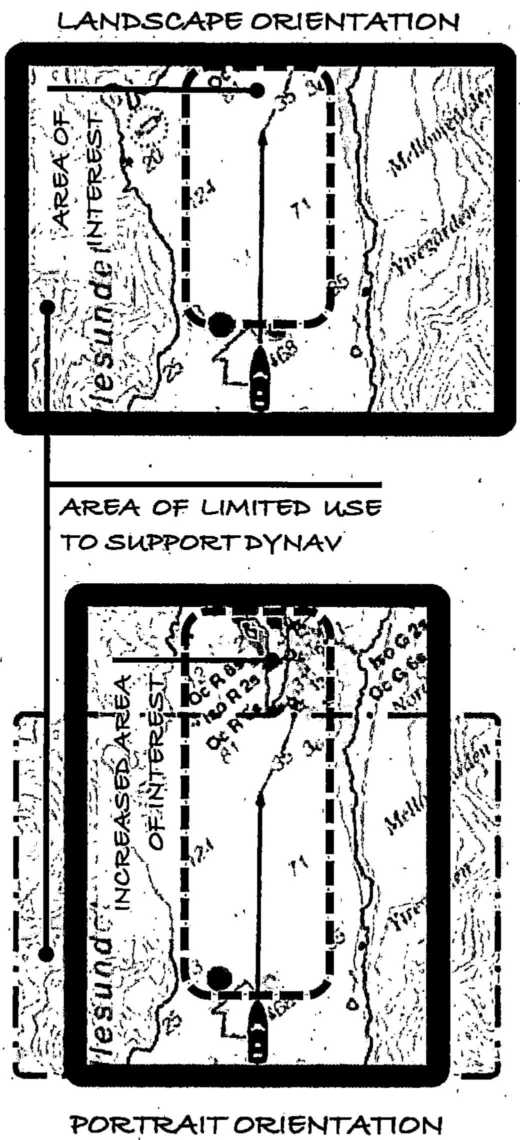


Figure 3.11: Example of how Portrait Display Orientation Supports Enhanced Situation Awareness (SA) and Dynamic NAVigation (DYNAV)

It is essential for the navigation display to maximise the information about future transit legs, hazards, etc., as described above in Section 3.4. Viewing more about the area (in this case land) to the sides of the craft is of little value. Therefore orientating the display in portrait layout can help to improve SA and **DYNAV** performance. To achieve this orientation and maximise the size of the display the craft console may need to be redesigned.

3.8: CONTROLS

The navigation system is used under two environmental conditions;

1. Planning and programming – minimal RS & WBV exposure
2. Underway – high levels of RS & WBV exposure

3.8.1: Planning and Programming:

In this situation the craft is not subject to RS and WBV exposure and so the system may be operated by a number of control methods to input and adjust the system settings and functions.

3.8.2: Underway:

The system controls need to be effective when the craft is operating the edge of the operating envelope and when the crew requires the maximum postural stability.

Whilst underway, and exposed to high levels of RS and WBV, the system must be useable with the minimum of control / input errors being made, therefore;

- ***DO NOT USE A TOUCH SCREEN !***

- The operator's hand(s) must be stabilised, e.g. by holding onto a finger-rail and using the thumb to operate specific buttons (re: Figure 3.12), or using the appropriate arm-rest mounted controls.

- Buttons must be large enough for use with cold weather gloves, and there must be enough space between buttons

to minimise the risk of pressing the wrong button. Recommended dimensions[9] are shown below in Figure 3.11. An illustration of this relative button size and the issues described above are shown in Figure 3.12.

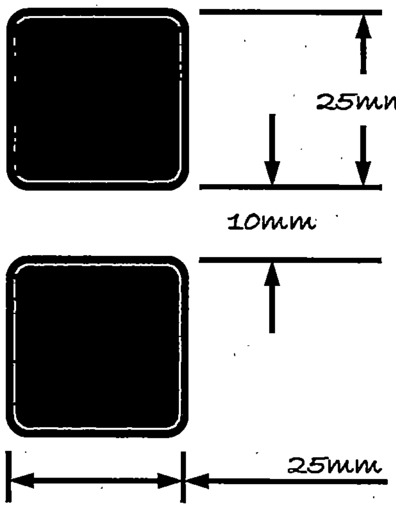


Figure 3.11: Recommended button size and gap for HSC operating in Harsh RS and WBV conditions

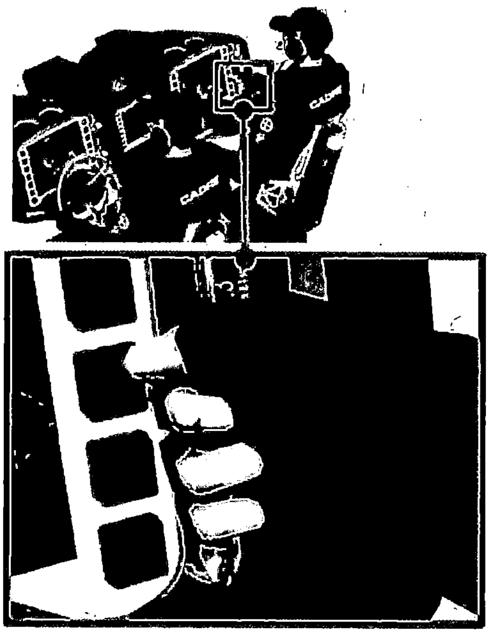


Figure 3.12: Example of relative button and thumb size, and the use of a support rail.

[9] UK MOD DEFSTAN 00-250; Human Factors For Designers Of Systems, and

ASTM F1166; Standard Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities

3.9: SYSTEM FUNCTIONALITY

Due to the high-tempo nature of the HSC Navigators workload, it is essential that control functions can be completed rapidly and with minimal risk of error. Therefore dedicated controls for specific functions provide a simple solution for some tasks. Examples of such functions are illustrated in Table 3.2 below.

Other functions that Navigators describe as useful is the ability to duplicate their display with the Drivers display. They can then either describe specific features on the display to the Driver, or use the cursor to point out specific features / details relating to the course, dangers, etc. The cursor control system must be appropriate for use in the high RS and WBV environment, i.e. provide a stable foundation against unwanted movement.

FUNCTION	CONTROL / BUTTON
Chart Format	• Course Up • North Up • Heading up
Chart scale / Zoom	• [+] • [–]
Chart position / Scroll	• ← • → • ↑ • ↓
Display Brightness	• [+] • [–]

Table 3.2: Examples for Specific Single Function Controls / Buttons

The display requirement described above is directly supported by the requirement described in MCA MGN 436, Section 4.6.2[10] (Navigation equipment and controls):

[10] MCA MARINE GUIDANCE NOTE (MGN) 436: Whole-Body Vibration: Guidance on Mitigating Against the Effects of Shocks and Impacts on Small Vessels.

When the vessel is moving across the water ***the instrumentation should provide a display that is of a size to allow the person conning the vessel to easily read the icons, text and images from their conning position.*** *This allows them to spend more time concentrating on the water they are about to travel across and also to keep a suitable posture without leaning in or adopting an awkward posture to read the instrumentation and operate the controls.*

3.10: FUTURE DEVELOPMENT

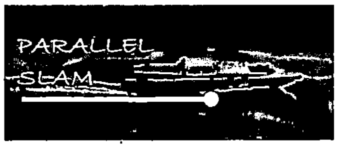
Future development of the C2 interface could take a number of paths, these may include:

1. Simplification – making the display and the controls more intuitive, reducing workload and the risk of errors.
2. Augmented Reality (AR) – providing information on the display to enhance the crews' understanding and sense-making of their situation.
3. Standardisation – the adoption of standardised display layouts and controls will facilitate the interoperability between crew and different craft from different Nations. This also reduces the training burden and enhances safety.

4. HSC REPEATED SHOCK (RS) MOTION

SUMMARY

The HSC occupants' exposure to Repeated Shock (RS) is known to cause Motion Induced Fatigue (MIF), severe discomfort and an increased Risk of Acute & Chronic Injury (RACI). A better understanding of the motion characteristic will result in the development of more effective shock mitigation and operational solutions to enhance performance and safety.



4.1: INTRODUCTION

Designing HSC for calm water conditions is relatively straightforward - the challenge is to design HSC to operate safely and effectively in rough water conditions. The repeated slamming that planing craft expose their occupants to, known as Repeated Shock (RS) has been shown to result in post-transit Motion Induced Fatigue[1] (MIF), discomfort[2], and an increased risk of acute and chronic injury[3] (RACI). When designing a planing craft it is essential to understand the slamming characteristics of the HSC as it impacts with the water. This helps to facilitate the design of hull geometry, and systems to provide enhanced shock mitigation. The wave slam events have been divided into three categories[4];

The **ALPHA** Slam: ***THE STERN SLAM***

The **BRAVO** Slam: ***THE PARALLEL SLAM***

The **CHARLIE** Slam: ***THE STUFF***

These slam categories and descriptions are illustrated below in Sections 4.1.1 to 4.1.3. Further details of the modelling, simulation and visualistion that developed the images and animation are available[5]. The motion examples can also be viewed as an animated video[6] as this provides an illustration of HSC motion and particularly the RS exposure. The craft modelled and the conditions were as follows:

- Length: 19 m
- Displacement: 27,500 kg
- Speed: 40 kts
- Wave length / height: 28.5m / 1.14m

It has been recognised that HSC RS motion is not effectively characterised by traditional WBV assessment methods, e.g. RMS. Although RS is recognised as the appropriate motion description, there are still limitations with the assessment methodology and calculated metrics.

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[1] Myers, S., Dobbins, T., King, S., Hall, B., Ayling, R., Holmes, S., Gunston, T. and Dyson, R. (2011) Physiological consequences of military high-speed boat transits. European Journal of Applied Physiology. Vol. 111(9), pp 2041-9. DOI 10.1007/s00421-010-1765-3.

Myers, S., Dobbins, T., King, S., Hall, B., Ayling, R., Holmes, S., Gunston, T. and Dyson, R. (2012) Effectiveness of Suspension Seats in Maintaining Performance Following Military High-Speed Boat Transits. Human Factors. Vol. 54(2):264-76.

[2] Dobbins, T., Myers, S., Dyson, R., Gunston, T., Pierce, E., Blankenship, J. and LaBrecque, J. (2008) Discrepancies Between the Perceived Discomfort of Experienced High Speed Craft Operators and Current Standards. Conference Proceedings; The 43rd United Kingdom Conference on Human Responses to Vibration, Leicester, pp 234-239.

[3] Hill, J., Forsman, F., Brand, T. and Dobbins, T. (2014) Risk, Competence, Interoperability and Qualifications For Fast Craft Operations'. Conference proceedings; RINA Human Factors. London, UK.

[4] Riley, M., Coats, T. and Murphy, H. (2014) Acceleration Response Mode Decomposition For Quantifying Wave Impact Load In High- Speed Planing Craft. NSWCCD-80-TR-2014/007

[5] Fu, T., Brucker, K., Mousaviraad, S., Ikeda, C., Lee, E., O'Shea, T., Wang, Z., Stern, F. and Judge, C. (2014) An Assessment of Computational Fluid Dynamics Predictions of the Hydrodynamics of High-Speed Planing Craft in Calm Water and Waves. Proceedings; 30th Symposium on Naval Hydrodynamics. Hobart, Tasmania, Australia,

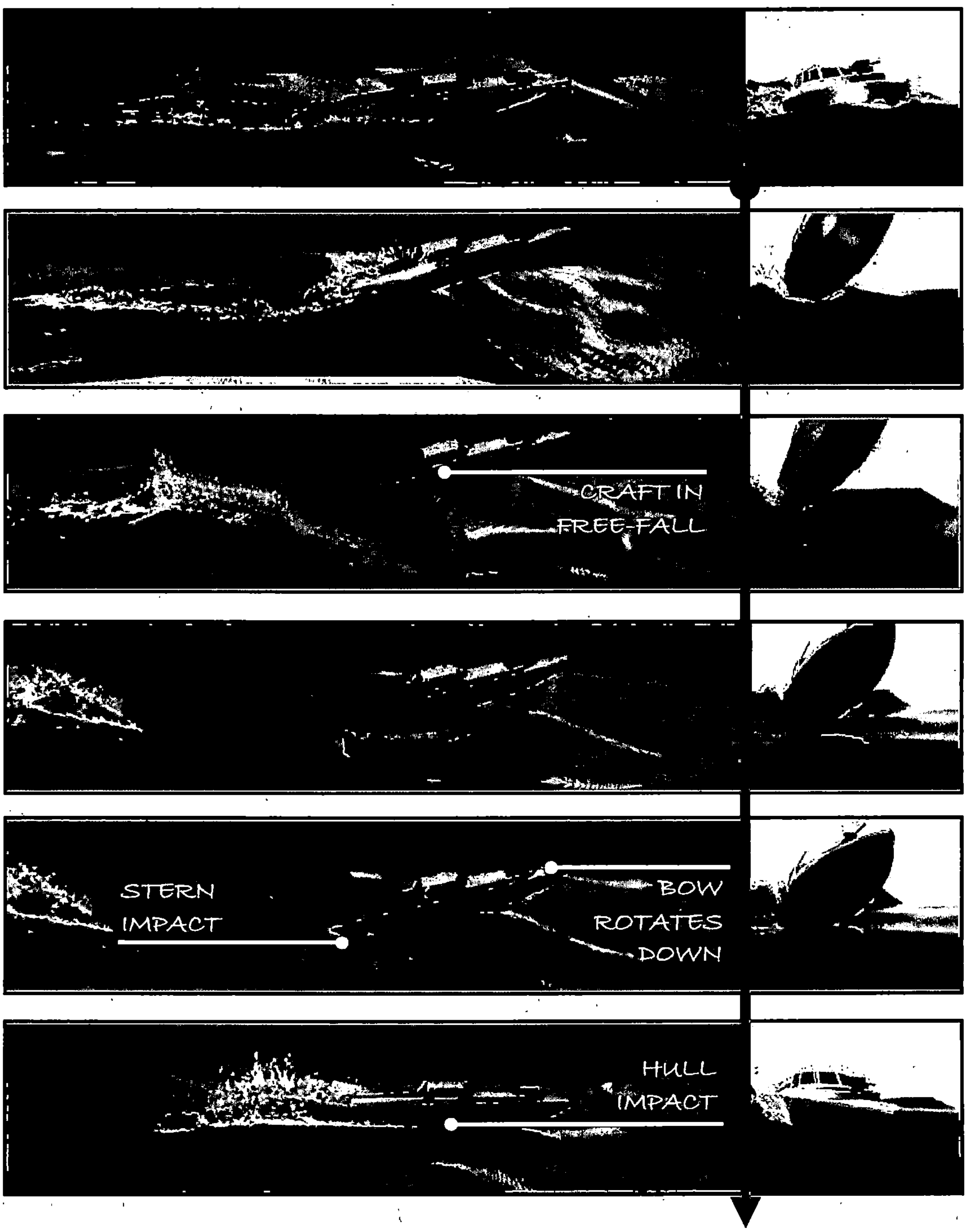
Numerical Flow Analysis (NFA) Simulation of a Planing Boat in Waves, DOD HPC Insights. Spring 2013. http://www.hpc.mil/images/hpcdocs/newsroom/hpcinsights_spring2013.pdf

[6] https://youtu.be/al-f9zODwjl

4.1.1: THE ALPHA SLAM: TYPE A: *'THE STERN SLAM'*

Characteristics:

- Typical launch from an upward sloping wave.
- A period of free fall
- A stern-first water entry / impact
- Bow rotates down initiating hull impact
- Human experience: Slam and pitching forward rotation (whip-lash effect)

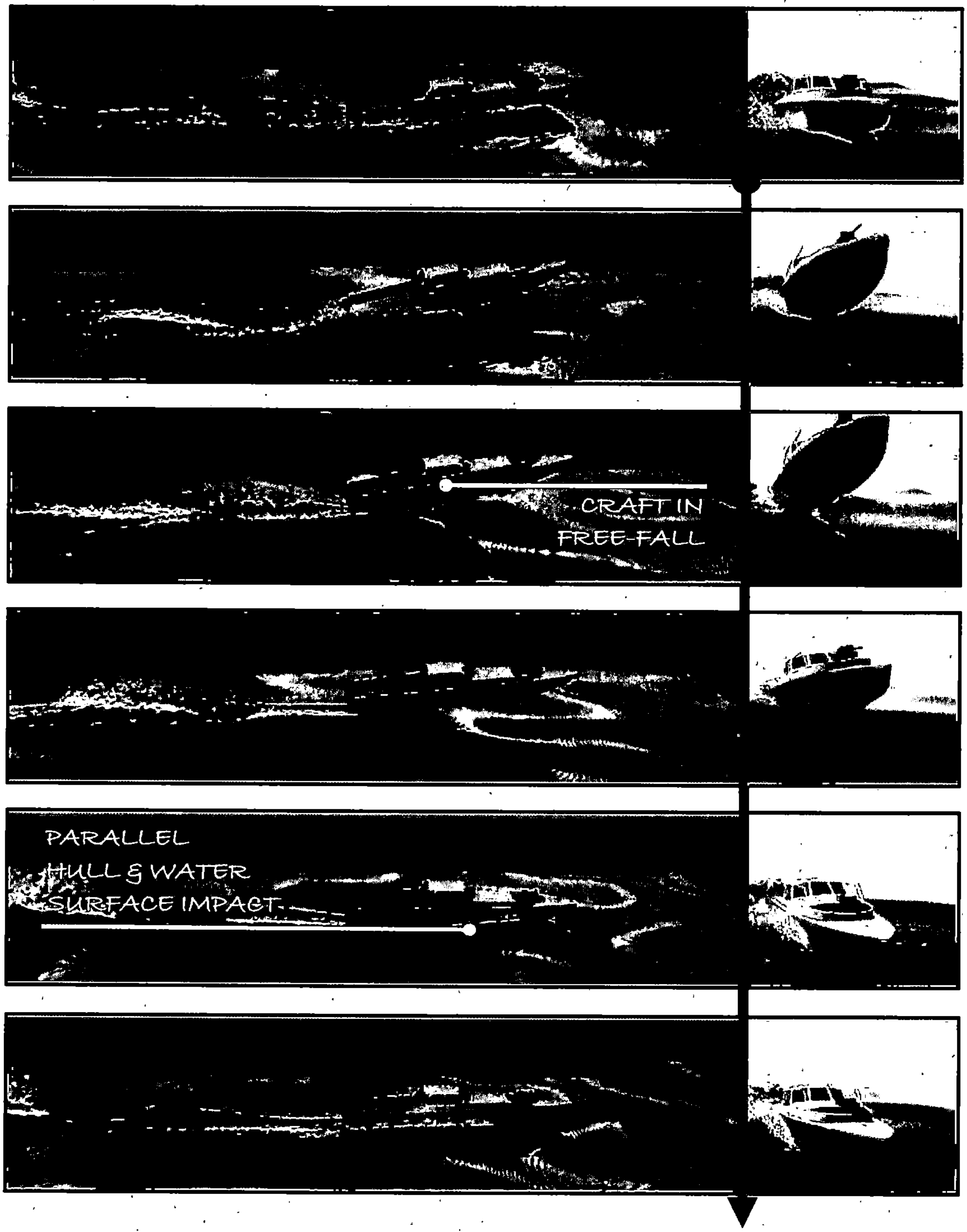


4.1.2: THE BRAVO SLAM: TYPE B: *'THE PARALLEL SLAM'*

Similar to the **ALPHA SLAM**, but with no indication of a stern-first impact.

Characteristics:

- Typical launch from an upward sloping wave.
- A period of free fall
- Impact occurs with the hull and water surface are parallel to each other
- Human experience: Vertical slam

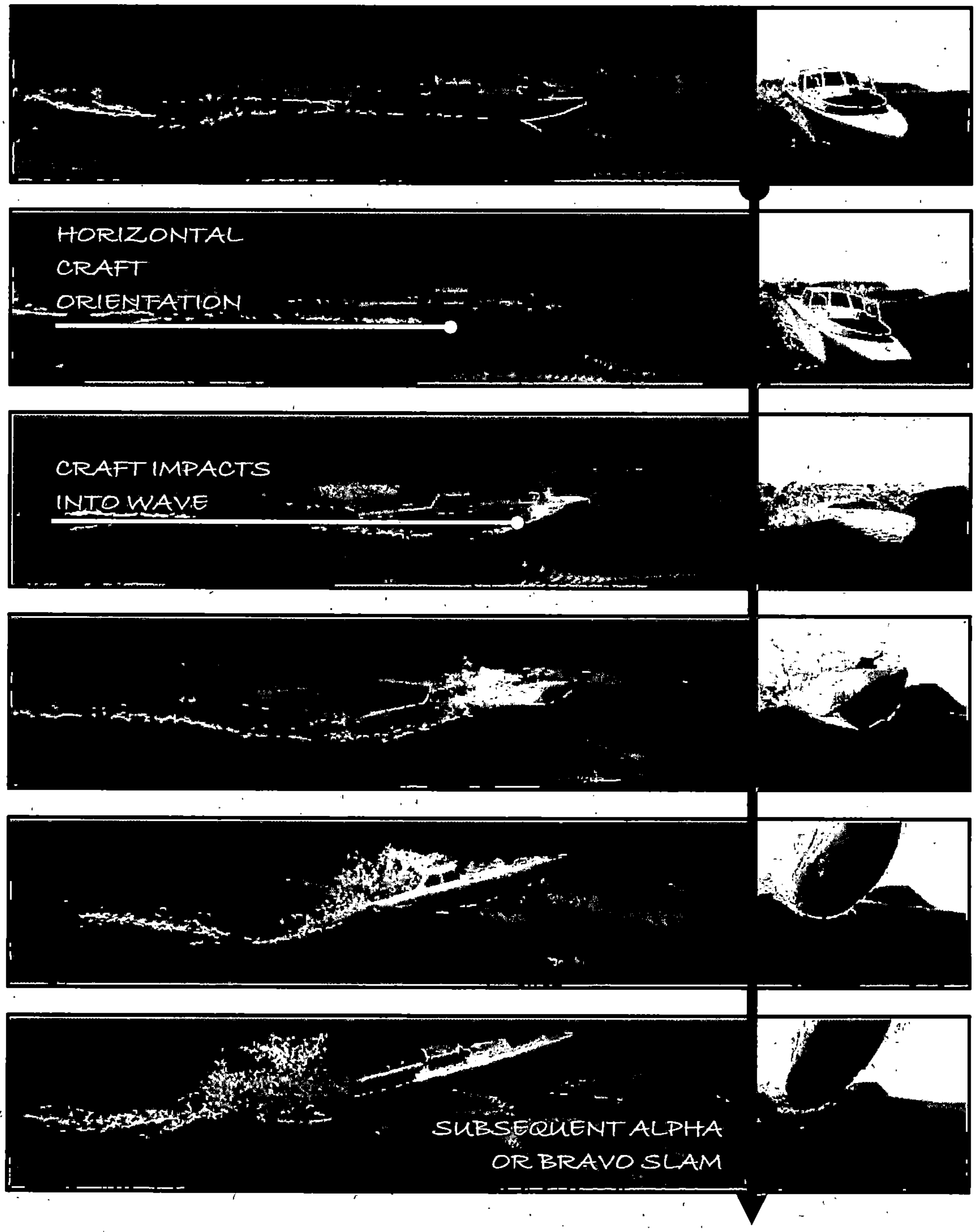


4.1.3: THE CHARLIE SLAM: TYPE C: *'THE STUFF'*

The **CHARLIE SLAM** is characterized by the lowest amplitude of peak vertical (Z-axis) accelerations

Characteristics:

- Craft typically traveling across water surface at a horizontal orientation.
- NO period of free fall
- Craft impacts, or 'stuffs' into wave
- No, or minimal, vertical acceleration
- Human experience: Sudden 'braking' force (similar to crash scenario, re: Chapter 5)
- Craft lifts within wave due to hull geometry and buoyancy



4.2: REPEATED SHOCK (RS) ANALYSIS METHODS

The analysis methods and parameters for HSC RS motion continue to advance. Currently the following methods / metrics described in table 4.1 are recommended:

Single slam events	• Peak impact (g) • Rate of acceleration onset • Pulse duration • Shock response spectrum
Single transits	• StandardG[7] • Impact Count Index (ICI)[8] • Vibration Dose Value (VDV)[9] • Sed8[10]
Multiple transits / Health Surveillance (H-SURV)	• Sed8[10] *Additional Enhanced Standardised Methods required*

Table 4.1: Repeated Shock (RS) Exposure Analysis Methods

With reference to Chapter 2, the assessment of the impacts is primarily perpendicular to the HSC deck. But, it is recognised that these approximately vertical forces are the greatest compared to the longitudinal and lateral forces and therefore the focus for RS mitigation solutions is on the vertical (perpendicular to the HSC deck) forces.

Lateral impact forces are uncomfortable for the HSC occupants and therefore where possible mitigation solutions should be developed. Similarly longitudinal forces, both from a Charlie slam (*STUFF*) into a wave (re: Section 4.1.3) or crash (re; Chapter 5), are of interest and the measurement of these forces should be undertaken to support the development of mitigation solutions.

4.3: REPEATED SHOCK (RS) MOTION LIMITS

Although it is essential that the structural limits of the HSC are not exceeded, it is the human occupants that set the operational envelope and therefore capability. This operational envelope requirement, relating to C2 issues, is described in Chapter 3. Guideline RS acceleration ranges have been described[11] for the A1/10(g)[12] and A1/100(g)[13] at the Longitudinal Centered of Gravity (LCG) and are described below in Table 4.2.

[7] Riley, M., Coats, T. and Murphy, H. (2014) Acceleration Response Mode Decomposition For Quantifying Wave Impact Load In High- Speed Planing Craft. NSWCCD-80-TR-2014/007

[8] Dobbins, T., Myers, S., Withey, W., Dyson, R., Gunston, T. and King, S. (2009) Impact Count Index for High Speed Craft Human Motion Exposure Assessment. Conference Proceedings; RINA, SURV 7 - Surveillance of Search & Rescue Craft, 27-28 May 2009, Poole, UK.

[9] ISO 2631-1; Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General requirements.

[10] ISO 2631-5; Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 5: Method for evaluation of vibration containing multiple shocks.

[11] Riley, M. and Marshall, J. (2013) Empirical Equations For Developing Ride Severity Envelopes For Planing Craft Less Than 55 Feet In Length. NAVSEA Carderock, Combatant Craft Division. NSWCCD-83-TM-2013/36. Sept. 2013.

Riley, M., Haupt, K. and Ganey, H.N. (2015) Ride Severity Profile for Evaluating Craft Motions. NAVSEA Carderock, Combatant Craft Division. NSWCCD-80-TR-2015/002. May 2015.

[12] A1/10 is the average of the highest 10% of peak shocks

[13] A1/100 is the average of the highest 1% of peak shocks.

Severity Zone	Description	A1/10(g)	A1/100(g)
1	Effective mission Duration **>4 hours**	<1g	<1.5g
2	Effective mission Duration **<4 hours**	<2g	<3.1g
3	Discomfort & Limited Mission performance	<3g	<4.6
4	*Extreme Discomfort*	<4 g	<6.1g

Table 4.2: Interim Recommended Repeated Shock (RS) Crew Comfort And Performance Zones[11]

It should be noted that these comfort and performance limits are **INDEPENDENT** of the HSC's physical characteristics. The human's tolerance to pain and discomfort, and performance in harsh environments is not influenced by the size, weight and design of the craft. These recommended limits[11] are illustrated below (Figure 4.1) in an operational envelope format. During the design phase the Naval Architect / Designer can predict the motion, e.g. VDV[14], A1/10 and A1/100 exposure, over a range of speeds and sea states for their proposed craft. From this data the design can be iteratively enhanced by changes to the craft's characteristics (e.g. geometry, weight, etc.) to minimize RS exposure. This process is undertaken during the Feasibility and Main Design Phases of the Integrated HSC Design Process (re: Chapter 1, Section 1.8 & Figure 1.8). If the capability is available, the motion of the craft can be calculated, and visualised as illustrated in Sections 4.1.1 to 4.1.3. The RS characteristics of the craft will be subsequently assessed during the Test & Evaluation (T&E) phase of the acquisition process. By integrating the predicted and measured RS exposure, an operational envelope - planning tool will be developed to support the training and operation of the craft.

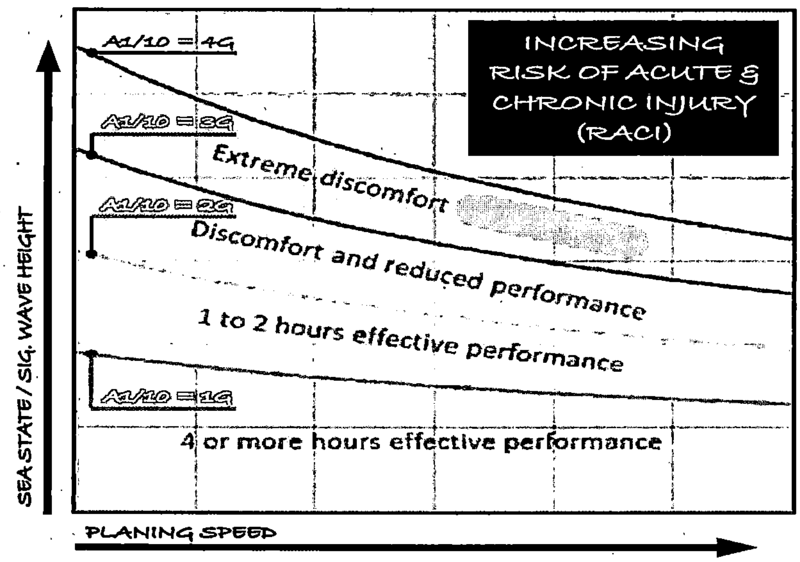


Figure 4.1: Recommended Repeated-Shock (RS) Crew Comfort And Performance Operating Envelope[11]

[14] Dobbins, T., Horton, J. and Scott, R. (2014) Defining Operational Envelopes To Support Human Systems Integration Within Fast Craft Design. Conference proceedings; RINA Human Factors Conference. London, UK.

4.4: RISK OF ACUTE & CHRONIC INJURY (RACI)

Injuries to HSC crew and passengers are generally classified as acute or chronic. Typically acute injuries are observed in 'novice' boat PAX, as illustrated by numerous MAIB accident reports. Chronic injuries are observed in experienced HSC operators[15] where aches & pains often become serious enough to result in medical down-grading and medical discharge from operating organisations. Figure 4.2 illustrates this Risk of Acute and Chronic Injury (RACI)[16] trend where: the risk of acute injuries is high in novices, there is a reduction in risk (which never reaches zero) as they gain experience, and then subsequently a gradual increase in the risk of chronic injuries over time. It is this risk of chronic injury that Health Surveillance (H-SURV) and health-monitoring programmes are designed to reduce. The development and implimentation of RS mitigation systems (both technical and operational) should reduce the risk of both acute and chronic injuries.

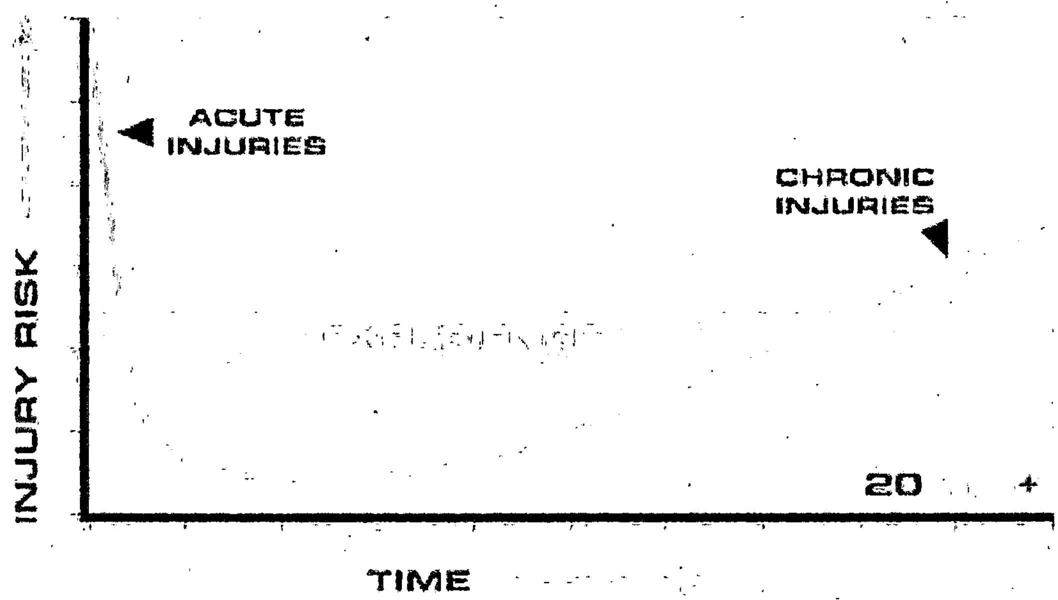


Figure 4.2: The Observed Risk of Acute & Chronic Injuries (RACI) in HSC Crew and Passengers

4.5: RS EXPOSURE & MITIGATION

To support HSC designers and operators a risk management matrix has been developed[17]. The class of craft and their typical speeds are compared against the anticipated RS exposure, this being related to the sea state. This 4x4 approach is shown below in Table 4.3. Once the Class of Craft and Level of RS exposure have been identified, the magnitude of RS mitigation required can be defined. Similarly, suppliers of RS mitigation systems (e.g. suspension seat

[15] Ensign, W., Hodgdon, J., Prusaczyk, W.K., Ahlers, S, Shapiro, D., and Lipton, M. (2000), A survey of self-reported injuries among special boat operators; Naval Health Research Centre, Tech Report 00-48.

Carvalhais, (2004) Incidence and severity of injury to surf boat operators. Conference Proceedings 75th SAVIAC Conference, Virginia Beach, VA. October 2004.

Lovalekar, M., Abt, J., Sell, T., Pockrandt, C., Morgan, P., Heebner, N. and Lephart, S. (2013) Frequency of musculoskeletal injuries and their impact on healthcare itilisation among Naval Special Warfare Combatant-Craft Crewmen. Proceedings; American Public Health Association Annual Meeting & Exposition.

[16] Hill, J., Forsman, F., Brand, T. and Dobbins, T. (2014) Risk, Competence, Interoperability and Qualifications For Fast Craft Operations'. Conference proceedings; RINA Human Factors. London, UK

[17] Colwell, J.L., Gannon, L., Gunston, T., Langlois, R.G., Riley, M.R. and Coats, T.W. (2011) Shock Mitigation Seat Testing and Evaluation. Conference Proceedings; RINA Human Factors in Ship design & Operation, London, UK.

manufacturers) can design and develop systems for specific applications, e.g. the RS mitigation solution for a Class 1 craft operating at Level 1 RS exposure will be different to a Class 4 craft operating in Level 4 RS exposure. This increasing risk of RS exposure is graphically illustrated in Figure 4.3.

CLASS	CRAFT TYPE	SPEED	LEVEL	RS EXPOSURE
1	Low speed commercial / leisure	<20 KTS	1	Mild
2	High speed commercial / leisure	>20 KTS	2	Moderate
3	Search and Rescue (SAR)	>30 KTS	3	Severe
4	Military	>40 KTS	4	Extreme

Table 4.3: Repeated Shock (RS) Exposure Risk Management Matrix.

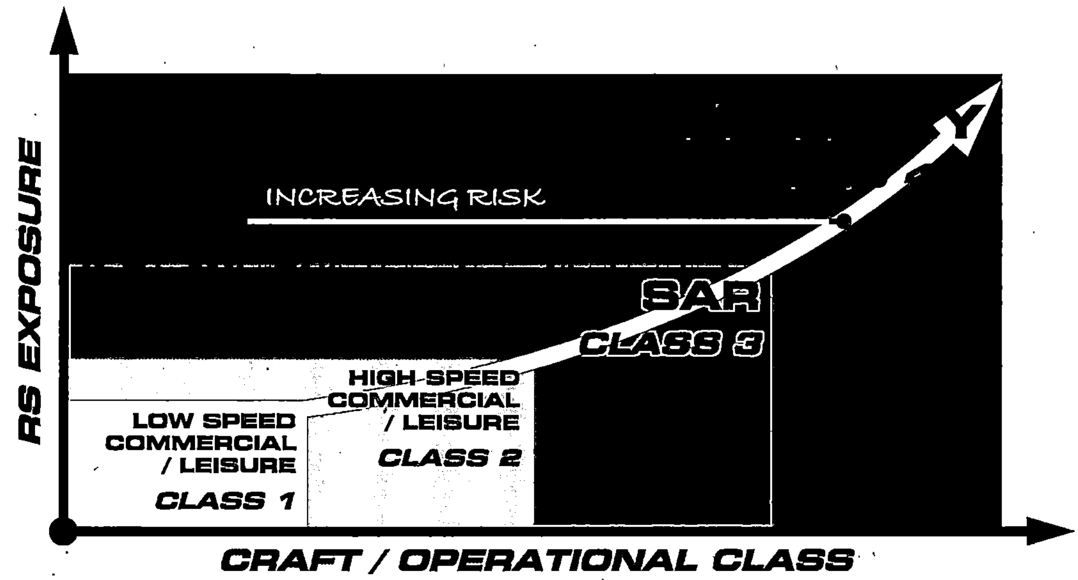


Figure 4.3: A Graphical Illustration of Increasing Risk, From the Interaction Between Craft Type / Speed and Repeated Shock (RS) Exposure.

4.6: RS MITIGATION STRATAGIES

The development of RS mitigation strategies is based on reducing risk at its source. From an HFE perspective, i.e. not including operational decisions such cancelling operations / training, enhanced training, reduced speed and specific fitness training, the following system hierarchy shown in Table 4.4 may be followed, noting that these are options and may not be included depending on the total system solution.

ORDER	MITIGATION SYSTEM	EXAMPLE SYSTEMS*
1	Hull geometry / Novel hull designs	Novel hull design: Bladerunner (ICE Marine)
2	Hull appendage	ARES (ICE Marine / Navatek) HYSUCAT
3	Increased HSC weight	
4	Suspended deck	Seactive
5	Suspended console	ICE Console (Shockwave)
6	Suspended Seats	• KPM • Scott • SHOXS • Shockwave • Ullman Dynamics
7	Exo-Skeleton (Personal Protective Equipment (PPE))	MARINE-MOJO (20KTS+)

* - EXAMPLE SYSTEMS: shown for illustration only.

Table 4.4: Repeated Shock (RS) Mitigation Hierarchy and Example Systems

4.7: LEGAL COMPLIANCE AND CREW DUTY-OF-CARE

This chapter focuses on the human exposure to RS during HSC operations and training. Whilst it is recognised that this exposure poses a Risk of Acute and Chronic Injuries (RACI), craft operators within Europe must still recognise that they need to comply with the EU Physical Agents Directive and their National legislation[18]. Examples of WBV / RS assessment have illustrated how far in excess of the Exposure Action Value (EAV) and Exposure Limit Value (ELV) typical planing craft motion is. Examples of typical exposure levels have been published[19], both relating to the measurement methods defined in the EU legislation (rms and VDV) but also as measures of RS exposure.

Test results[20], described in Table 4.5, have highlighted that 'robust'[21] individuals, who are accustomed to high levels of RS exposure, report the discomfort caused by the craft transits as being less than would be expected from the general public. This increased level of *'tolerable discomfort'* is illustrated below in Figures 4.4a, 4.4b and 4.4c. It must therefore be recognized that this type of crew / PAX are likely to expose themselves to higher levels of WBV / RS exposure – having a higher level of 'tolerable discomfort', thus increasing their risk of injury. Organisations operating HSC should acknowledge this trait and account for it in their RS exposure risk mitigation strategy, refer to Figure 4.5.

[18] UK Legislation; MCA Marine Guidance Notes; 353, 436 and 446.

[19] Dobbins, T., Myers, S., Withey, W., Dyson, R., Gunston, T. and King, S. (2009) Impact Count Index for High Speed Craft Human Motion Exposure Assessment. Conference Proceedings; RINA, SURV 7 - Surveillance of Search & Rescue Craft, 27-28 May 2009, Poole, UK.

Hawkins, M. and Finnemore, R. (2013) UK MOD Approach to Managing Whole Body Shock and Vibration in Small Fast Craft. Conference Proceedings; RINA SURV-8, Poole, UK.

[20] Dobbins, T., Myers, S., Dyson, R., Gunston, T., Pierce, E., Blankenship, J. and LaBrecque, J. (2008) Discrepancies Between the Perceived Discomfort of Experienced High Speed Craft Operators and Current Standards. Conference Proceedings; The 43rd United Kingdom Conference on Human Responses to Vibration, Leicester, pp 234-239.

[21] Robust, in this context, is defined as individuals who are resilient to RS / WBV exposure.

TRIAL DETAILS	• Boat length: 18m • Speed: ~40 Kts • 3-hour night transit • Sea-state: ~2-3.	

TRIAL WBV EXPOSURE		EU Physical Agents Directive WBV Limit Values	
		Exposure Action Value (EAV)	Exposure Limit Value (ELV)
wRMS	2.43 m.s^{2}	0.5 m.s^{-2}	1.15 m.s^{-2}
CREST FACTOR	23		
VDV	50.3 m.s$^{1.75}$	9.1 m.s$^{1.75}$	21 m.s$^{1.75}$

Table 4.5: WBV Exposure Level During Discomfort Assessment Trial (refer to Figure 4.4)

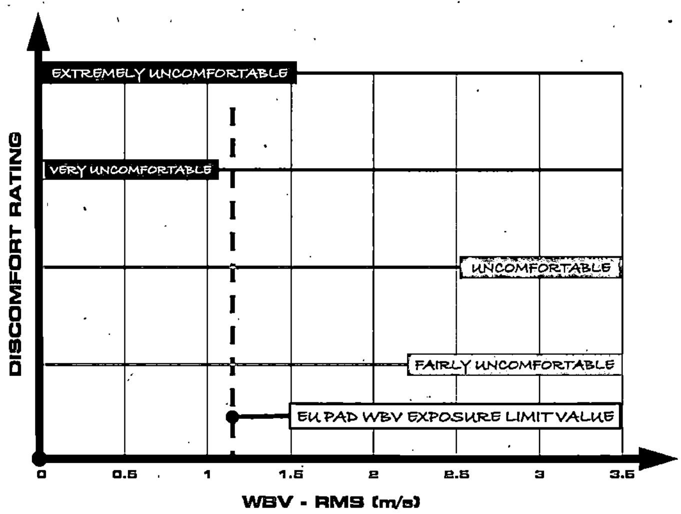


Figure 4.4a: Discomfort Rating Scale (BS 6841;1987) for Discomfort Assessment within a Whole Body Vibration (WBV) Environment. For reference, the EU Physical Agents Directive (PAD) WBV Exposure Limit Value (ELV) is Illustrated.

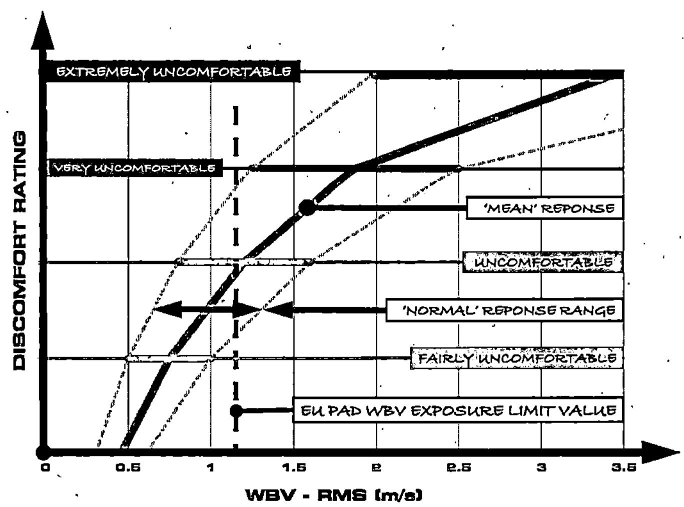


Figure 4.4b: Normal Population Discomfort Responses (BS 6841;1987) to increasing WBV Exposure.

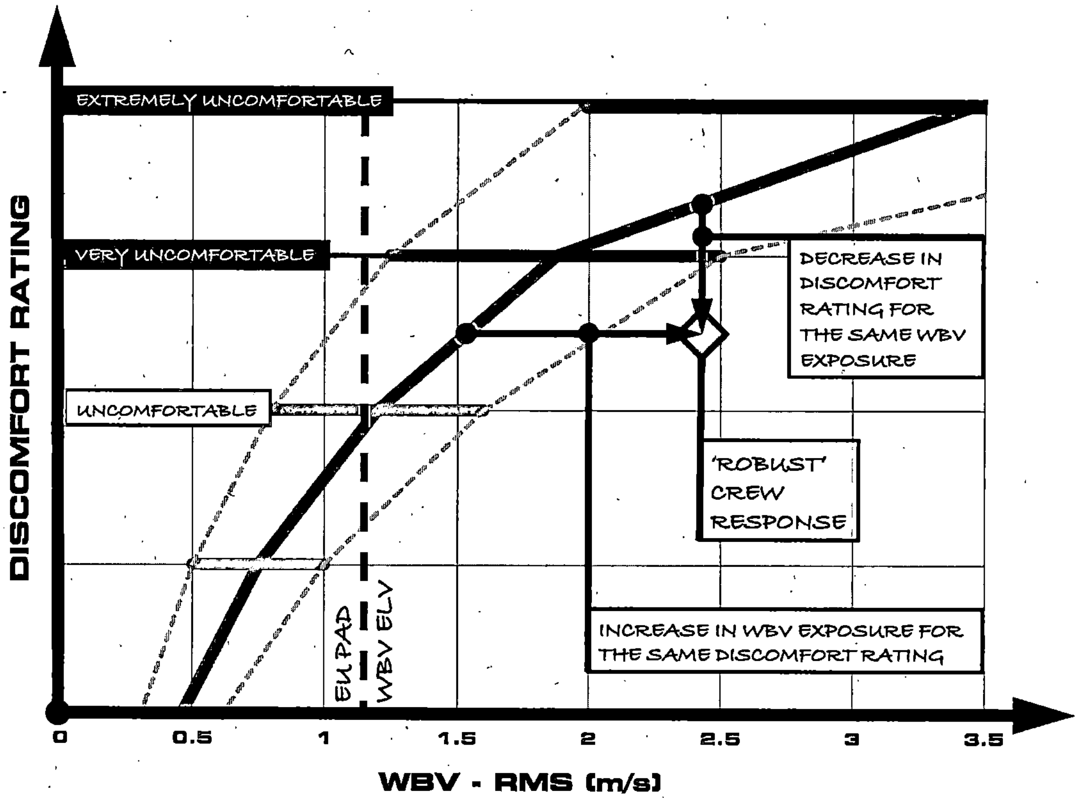


Figure 4.4c: The Difference Between a 'Normal' Population and the Reduced Discomfort Response from Robust, Experienced HSC Crew Illustrating Greater Tolerable Discomfort.

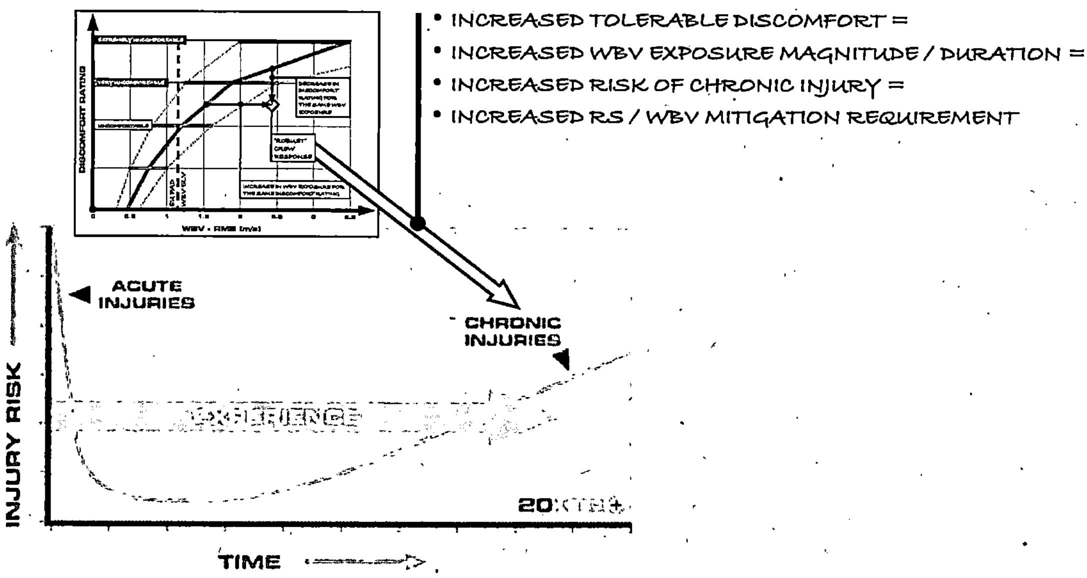
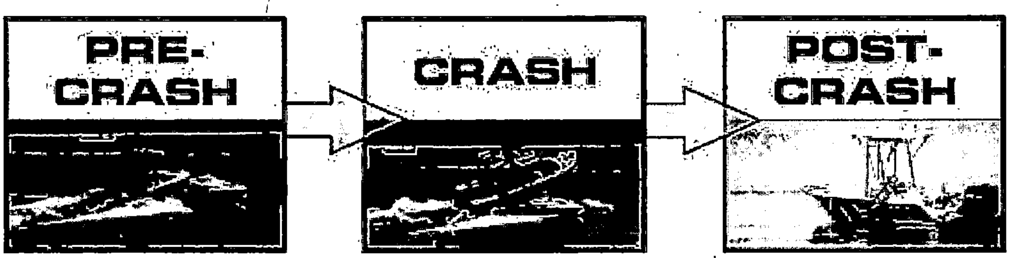


Figure 4.5: Illustration of the Increased Risk of Injury to Robust, Experienced HSC Crew with Greater Levels of Tolerable Discomfort and their Subsequent Requirement for Increased levels of Protection from RS / WBV Exposure.

5. CRASH & IMPACT SAFETY

SUMMARY

High speed and high tempo operations will always have a degree of risk associated with them. To enhance safety in planing craft, incidents can be analysed using a matrix that breaks down the incident into three phases, pre-impact, impact, and post-impact – see diagram below. For each of these phases the following aspects are analysed to reduce risk: the human, the craft, and the environment. By addressing each element of the matrix, both individually and from a holistic perspective, risk to both the individuals and the operation is reduced.



5.1: INTRODUCTION

High speed and high tempo operations will always have a degree of risk associated with them. History has many examples of incidents that have resulted in injury and tragic fatalities. In addition to having the risk of crashing into other vessels, floating structures and running aground, planing craft also expose their occupants to repeated slamming events, i.e. wave impacts, which can be severe enough to have the same result as the craft crashing. Therefore crash and impact safety is of particular importance to HSC design and operation. The priorities for the design and operation of the vessel should be:

1. Minimise the likelihood of a crash occurring
2. Survive the crash, without injury, if possible
3. Move to a place of safety (potentially leave the vessel)
4. Survive until rescue arrives (if in the water - wear a life-jacket, if in cold water - wear a survival suit, etc.)

5.2: EXAMPLE INCIDENTS

There are many examples of HSC crashes and incidents. The following four cashes are highlighted:

5.2.1: SEA SNAKE

An example of a HSC crash that was investigated by the UK Marine Accident Investigation Branch (MAIB) was the 'Sea Snake' incident[1]. Unfortunately this crash resulted in three fatalities.

POSTMORTEM EXAMINATION RESULTS:

GT: *There were multiple injuries to Mr T's chest, which resulted in severe internal bleeding. The forensic pathologist reported that the injuries were consistent with a heavy impact against a hard surface, such as a cockpit or wheel.*

RB: *The postmortem examination concluded that Mr B died from severe injuries to his chest. The forensic pathologist reported that the injuries were consistent with a hard impact against a hard surface such as a cockpit or wheel. There were sharp force injuries to his left hand.*

IF: *The postmortem examination concluded that Mrs F died from severe injuries to her chest. She also suffered severe injuries to her neck.*

The injuries to the occupants, located towards the front of the cockpit, and damage

[1] MAIB Report; Sea Snake. Report No 10/2006, March 2006

to the steering wheel and console, are indicative of a high-speed collision.

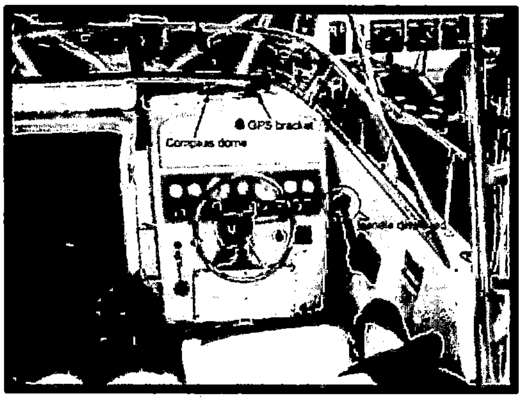


Figure 5.1: The Damage to Sea Snake's Console and Throttle. Image: MAIB[1]

The following text is taken from the MAIB Report to highlight some of the issues related to the incident. Text in **bold** highlights issues relating to design, training and operational guidance:

NAVIGATIONAL ERROR [PRE-CRASH PHASE]

A more likely scenario is that as the boat approached the entrance to the inner harbour at high speed, ***the helmsman became confused and unsure about the disposition of the navigation marks leading him into the inner harbour.***

Both of the helmsmen had received RYA training for daylight operation of a powerboat, ***but had not received RYA training in the operation of powerboats during darkness.***

IMPACT WITH THE ROCKS [CRASH PHASE]

When Sea Snake's forefoot hit the rocks, ***the forward part of her main deck parted from the hull, and there was extensive damage to the forefoot.*** *The forefoot impacted the rocks above the high water mark, and the aft end took on sea water. The forefoot slid down the rock and the boat re-floated into deeper water. Afloat she began to take water through the damaged areas at the forefoot. By the time the yachtsman arrived,* ***Sea Snake was filling with water, and was in danger of sinking, with everyone onboard*** **[POST-CRASH PHASE].**

5.2.2: FAST RESCUE CRAFT; G.R.1[2]

Summary

The Fast Rescue Craft (FRC) "G.R.1", dispatched from the "GORDON REID" on 29 March 1997 in response to an urgent SAR (Search and Rescue) call, struck a rock at about 0140 at a speed of approximately 30 knots. All three occupants were thrown from the boat and projected over the rock, landing in the water on the opposite side. The boat, carried by momentum, flew through the air some 18m and came to rest at the water's edge also on the other side. The three persons, with various injuries, were rescued by other boats and taken to hospital. The badly damaged FRC was removed from the rock and transported to the CCG yard in Victoria, B.C. where it was declared a total loss.

Causes and Contributing Factors

The navigation of the boat by radar alone, set to a short range; the reduced visibility; the obstructed access to the equipment; and a lack of teamwork contributed to this accident. Its occupants were injured as a result of being ejected from the FRC by its sudden deceleration on striking.

The crews of the CCG patrol ships using similar FRCs will be reminded to ***use the mandatory safety equipment (helmets) and to apply the principles of the Bridge Resource Management when navigating the boats.*** The latter procedure is to include pre-deployment briefings, communication between the FRC crew, cross-checking of intentions.

Regional orders will be introduced to amplify the existing ***FRC standard operating procedures and restrictions regarding weather conditions and crew experience.*** The ships' commanding officers (masters) will be instructed to include specific or local operating instructions in standing orders. All FRC operators will be reminded of obligations imposed by the normal practice of mariners and, whenever possible, ***given refresher training in blind pilotage.***

[2] Transportation Safety Board of Canada, Marine Occurrence Report No M97W0048.

5.2.3: GROUNDING OF A CB-90[3].

Abstract:

During the night between April 24 and 25, 2003 ten Combat Boats (Type 90h) transported troops from the Amphibious Corps from Uddevalla area to Styrsö. The boats ran line-astern in teams of two through the archipelago before darkness. The speed was 25-30 knots. In the transition from an open bay to a narrow strait between the islands Big and Small Brorn it is likely that the turn was delayed. The crew also had an unclear picture of their position in the fairway. They tried to resolve the situation by turning away from land. They didn't slow down. After two turns ***the boat ran up on shore, where it bounced several times and stayed upright with the bow about 30 yards from shore*** (the track of the craft is shown in Figure 5.2 below). On board were 20 soldiers and a crew of three men. ***Three persons received minor injuries. None had permanent damage. The Combat Boat suffered extensive damage, but was repaired and returned to service.*** No damage to the environment has been reported to the Board. The accident occurred during Exercise Amphibian, which is an annual training exercise for Amphibious soldiers. Combat boats and their crews had the task of transporting troops between the two practice areas. Crews participated in just the transportation, not the rest of the exercise. The Board notes that there was no functioning transport officer present during exercise. If the crew had been led by an officer during the exercise he could have checked the preparation for transport including preparation of charts. The board has not been able to find explanations for the accident on technical faults. Technology experts have found that both controls, compasses and radar worked as they should. The direct cause of the accident may, under the Board's view, be considered to be the fact that the crew didn't slow down, although it has repeatedly been called for. This may be considered remarkable especially given that the training includes the practice of "staying", i.e. stop the craft as soon as there is uncertainty about the situation. The evidence suggests that the crew lost attention to their task and were lulled into a false sense of security.

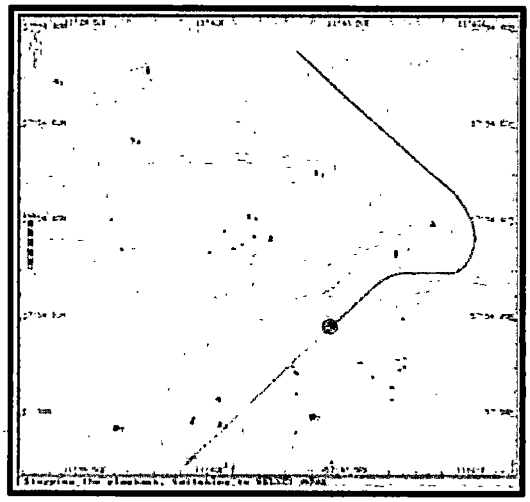


Figure 5.2. The track of the CB-90 prior to grounding.

Causes:
The direct cause of the accident may be considered that the crew did not slow down when they lost their orientation. Contributing factors to the accident:

- The preparation of charts was not performed in accordance with applicable rules.
- The absence of a functioning transport officer.
- ***The design of the interface for adjusting the radar may have contributed to mistakes or confusion when the navigator attempted to adjust the radar picture.***

Recommendations:

- Investigate the selection process for applicants who want to be CB-90 crew and instructors, and subsequently assist in formulating the recruiting criteria and manage the selection of personnel.
- Evaluate the implementation and results of the selection and training for crew and instructors, on a regular basis.
- Review the instructions for the planning of exercises for safety, and maritime safety analysis of activities that contain risk.
- ***Investigate the design of the environment in The CB-90 wheel house in order to include designing***

[3] Swedish Accident Investigation Board. Report RM 2004:01. (Translated from Swedish)

control devices for the radar to avoid mistakes and/or confusion.

- ***Specify checklists for tasks that are safety crucial.***
- ***Ensure that the combat boats have their navigation systems switched on during transiting so that track data can be saved in the case of an accident or incident.***

5.2.4: WINDFARM SUPPORT VESSEL INCIDENTS

The MAIB issued a single report[4] on two Wind Farm Support Vessel (WFSV) incidents, due to the similarities between the incidents. The vessels, both catamarans, are illustrated below in Figure 5.3. The first, *Windcat 9*, struck a floating target. The second, *Island Panther*, struck a wind turbine. The report, highlights a number of HSI related issues, including Situation Awareness (SA) and training. Of specific relevance to HFE are the designs of the bridge layouts (re: Figures 5.4 and 5.5) that should support the crew's SA. With reference to Chapters 2 (Digital Human Models) and 3 (Command & Control (C2)) the following issues are highlighted:

- *Windcat 9*: **The bridge design does not appear to directly support the required team-work between the Navigator and Driver. The Driver is expected to attend to the navigation displays and drive the boat.**
- **From the seated position it would be difficult to operate the majority of the systems, particularly in a harsh RS & WBV environment.**
- **From the seated position it would be difficult to read some of the displays.**

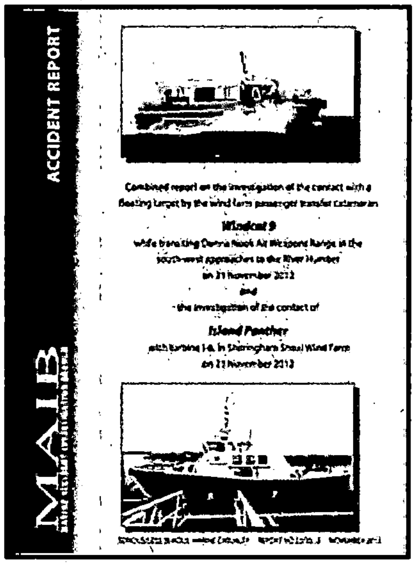


Figure 5.3: The Wind Farm Support Vessels involved in the incident investigations.

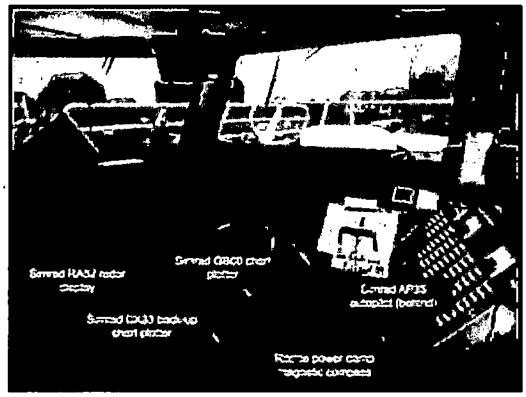


Figure 5.4: The *Windcat 9* Helm Position, Image: MAIB[4].

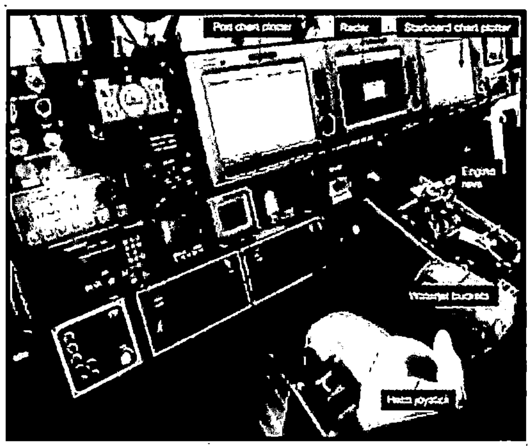
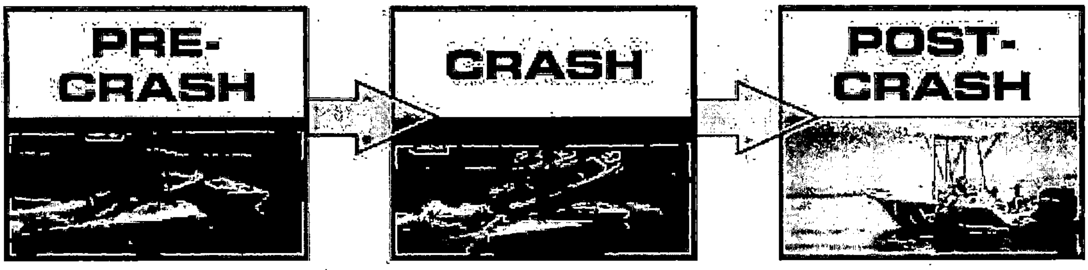


Figure 5.5: The *Island Panther* Helm Position, Image: MAIB[4]

[4] MAIB Accident Report, Combined report on the investigation of the contact with a floating target by the windfarm passenger transfer catamaran Windcat 9 while transiting Donna Nook Air Weapons Range and the investigation of the contact of Island Panther with turbine I-6 in Sheringham Shoal Wind Farm. Report No. 23/2013.

5.3: THE PHASES OF A CRASH

Three phases are used to describe how a crash occurs and how a range of factors may influence a crash / incident. Subsequently the factors are addressed to reduce the risk of the crash occurring, the severity of the crash, and the risk from the post-crash situation.



5.4: THE HSC CRASH ANALYSIS MATRIX[5]

To develop risk reduction solutions the three crash phases are examined using three factors, the human, the craft (technical system), and the environment – these three factors making up the Joint Cognitive System (JCS) (Refer to Chapter 3). This matrix[5], as used by the automotive industry, is shown below in Table 5.1 highlighting each element of the matrix.

	PRE-CRASH→	CRASH→	POST-CRASH
HUMAN	• Situation awareness • Posture	• Human impact with cockpit structure • Restraint systems	• Secondary impact • Survival
CRAFT	• Speed • Motion (6DOF)	• Structural response • Crash impulse received at cockpit	• Motion (6DOF)
ENVIRONMENT	• Visibility • Sea State	• Impact type; other craft, hardness of impact site, gradient / angle of impact	• Craft orientation / position

Table 5.1: The HSC Crash Analysis Matrix

It can be seen that the nine elements of the matrix each have specific design requirements and constraints that the HSC designer must consider. The design of the JCS is an integrated process and requires a total systems approach to identify an optimised design solution, i.e. focusing on any single issue will compromise the overall effectiveness of the total system.

The development of features designed to help survive a crash, and reduce the risk of injury (e.g. restraint harnesses, helmets, safety structures, etc.), and to survive in the water (e.g. immersion suits and life-jackets) are often perceived as compromising comfort and operability. This need not be the case, as demonstrated by the automotive and aviation sectors where both operational effectiveness and safety are successfully incorporated into their platforms.

[5] Dobbins, T., Thompson, T., and McCartan, S. (2015) Addressing Crash and Repeated Shock Safety Design Requirements of Fast Craft. Proceedings; RINA Marine Design Conference. London, UK.

5.5: EXAMPLE OF A HSC CRASH / COLLISION

To provide a degree of context to the development of safer HSC the following graphical example is provided to illustrate the crash phases and some of the elements highlighted within the safety matrix. The images are taken from research[6] examining staged collisions between HSC on-board, instrumented, crash-test mannequins.

5.5.1: PRE-CRASH→ PHASE

HSC transiting at high speed on collision trajectories.

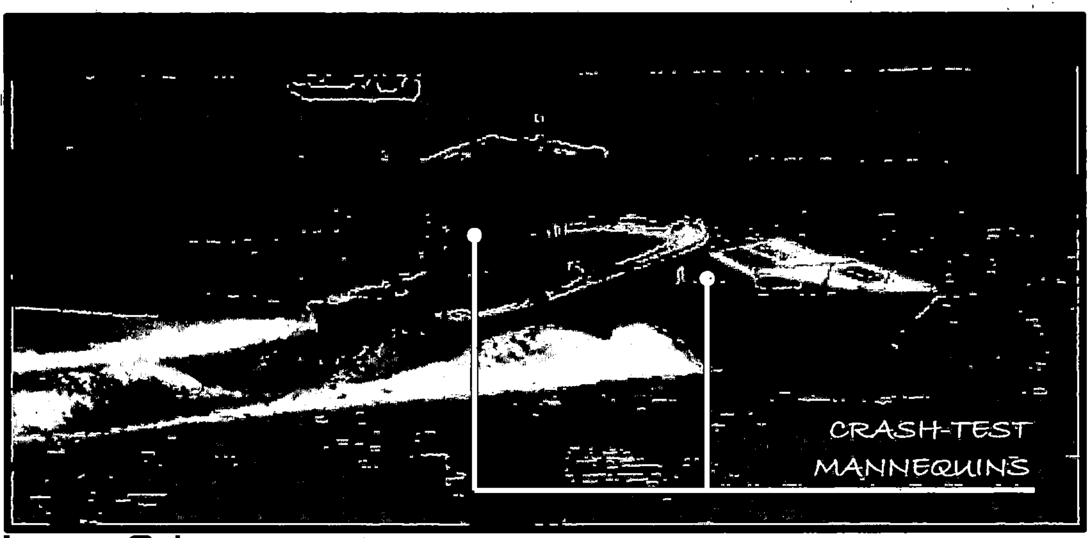


Image: Salzar

5.5.2: CRASH→ PHASE

The HSC collide with one over-riding the other. The impact forces recorded ranged from 5 to 12g. Compared to car crash scenarios the boat impacts illustrated greater vertical (Z) forces that contribute to the risk of occupant ejection from the craft.

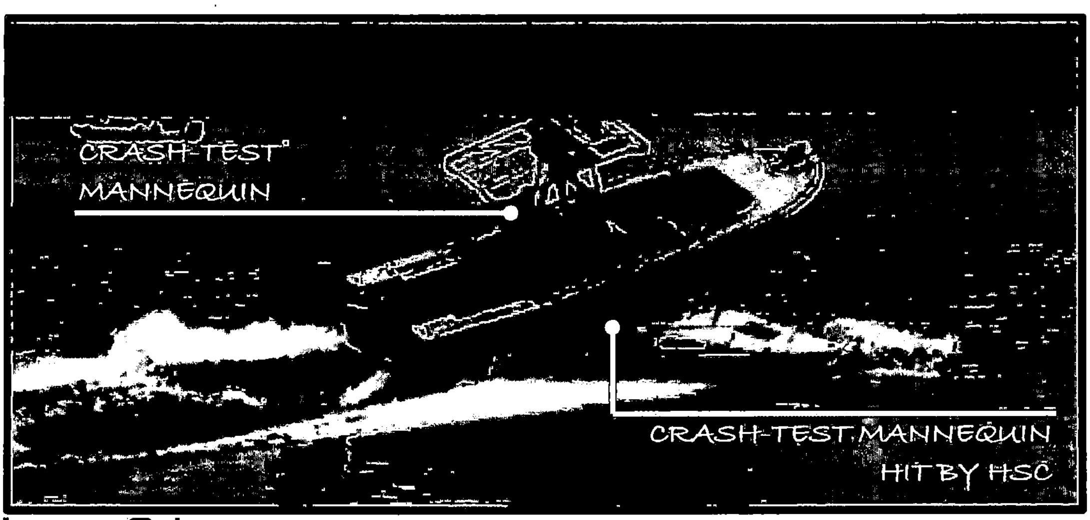


Image: Salzar

[6] Salzar, R., Ash, J., Lucas, S., Planchak, C., Dalton, A., Emond, B. and Getz, J. (2010) Dynamic Analysis and Injury Prediction for Small Craft Collisions. Journal of Ship Production and Design: Vol. 26(2), pp 89-97.

5.5.3: POST-CRASH PHASE

Examples of craft condition following collisions illustrating the fate of the occupants (crash-test mannequins). The results demonstrate the risk of head and neck injury, and the likelihood to ejection from the craft. Therefore the need to wear effective Personal Protective Equipment (e.g. life jacket) is highlighted.

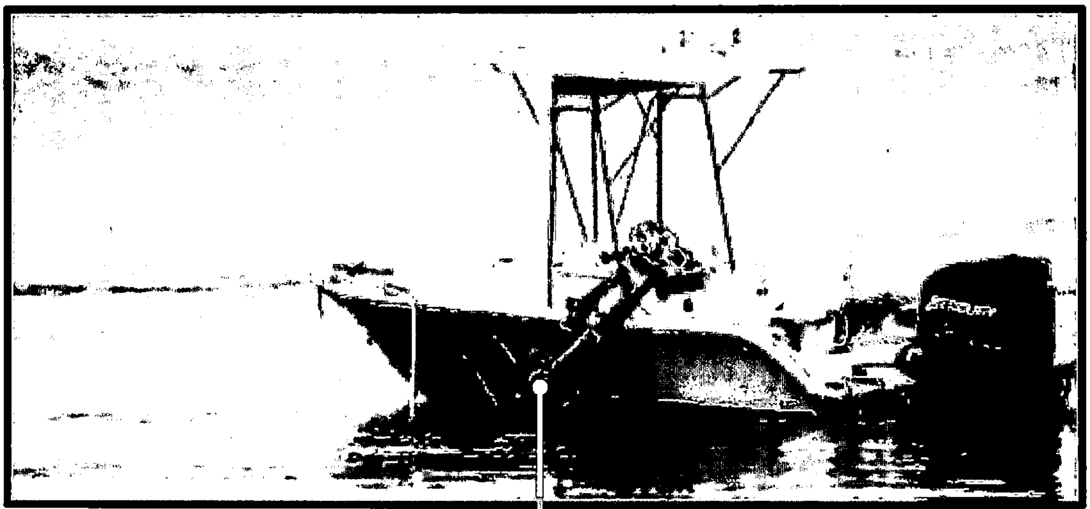


Image: Salzar

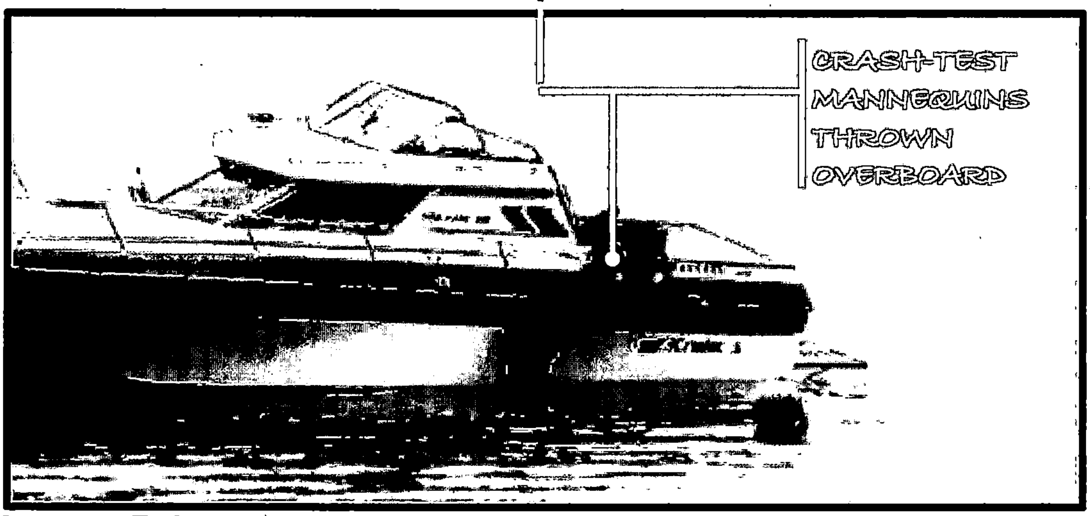


Image: Salzar

5.6: EXAMPLE OF POOR POSTURAL STABILITY AND THE SUBSEQUENT RESULTS

This section illustrates the responses of a HSC's occupants to the harsh motion environment. Note that these examples are not crashes, but rather typical planing craft motion that can result in injury. Images sourced from Internet video.

5.6.1: LEISURE & PROFESSIONAL CRAFT

1. Occupants position at start of transit in standing position

2. Occupants attempt to obtain better hand holds to improve postural stability

3. Driver reduces power, Girl in centre struggles to maintain position

4. Passengers react to boat pitching motion

5. Boat lands, occupants are forced downwards, girl in centre hits head on seat

6. Boat pitches up and rolls to starboard forcing occupants down into boat

7. Boat rolls further to starboard, occupants struggle to maintain position

8. Boat rolls to port, occupants forced to starboard

9. Boat stops rolling, occupants continue to move to port. Note that the throttle handle (drivers left hand) is **NOT** an effective handhold to provide stability.

10. Occupants continue to move to port. Girl on port side hits head on window

11. Occupants collapsing into the bottom of the boat

12. Boat starts to roll back to starboard, occupants continue to collapse into the bottom of the boat

13. Boat continues to roll to starboard, driver collapses to the floor, occupants move to starboard.

14. Boat rolls back to port, occupants collapse downwards into boat

15. Occupants collapsed into the bottom of the boat, water starts to cover boat

16. Occupants thrown to the front of the boat


17. Occupants pitched to starboard


18. Occupants collapse into the bottom of the boat and are covered in water.

CONCLUSION:

Although the boat in this example may be considered to be a leisure boat, it's occupants are still exposed to the same RS, WBV and incidents, and therefore risk of injury, as professional / commercial HSC crew and passengers. Therefore best-practice guidance, e.g. MCA MGN 436 (Whole-Body Vibration: Guidance on Mitigating Against the Effects of Shocks and Impacts on Small Vessels.) should be considered as the **MINIMUM** design standard (refer to Chapter 2).

5.6.2: RACE BOAT

The following is an example of race boat occupants being eject from their seats. Note that the individuals have tight fitting seats but the roll-acceleration is violent enough to eject them, even with what may be considered to be good postural stability support features.

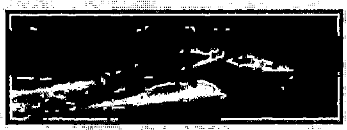

1. Occupants pitched to starboard


2. Navigator ejected from the boat

5.7: CRASH ANALYSIS MATRIX DESCRIPTIONS

The phases of the crash and the Joint Cognitive System (JCS) are decomposed and each element of the matrix analysed to identify factors and potential solutions that may reduce the risk to the JCS, including injury to the human. These descriptions (other factors will be identified for specific applications and operations) and examples of potential solutions are shown below in Sections 5.7.1, 5.7.2 and 5.7.3.

5.7.1: PRE-CRASH→



Factor	Description	Solution
HUMAN		
Situation Awareness (SA)	The crew needs to have acquired, and maintain a sufficient level of SA to support safe and effective decision-making, i.e. reduce the risk of navigation errors being made	Systems; the craft's systems must be designed to support the crew and their SA requirement as part of the JCS. Therefore the information displays must be optimised to support the DYnamic NAVigation (DYNAV) methodology and related Standard Operating Procedures (SOPs) Training; The crew must be appropriately trained and competent to execute their operations.
Position & Posture	The crew's position and posture in the craft must support the acquisition and maintenance of SA, and reduce the risk of injury during an impact / crash	Ensure that the crew has the correct external views and can see, and control the information displays. The information architecture must enable the crew to rapidly access, perceive and assimilate the information The crew & PAX must be in a location / posture that minimises their risk of injury during the transit from RS and if an incident / crash occurs suddenly
CRAFT		
Speed	Higher speeds reduce the time available for decision-making	System information displays must support rapid information assimilation to support effective decision-making. Reduce speed when and where appropriate
Motion	When not operating in benign sea conditions the HSC is subject to 6 Degrees Of Freedom (DOF) motion, therefore stability, and the control of the craft is reduced	The design of the hull should reduce RS and WBV exposure The craft should be inherently stable and not surprise the occupants The craft should be easily controllable to alter direction / heading
ENVIRONMENT		
Visibility	HSC operate in poor / restricted visibility – therefore SA can be compromised	The crew should have the best viewing systems to support their SA. This may include infra-red cameras / displays, Augmented Reality (AR), etc.
Sea State	Higher sea states can result in reduced control, risk of stuffing into waves and injury to occupants	Higher sea states are more difficult to operate in and the crew must be trained to operate effectively in them. They must be able to terminate a transit if safety is likely to be compromised

5.7.2: CRASH→

Factor	Description	Solution
HUMAN		
Human impact with cockpit structure	As the craft rapidly decelerates an unrestrained occupant will be thrown forward and impact with the cockpit structure / furniture[7]	Restraints should be considered Surfaces should be angled to provide a pathway away from higher risk surfaces / edges. Edges must be radiused – i.e. no sharp edges, or sharp corners, impact absorption should be provided where ever appropriate.
Posture	The direction of seating / standing will influence potential injury risk	Compliance with MCA MGN 436[8] for issues with the seating, posture and postural stability
CRAFT		
Structural response	Direction of impact (and secondary impact), e.g. front, side & / or rear How is the force transmitted from the point of impact (e.g. bow) to the cockpit ?	Consider impact mitigation from different directions Methodologies for absorbing energy before the crash impulse arrives at the cockpit Sacrificial structures and energy absorbing systems / materials should be considered Consider cockpit safety structure
Crash impulse received at cockpit	What forces reach the cockpit ? How are these resulting forces dealt with ?	Protection systems to reduce cockpit crash impulse and / or protect the occupants
Cockpit equipment	Injuries to human caused by loose equipment	All equipment and accessories should be securely stored to stop them moving around the cockpit
Fire	During the craft there is a risk that the HSC could catch on fire	Fire prevention features must be included in the design
ENVIRONMENT		
Crash site	Impact type; other craft, hardness of impact site, gradient / angle of impact	Consider crash / impact scenarios related to areas of operation and the subsequent risks
Inversion	In the event of a roll-over the occupants may be struck by the boat structure, and / or stuck under the boat	Consider minimising risk from the boat structure Consider self-righting, air pockets, Short Term Air Supply (STAS), etc.

[7] MAIB Report; Sea Snake. Report No 10/2006, March 2006

[8] MCA MARINE GUIDANCE NOTE (MGN) 436: Whole-Body Vibration: Guidance on Mitigating Against the Effects of Shocks and Impacts on Small Vessels.

5.7.3: POST-CRASH

Factor	Description	Solution
HUMAN		
Secondary impact	Craft may be exposed to additional impacts from other craft, being washed ashore in rough conditions, etc.	Develop safety features to maintain the integrity of the occupant space
Survival	The occupants may be at risk of drowning, immersion, hypothermia, etc.	Ensure design features protect the human in the event of the craft integrity being compromised
CRAFT		
Orientation	The final orientation of the craft may make evacuation and rescue difficult	The craft design should account for rescuing the occupants if the craft is inverted; on it's side, etc. Maintain the occupant space above the waterline
Motion (6DOF)	Subsequent motion of the craft may cause further injury risk	The craft may be required to transit with injured person / casualty. Consider how they will be made comfortable / secured Consider how the vessel could cope with large sea state / waves with no power, control, being inverted etc.
Craft Condition	Craft may be damaged (sacrificial impact protection) and lack enough buoyancy to float There may be no environmental protection	Consider designing in reserve buoyancy than can survive a crash / damage to the HSC Consider how environmental protection may be provided when the craft structure is damaged
ENVIRONMENT		
Craft orientation / position	The craft and the occupants may be at risk from the environment The occupants may be unable to exist the craft	Ensure occupants don't drown Ensure the occupants can exit the craft even when significant damage has occurred to the craft
Extended duration before rescue	Deterioration in the condition of injured and non-injured people	Ensure communications to SAR services and local vessels. Vessel power may have failed, therefore backup communications system(s) must be considered. Provide protection from cold and wet Provide storage for enough food and water to last until help arrives.

5.8: DELIVERING SOLUTIONS

Crash and impact safety for HSC is not a topic that receives a lot of attention in the maritime sector. Therefore it is essential to engage with lessons learnt and best practice from related sectors. The following sections provide further information for enhancing HSC crash and impact safety.

5.8.1: CRASH TESTING REGULATIONS

The following section is based on a RINA[9] Conference paper[10] and describes some aspects of marine seating design and subsequent crash testing.

In alignment with the automotive, rail and air travel industries, the HSC 2000[11] defines a specification for crash testing seat systems and mounting points. The test specification defined in the HSC Annex 10 uses the ECE 80 passenger train core code, and specifies the following scope;

- Dynamic testing
- Static testing
- Projection and contact surfaces
- Escape measures

DYNAMIC TESTS:
The regulations as laid out in Annex 10 state that the seat system has to be tested as it is to be fitted in the vessel and this includes the structural fixing to the floor. The dynamic test is undertaken on a crash test track with instrumented Hybrid III crash test dummies, which provide information of the forces and damage done to the dummy and consequently the occupant in real life. The key data points captured from the test include the Head Injury Criterion (HIC), the neck including flexion and extension, the force on the chest, femur and pelvis which all have to pass. The important aspect for the vessel designer is to understand the Collision profile of the vessel referred to as the GColl. If the vessel has a GColl Design level 1, then the test can undergo a lesser 3g test and in some instances a static test is acceptable. If the GColl is to level 2 the test impulse has to be 12g.

Each configuration has to be tested with 95%ile 100kg dummies with head, chest and pelvis accelerometers, chest potentiometer, neck load cell and femur load cells. All occupied seats must have test dummies to simulate the loading of the pedestals, both restrained and unrestrained.

STATIC TESTING
The purpose of the static or pull tests are to ensure the seat can withstand forces from multiple directions that may not be fully addressed in the Dynamic tests. The tests include vertical, forward and rear loadings to 2250N. The test is deemed to have passed if the seat does not give way or detach. A vertical upward pull and side load pull is undertaken at 1500N to ensure there is no feature that detaches. More significant is the arm side load test at 800N and arm down force at 1000N.

PROJECTION AND CONTACT SURFACE TESTING:
Annex 10 details the requirement for testing projections and contact surfaces in order to protect the body from lacerations and penetrations. Whilst Annex 10 does not specify the methodology for the test, National testing standards should be considered. Example tests include a 160mm ball being rotated around the seat, with the contact points on the ball having a minimum of a 5mm radius. If the ball makes contact with a radius less than 5mm then the sharp area needs to be addressed in the design.

ACCOMMODATION AND ESCAPE MEASURES:
After a crash it is vital that the occupant can egress from their seating position and access safety equipment. The test does not only apply to fixtures and fittings but also stowage of luggage and equipment that may become dislodged and create injury or restrictions to egress. With mass transit seating there is also a need to consider occupants that has become incapacitated and cannot exit on their own. In this instance if the injured party is at the end of a seating row then features such as excessive seat moldings and arm rests will complicate the extraction of the occupant whom may weigh in excess of 100kg. As

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9 Royal Institution of Naval Architects

10 Morgan, J.R.J (2014) Developments in Marine Seat Design and Regulation. RINA Conference Proceedings; Design and Operation of Wind Farm Support Vessels, 29-30 January 2014, London, UK

11 International Code of Safety for High-Speed Craft, 2000

such, armrests should be able to be put into the vertical position and the occupant's legs lifted and swung round onto an adjacent seat. If the seats are devoid of moldings and supports the injured occupant can be pulled along the platform created by the row of seats to aisle. In addition to these simple measures the HSC code also details that there should be sufficient grab handles to aid these operations.

5.8.2: UIM RACE BOAT SAFETY

The Union Internationale Motonautique (UIM) is the International governing body for powerboat racing, which includes offshore marathon racing. Many HSC have design features that are similar to racing powerboats and therefore aspects of the safety rules that govern UIM racing are relevant for HSC design to support crash and impact safety. **The following points (in this following section) are taken from the 2015 UIM Offshore Rules[12], both general requirements and Marathon racing**. This is only a small section, with editing, from the rules - readers should refer to the original document for the full details. Note that the dimensions quoted are for crewmembers who are unlikely to be wearing bulky PPE and additional operation equipment. Therefore designers must consider the specific people, equipment and operations they are designing for.

A reinforced cockpit with a canopy is defined as a containment area for crew and can be constructed as an integral part of the boat. This reinforced cockpit area must be designed and constructed to a specification capable of withstanding the forces of a water impact when running at the highest design speed of the boat, and therefore protecting all members of the crew in the event of an accident.

The driver and co-driver have clear, safe and undisturbed visibility ahead at sea level whilst racing. For Class 1 it is strongly recommended that these polycarbonate areas are built using 12 mm thickness, or more. The combined visibility of driver and co-driver must be through a horizontal arc of 225 degrees (112.5 degrees either side of the centre line of the boat).

These restraint cockpits must be fitted with an internal roll bar, two in a tandem cockpit as a minimum. Cockpits with restraints must be fitted with rear head protection for each crew member. This must be an integral part of the seat, which must be attached directly to the structure of the Restraint Compartment. The head protection must be a minimum of 0.2m wide and extend at least 75% of the height of the safety helmet as worn by the crew whilst in the normal seating position. There must be a minimum of 0.12m vertical and lateral clearance between the canopy and each of the crewmembers when in the normal seating position.

The Restraint System must consist of a 5 or 6 strap harness and should utilise a 75 mm lap belt, a 50 mm strap over the shoulder harness rated at 4,100kg (9,000 lb.) and grommeted to prevent chafing or cutting of the belt. Harness straps must be attached directly to the cockpit structure. Those straps close behind the driver's head and neck must be 100 mm to 150 mm apart at the point of attachment. The shoulder harness should be installed at 90 degrees to the spine at shoulder line to minimise compression injuries under high "G" loading. All straps must be free to run through intermediate loops or clamps/buckles. All anchor point bolts must be fitted with backing plates of 10cm minimum width.

When using seats with suspension, and therefore not using a bulkhead restraint anchorage, drawings must be lodged with the National Authority and approved.

All restraint systems must have a common method of release. The single lever method (sometimes called the NASCAR type) or rotary type, are both acceptable restraint release systems.

Boats with restraints must have stop buttons/switches located in the cockpit area, immediately accessible to driver, co-driver and rescue officers. The stop buttons / switches must be identified by a fluorescent colour. These switches must shut off all fuel pumps as well as the ignition circuit. In the case of diesel boats, the stop control cable for the fuel injection pump shall be a non-sleeved cable, so as to eliminate the cable being able to bond in a fire. Carbon

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[12] UIM Offshores Rules, 2015. http://www.uimpowerboating.com/files/9614/2435/2911/2015_offshore_rulebook_-low_def___Locked..pdf

monoxide sensors and alarms must be fitted in all canopied boats.

All competitors and crew members who race in boats with restraints, canopies, and partial canopies must hold a current immersion test certificate.

The crew must be able to demonstrate that they can safely exit the boat (maximum recommended exit time 30 seconds).

There must be an opening hatch with a minimum open space sufficiently large (**MINIMUM** 55cm X 82.5cm) for each person in the boat to exit immediately. Alternatively, there must be an open space in the rear of the craft sufficiently large (**MINIMUM** 1.3m X 1.3m) for all crew to exit the boat immediately. Access at this opening must not be restricted in any way whatsoever. ***[NOTE:** these **MINIMUM** dimensions are unlikely to be large enough for people wearing PPE and operational equipment].*

Partially canopied boats may have restraint systems fitted which, if fitted, must comply with the Offshore Rules. The structure of the partial canopy must be of similar strength to the hull/running surface of the boat. The windscreen must be of suitable materials and have flanges adequate to offer the strength required to meet the anticipated loads and speed of the craft.

Doors or hatches must be designed to allow them to be easily opened from inside and out and must be labelled to allow rescuer to immediately understand opening system and backup system – hinges must have removable pins. There must be an air system provided for each crewmember. There must be a minimum clearance between seats or door aperture of 40cm if this is the primary exit route.

No seat belts or restraints whatsoever are permitted in open boats, i.e. boats with no canopies or boats with no partial canopies.

All Craft with a top speed in excess of 50 knots, which do not have a forward cabin structure, must have a Reinforced Water Deflector over and under the deck, designed and constructed of materials with sufficient strength to provide adequate crew protection. The forward fairing on deck must rise to a minimum height of the chin of the tallest crewmember when in the normal driving position. The top 5cm of the water deflector must be at least 45 degrees from the horizontal with a minimum of 30cm width per person measured transversely in the horizontal plane. The Reinforced Water Deflector must be designed and constructed so as to present no hazard if the crew is thrown forward and must be so designed that it would not restrict the crew from being ejected in all cases.

Open RIBs must have a solid fitted console to deflect water. In addition, all vessels must have a means of preventing the riding crew from sliding forward under the foredeck when in their normal racing position. A bulkhead or suitable kick-board in front of each of the riding crew must be fitted and be of sufficient strength to prevent the riding crew from forward movement in the event of rapid deceleration. The bulkhead/kick-board must be secured so that there is no more than 1 inch space between the crews' floor and the bulkhead.

It is recommended that enough buoyancy is provided in the race boat or in the material used for its construction to ensure that the boat floats if capsized or holed.

Suitable, automatic bilge pumps shall be fitted to the boat capable of pumping out all sections of the boat even where water-tight bulkheads are fitted. They shall be accessible and be fitted with a suction pipe leading to the lowest point of the bilge and with a discharge pipe overboard. There shall also be at least one manual bilge pump in the boat.

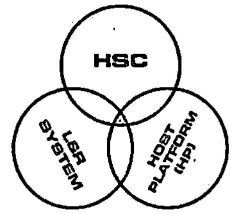
Engine cut-off devices for connection to the crew are mandatory (first man out shuts off engine). An emergency over-ride system to restart the engine/s shall be mandatory. The lanyards used must not exceed 120cm between driver and the boat. The emergency cut-off devices must be positioned so that when they operate the lanyard and cap (or clip) will not catch or foul. The lanyards shall be attached to all crew members at all times when the boat is racing.

All boats with inboard engines shall carry a fixed automatic fire extinguishing system. This system shall be properly installed, engineered and maintained. ALL boats including inboards shall carry a minimum of 2 fully charged dry powder 2kg fire extinguishers.

6. LAUNCH & RECOVERY (L&R)

SUMMARY

The HSC operational capability requires more than the HSC on it's own. It must have the ability to deliver the HSC to the area of operation, by sea – via a Host Platform, land – on a trailer, and air – underslung from a helicopter. To achieve this capability, the HFE aspects of the HSC, the L&R system and Host Platform (HP), and potentially more importantly, the interaction between these components must be optimised to ensure the safety and performance of the human operators within the system.



6.1: INTRODUCTION

Although much HFE effort is invested in the design of the HSC, the total system includes the ability to L&R the craft via land, sea and air. This section focuses mainly on the L&R for HSC from maritime host platforms, but many of the issues are also common to land and air L&R systems. A HSC could have the best design allowing it to operate safely and effectively on the water. But, it is potentially useless if it cannot be deployed / transported to its area of operation. Therefore, depending on the requirements, the design of the HSC may be compromised by its transportation constraints. For example:

SEA:

- Crane capability to L&R the HSC between the host platform and the water – Safe Working Load (SWL).
- Transport to shore location
- Shore / Port-based infrastructure
- Host platform storage concept, e.g. standard container, on-deck, or davit.

AIR:

- Dimensional and weight constraints for carriage within aircraft.
- Weight and size for under-slinging beneath helicopter
- Transport to the airfield

LAND:

- Trailer limitations
- Towing vehicle imitations / availability
- Height, width and length for road transport laws
- Slipway launch trailer
- Crane availability
- Access to the waterfront within the area of operation

Whilst most of the aspects addressed within this chapter relate to manned HSC, many of the features addressed are relevant to Maritime Autonomous Systems (MAS), particularly Unmanned Surface Vessels (USVs). Although a USV may itself have no human occupants, it's operation relies on humans to undertake C2 functions, L&R, etc. Currently most USVs operate at various levels of automation, rather than being autonomous. This may range from remote control (the operator being located on-shore or on a host platform) to a highly automated USV that operates via a sophisticated control system running pre-programmed instructions. The requirements of the USV L&R system have similarities with the development of manned HSC L&R systems where automation can play a greater role in enhancing safety and supporting lean manning requirements.

6.2: THE PRINCIPAL DESIGN DRIVER - THE HSC NOT THE HOST PLATFORM (HP) / SHIP

It is essential to understand the order of importance of the system components. If the operational need is to deploy assets (e.g. HSC) for essential functions (e.g. SAR, surveillance) from a Host Platform (HP), e.g.

a ship or floating platform, then the deployable assets take priority and their design is NOT compromised - therefore delivering the maximum operational effect.
If, alternatively, the HSC plays a minor role in support of the HP then it's design will be compromised – potentially increasing risk and reducing performance.

The perspective taken here is that the deployable HSC (including USV) is an essential part of the system that delivers operational capability and therefore any design compromises are not made to the HSC.

6.3: THE OFF-BOARD SYSTEM

Although the focal point for deploying HSC from host platforms is the L&R system – this component makes up a small part of delivering a capable off-board system. The system – described as a Joint Cognitive System (JCS) – refer to Chapter 3, Section 3.1 – functions as the integration of the human, the technology and the environment.

The off-board system can be considered as being the integration of three components:

1. The HSC
2. The Host Platform
3. The L&R System

Traditionally the three components have been considered individually, with insufficient integration between them at an early enough point in the design process. The operational capability is delivered by the optimisation of the interaction between the component and therefore the Designer needs to focus on these aspects to deliver the required operational performance and safety. The three components and the interaction between them is illustrated in Figure 6.1.

The following issues are highlighted that are specific to the L&R systems components, and the interaction between them.

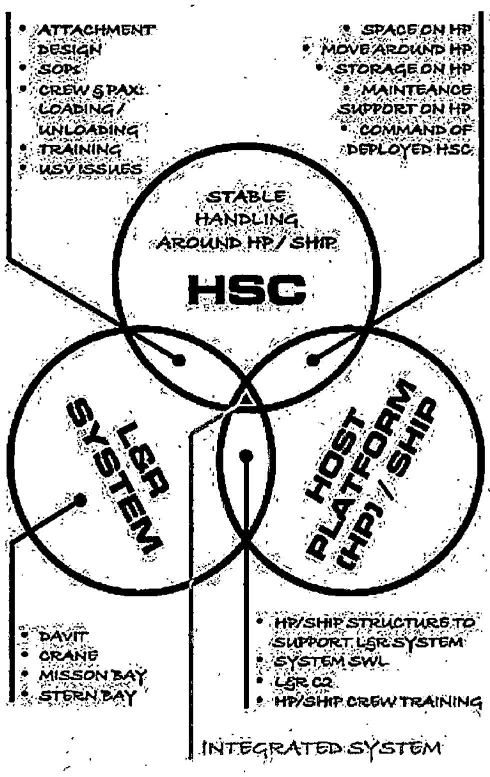


Figure 6.1: The Relationship Between the HSC, the L&R System, and the Host Platform (e.g. Ship)

6.3.1: HSC ISSUES

The HSC is required to have handling that is stable, predictable, and controllable around the HP. The following considerations should be made to the design of the HSC to support the operational effectiveness and safety:

- The HSC must be designed to operate around HPs; it must be able to cope with the movement of the HP and the water around it.
- Where HSC are required to operate around HPs the propulsion drive system should be specified in accordance with the control requirement, e.g. water-jets may not provide the appropriate level of performance.
- The HSC must be inherently stable when operating alongside and near the HP, i.e. maintaining positional accuracy should not require a high level of skill from the Driver, i.e. this should not be an edge of the operational envelope activity for the JCS. The Driver should have enough spare workload capacity to cope with maintaining his / her SA for

the operation, undertaking effective communication, and must be able to cope with unexpected circumstances / emergency situations.

- The HSC must have the appropriate responsiveness / acceleration for maneuvering around the HP, particularly for conditions at the edge of the operational envelope.
- The HSC must have an appropriate maximum speed to provide the required relative (overtaking) speed for operations at the edge of the operational envelope
- The HSC must have the required longitudinal and lateral control for accurate maneuvering to allow rapid interaction with the L&R attachment system.
- The HSC Driver / Helm location be optimised for the HSC's primary operational role. This will typically be at the front of the HSC to maximize SA and reduce the PAXs potential RS and WBV exposure. It may appear to be easier to place the Helm location at the rear of the HSC, thus allowing the Driver to see the L&R attachment point, this potentially compromises the HSCs' primary operational role. The HSC will have a minimum crew of two and therefore the second crew member, in coordination with the Driver at the front of the HSC, can effectively undertake the L&R attachment procedure.

6.3.2: HOST PLATFORM ISSUES

The HSC's HP will typically be one of the following:

- A land base
- A fixed floating platform
- A ship

Each of these HPs have specific requirements, but they also have similar characteristics.

Note that this section does not cover free-fall lifeboats that are often located on ships and fixed platforms.

HP: LAND BASED

Land based HSC may have the following L&R systems:

- Crane L&R system
- Trailer / slipway L&R system
- Bespoke L&R system[1]

HP: FIXED FLOATING PLATFORM

The deployment of HSC from fixed-location floating platforms is typically undertaken using either:

- Crane L&R system
- Davit L&R system

HP: SHIP

The deployment of HSC from ships can be achieved using a number of different methods, these include:

- Crane L&R system
- Davit L&R system
- Side mission bay (a type of crane)
- Stern launch

There are many specific HFE design issues related to each of these methods that are covered below.

One aspect that should be considered is the design challenges that occur with installing a new HSC capability onto a legacy platform. It should be noted that rarely will a new HSC system be simply 'bolt on' to an existing ship, and therefore sufficient resources should be allocated to modifying the HP (e.g. allocate more deck space, new cranes / davits, etc.) to fully exploit the enhanced capability that the new HSC provides.

[1] e.g. RNLI Shannon Class Lifeboat L&R System

6.3.3: L&R ISSUES

Most L&R Systems that designers incorporate into their designs can be considered to be Commercial-Off-The-Shelf (COTS). This is an example of Catalogue engineering[2]. Although it can make the task of designing the ship simpler, it can also lead to important compromises that degrade the potential capability of the HSC and thus the total ship system. But, it is important to recognise that COTS (or often Modified Off The Shelf (MOTS)) can bring the advantages of Standardisation for Interoperability (S4I), and reduced training and maintenance costs. Therefore the optimisation of the total system must be considered through out the design of the system. Typical L&R systems used on HPs include:

- Crane L&R system
- Davit L&R system
- Side mission bay (a type of crane)
- Stern launch

Other than the Stern launch methodology all of the others have a Safe Working Load (SWL) limitation. Therefore the designer needs to carefully match the crane capability with the HSC's characteristics. If the HSC is to undertake L&R with the Crew and PAX (and operational equipment) onboard then the L&R system must be approved for 'Man-Riding', which requires an increased safety margin.

Mission bay systems are becoming more common and provide an enhanced degree of flexibility for the HSC. Examples of the issues that must be addressed have been described[3] and should be must be considered by the designers.

If the Crew & PAX are not embarked for the L&R then the Designer must provide an appropriate method for embarkation and disembarkation, both for the people and the loading of equipment. This can be a challenge when the requirements of the HSC L&R system are not considered at the start of the design process and are not a primary design requirement. Trying to incorporate these requirements during the later phases of the design process often leads to poor, and potentially dangerous design solutions.

6.4: OPERATING ENVELOPES

Undertaking L&R in benign conditions can be considered to be relatively straightforward. It is more important to understand the L&R system's required operational envelope. This has to account for the following aspects:

- Weather / Sea State
  - e.g. the swing of HSC across the deck.
- Speed of the ship
- The ship's heading
  - Head, following or beam sea
- Ship speed relative to heading and wave frequency
  - How fast do the waves pass the L&R point ?
- The magnitude of the interaction effect between the ship and the alongside HSC[4]
- The tying of HSC to the deck edge during foul weather due to crane limitations
- Does the system include motion compensation ?
  - Can the crane / davit follow the wave height / frequency ?

In developing the L&R operational envelope techniques such as circling the ship should be considered. This reduces / minimises wave height within the circle and allows for easier, and therefore safer L&R operations. This capability, developed by the Swedish Sea Rescue Society (SSRS), and known as the Sea Calming Turn, is part of the First-Rescue project[5]. An example of the Sea Calming Turn is shown in Figure 6.2.

[2] Dobbins, T., McKesson, C. and Stark, J. (2012) Embedding Human Systems Integration within Marine Systems Engineering. Conference Proceedings; RINA Systems Engineering in Ship & Offshore Design Conference, London. March, 2012.

[3] Eaton, M., Ambrose, G and Pass, D. (2014) The Integration of Launch and Recovery Systems into the Mission Compartment. Proceedings; ASNE Launch & Recovery Symposium.

[4] McTaggart, K. (2014) Hydrodynamic Interactions during Launch and Recovery of a Small Boat from a Ship in a Seaway. Proceedings; ASNE Launch and Recovery Symposium Linthicum, Maryland.

[5] http://www.first-rescue.org

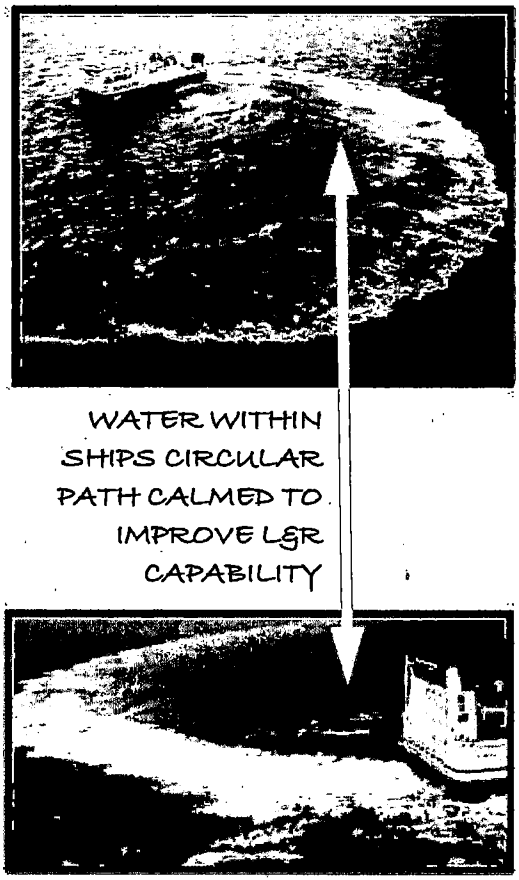


Figure 6.2: An Example of the Sea Calming Turn developed by SSRS as part of the First-Rescue project.

6.5: SYSTEM INTERACTION ISSUES

Within the development of the off-board system the integration of the three components is as essential as the design of the components themselves. The following describes some of the issues that designers need to address:

6.5.1: HSC : HP ISSUES

- Space on the HP to store the HSC
- Space on the HP to move the move the HSC around, this may be using a crane or on a wheeled trolley.
- Storage on HP for HSC fuel, spares, equipment in a convenient location
- Space and facilities on HP to allow HSC fueling with the required safety precautions
- Space and maintenance support for the HSC on the HP
- The command of the deployed HSC from the HP
- Space on the HP for the crew and PAX to prepare their equipment and position themselves pre-launch so they are in a convenient location to easily board the HSC
- The design of the HP Ship influences the wave pattern along the side of the vessel. The position of the wave peaks and troughs should be used to identify optimum locations for L&R systems to be positioned

6.5.2: HSC : L&R ISSUES

This component interaction is where the Designer has to focus on NOT compromising the design of the HSC to facilitate an easier L&R design task.

- The design of the attachment device must be simple, reliable and attach/detach quickly
- The system must be designed in cooperation with the users to ensure that the operation of the attachment device is coordinated with the users' Standard Operating Procedures (SOPs)
- The system must be designed to coordinate with the loading and unloading of the crew, PAX and equipment
- The system must be have the required SWL and where appropriate be man-rated
- The system must be designed to reduce the crew skill level and the training required to operate the attachment device effectively and safely
- Where possible L&R system motion compensation should be considered
- The system, where possible, should consider the use of automation to enhance efficiency and safety
- Where the system is [potentially] used for the L&R of USVs the designers must

understand how automation is to embedded within the system

- The type of attachment is essential for not compromising the design of the HSC. Attachment types / devices issues include:
  - o Single point attachment
  - o Double point attachment
  - o Type of hook – including quick release options
  - o The use of strops, attachment, storage, holding in position, risk of crew entanglement and injury, etc.
  - o The use of fixed point attachment devices
- Standardised attachment devices are required to facilitate support interoperability
- The ability to cope with changes in the HSC Centre of Gravity (COG)
- Consider novel attachment designs

6.5.3: L&R : HP ISSUES

- The design of the system must support the operational requirement / envelope, this includes:
  - o Speed, including minimum to maintain HSC steering ability
  - o Sea state
  - o Ship heading
- Once the design of the L&R system has been confirmed the structure of the HP can be designed around the L&R system
- Where the HSC is stored within a bay / aperture the HP designer must allow the required clearance between the HSC and edge of the aperture. The size of the aperture must also allow for future HSC of greater size.
- The HP structure must accommodate the weight of the L&R system, the HSC, crew, PAX, equipment, safety margins and potential future developments
- The location for both crew and PAX embarkation / disembarkation, and the loading / unloading of equipment position must support operational efficiency and safety; i.e. there must be direct access to the HSC both on the HP and when along side at the waterline.
- The control / operation of the L&R system must be simple and intuitive.
- There must be direct communication between the L&R system controller and the HSC crew
- The C2 of the L&R system, between the HSC crew, the HP L&R personnel, and the HP Bridge crew must understand the L&R SOPs and the roles and functions of:
  - o HSC and it's crew
  - o HP and it's crew
- Where the L&R system requires the use of lines to control the HSC the HP personnel must be fully trained on their use including unusual and emergency situations.
- The HP L&R Personnel must be trained to operate the system throughout the operational envelope, and demonstrate competence.

6.6: STANDARDISATION

Standardisation For Interoperability (S4I) is an essential concept for current and future operations. With respect to off-board operations it is essential to be able to be launched and recovered from a range of HPs. Examples of how such standardisation is being developed by the Joint Industry Project (JIP) LAURA (LAUnch and Recovery of Any small craft)[6]. In addition to facilitating enhanced operational capability S4I also provides enhanced:

- Training – having standardised systems means that the crew only needs to be trained once to be able to complete L&R on a range of HPs. This means that C2 and SOPs are standardised across HSC and HPs
- Maintenance – having standardised systems means that the crew only needs to be trained once to be able to

[6] Kremer, F.G.J and Takken, E.H. (2014) Development Overview of a Launch and Recovery System Standardization. Proceedings; ASNE Launch and Recovery Symposium, Linthicum, MD, USA.

support and maintain the L&R systems on a range of HPs

6.6.1: COMMERCIAL OFF THE SHELF (COTS) L&R SYSTEMS

The use of COTS L&R systems have the potential to support S4I, **BUT ONLY** if the system fulfills the operational requirements.

6.8: SYSTEM FAILURE

When things go wrong during L&R operations they go wrong very quickly, and unfortunately fatalities have in the past occurred.

It is important for Designers to understand typical L&R system failures and to develop solutions to reduce the risk of these incidents occurring.

6.9: OPERATIONAL CONCEPTS

Within the CONcepts of OPerations (CONOPS) it is essential to develop and instigate the required Command, Control & Communication between the HSC, the HP deck crew and the HP bridge team. Although the communication may normally use voice (e.g. via a radio), alternative / emergency systems must be put in place. Non-verbal communication may be via visual signals using lights and flags.

The following example uses an over-the-side launch of an HSC using a davit, crane, or mission bay system. A similar deconstruction of the L&R phases can be completed for a stern launch from a ship etc.

6.9.1: LAUNCH PHASES:

PREPARATION:

- Issue operational orders
- Ensure the use of SOPs
- Complete sufficient rehearsals to maintain competence and develop teamwork
- Ensure maintenance / servicing is completed and the System prepared to the Operation

PRE-LAUNCH:

- Ensure HSC Crew & PAX are prepared and ready to deploy
- Ensure the HP deck crew are ready

LAUNCHING:

- Enact SOPs
- Ensure Emergency SOPs are ready enact

MOVING AWAY:

- HSC departs HP, maintaining communications with HP Bridge team
- HP Deck Crew prepare for subsequent HSC recovery

6.9.2: RECOVERY PHASES:

PREPARATION:

- HSC and HP communicate to confirm recovery including HP location, speed and heading and no intention to maneuver once the recovery phase has started
- HSC crew prepare for recovery onto HP
- HP Deck crew prepare for HSC recovery

MOVE ALONG SIDE:

- Confirm HP Deck Crew ready
- HSC PAX disembark if required, ensuring system components are deployed appropriately, e.g. pilots ladder / walkway, etc.

ATTACHMENT TO RECOVERY SYSTEM:

- HSC crew complete attachment
- Ensure alternative / emergency SOPs are ready to be enacted

RECOVERY:

- **Part 1:** HSC raised from water to HP deck edge

- **Part 2:** HP deck edge to Cradle
- Ensure alternative / emergency SOPs are ready to be enacted
- HP Deck Crew secure HSC to cradle

DE-SERVICE:
- De-service L&R and HSC Systems
- Complete operation debrief, ensure lessons learnt are enacted
- Prepare for next HSC Launch if required

SYSTEM MAINTENANCE:
- Complete HSC and L&R system maintenance
- Ensure HSC Crew equipment is maintained and prepared for the next operation

6.9.3 RESPONSIBILITIES

The HSC Commander is responsible for the safety of the craft, his crew and PAX. Therefore the HP Deck Crew takes their instructions from the HSC Commander as the HSC is at the greatest risk during the L&R operation. The following points are highlighted to support operational capability and safety:

COMPETENCES:
- The C2 of HSC, including L&R, is a specialized skill that takes a long time to gain.
- The HSC competences are very different from the C2 of the HP, therefore the HSC Commander is responsible for the L&R of the HSC and has authority for actions relating to the safety of the operation.
- The competence and SA of the HP Deck Crew is essential as the HSC Commander / crew cannot see the HP deck from the waterline.
- The Commander of the HP must ensure that the HP crew, both Deck and Bridge, have the required Knowledge, Skills and Aptitude to support the L&R of the HSC as they will be responsible for the safety of the HSC crew and PAX during the operation
- **NOTE:** HSC L&R is a high risk operation and **fatalities** do occur. Good design can reduce this risk

TRAINING AND REHEARSAL:
- It is essential that the HSC L&R team regularly train and rehearse together, including emergency SOPs
- Generally the individual parties do not train together enough
- Training is generally completed in good weather. It is **ESSENTIAL** to practice in bad weather
- Operations undertaken in poor weather / sea conditions require good risk management to ensure system safety

6.10: AUTOMATION

The capability of automated systems has increased greatly, particularly related to the unmanned systems. The capability to deploy Unmanned Surface Vessels (USVs) from HPs is continuing to be developed and this will have the potential for automating aspects of the L&R of manned HSC in the future.

6.11: TEST & EVALUATION

It is essential that the HSC end-users effectively articulate their L&R requirement. As part of objectively defining this requirement, the subsequent Test & Evaluation (T&E) process must be considered, and how the L&R system is assessed to deliver the required capability. The following points should be considered:

- What is the operational envelope that the L&R system must achieve ?
- What are the objective performance and safety metrics that the system must achieve ?
- How is the T&E to be undertaken to evaluate the system at all aspects of the operational envelope ?
- The T&E process most be undertaken by the appropriately trained and experienced personnel[7]. This must

[7] Hill, J. and Dobbins, T. (2013) The Test Coxswain: The Human Element within Test & Evaluation. Conference Proceedings; RINA SURV-8 conference, Poole, UK.

include ensuring the L&R system is appropriate for use by both HSC and HP Deck crew with the minimum qualifications / competence / experience

- Ensure the appropriate risk management system is utilised for the T&E process

6.12: TRAINING

Training is an essential aspect of the HSI process that is inherently linked to HFE. Due to the risks involved in HSC L&R operations the system designer must minimise the training requirement of both the HSC and HP Deck crews. This reduces the potential for the crews making an error and the training burden of maintaining crew competence.

To deliver the required L&R capability the system must work effectively and safely throughout the operational envelope – i.e. in all conditions. The system also requires the crew to rapidly cope with abnormal and emergency situations – these situations require regular training and adaptability (resilience) from the crew and the total system.

The design of the L&R system and the training must also include the HP Bridge Crew who must understand both the capabilities and limitations of the HSC and HP Deck crews. The HP Bridge team must also understand and practice positioning the HP in the correct location, orientation / heading and speed – in all environmental conditions. The required level of capability **CANNOT** be achieved from undertaking a small number of L&R serials, rather from undertaking regular training of multiple serials in the full range of environmental and operational conditions – including night time with poor sea conditions.

6.12.1: SIMULATION

Simulation is a recognised methodology of undertaking education training. Although simulation cannot fully replicate L&R in the full range of operational / environmental conditions it is ideally placed for training operational procedures. An example of a simulator designed to practice HSC L&R is shown in Figure 6.3. Once the crew has become competent in the L&R SOPs they can move onto at-sea training.

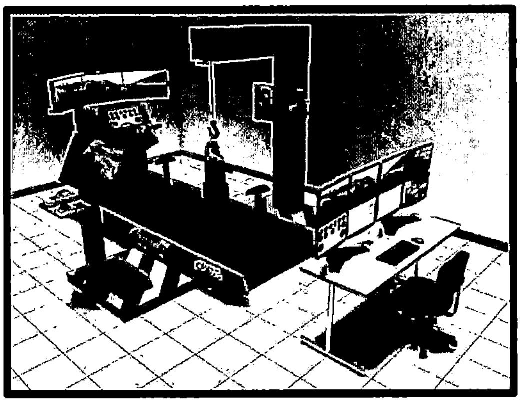


Figure 6.3: Example of L&R simulator for procedural training. Image: VMT

6.13: USVs

Unmanned Surface Vessels (USVs) are increasing being used for a range of both civilian and naval applications. To effectively deploy USVs from HPs the systems require an increased level of automation of the L&R system.

Currently this may be achieved via remote control but this requires the USV controller to have an appropriate level of SA, which can be difficult to achieve, particularly in poor environmental conditions.

Although the USV system may have an enhanced level of automation the designer must understand the system's potential failure modes and how this will be rectified – including how the crew members will step-in and take control of the situation. Therefore, until the USV attains the required level of reliability the USV will need to retain the ability to switch to a manned control situation.

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6.14: HELICOPTER UNDERSLINGING:

Many HSC have the capability to be underslung from helicopters. Although there are similarities with some of the attachments used with crane operations there are specific aspects that the designer must take into account. These include:

- Reduce risk of HSC spin by using a double-point lift rather than single-point
- The design and configuration of the double point lift
- The need to maximise stabilisation in flight. This can include the decision to fly the HSC stern first (see Figure 6.4) to reduce the aerodynamic lift from the hull if flown bow first

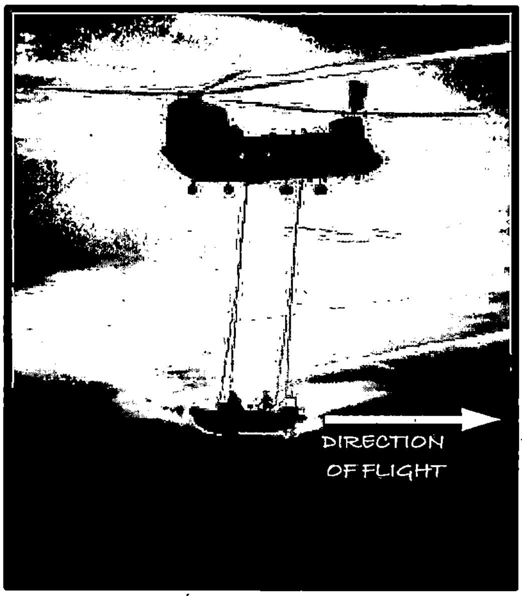

Figure 6.4: Example of RIB being flown stern first to ensure stable flight. Image: UK MOD

- Minimal risk to HSC crew from strop entanglement
- Embarkation / disembarkation of the crew to and from the helicopter. An example of a crew member fast-roping into a HSC is shown below in Figure 6.5

Figure 6.5: Example of HSC crew fast-roping into RIB whilst underslung below a CH-47 helicopter. Image: US DOD

- Rapid attachment and disconnection of strops, see Figure 6.6
- Minimise the training requirement by designing a system that is simple to operate

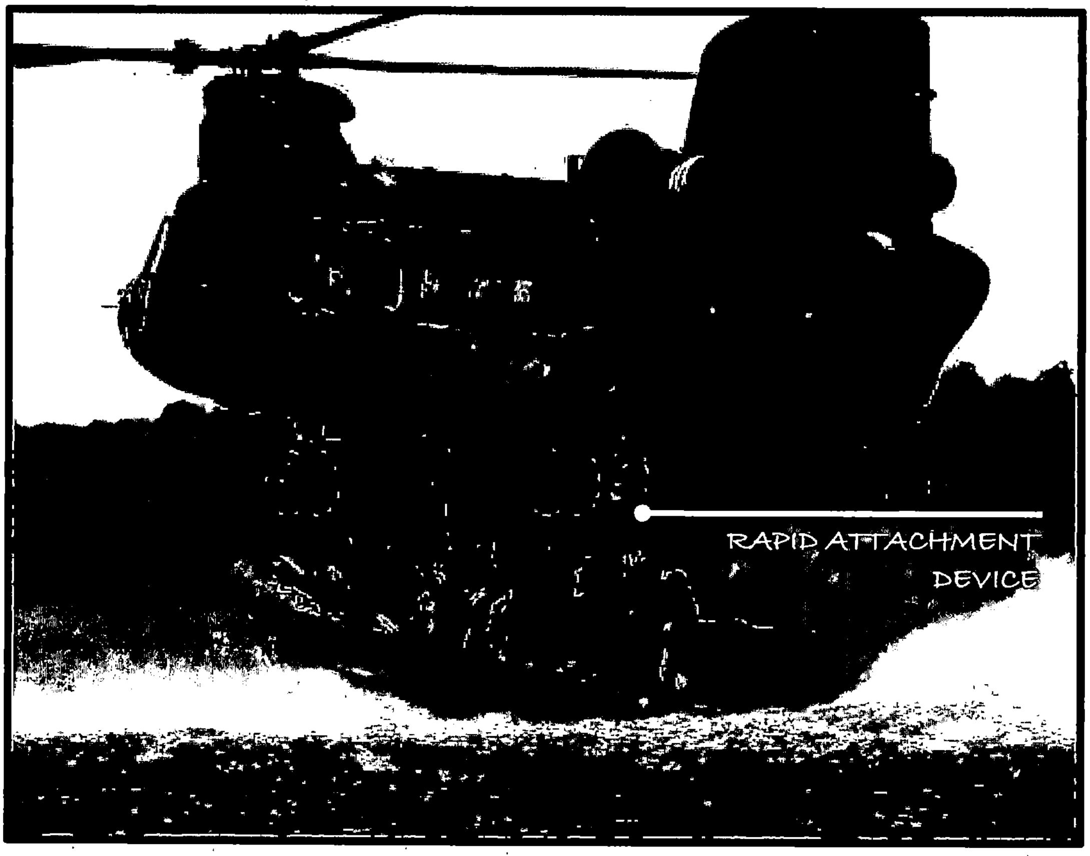

Figure 6.6: Example of RIB being hooked-up to helicopter illustrating the need for rapid, simple attachment - as is also required for attaching to HP L&R system in poor sea conditions. Image: US DOD

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APPENDIX 1:

Human Factors Integration (HFI) & Human Systems Integration (HSI)

Human Factors Integration (HFI) and Human Systems Integration (HSI) are, respectively, the UK MOD and US DOD initiatives to support integration of the human element in the acquisition of military capability. The two initiatives share their roots in a common approach developed by the US Army in the 1980s, known as MANPRINT (MANpower PeRsonnel INTegration). Over time, UK HFI and US HSI have developed and diverged in terms of scope and terminology, but in essence they retain the same overall objective of integrating the human element to support the acquisition of an effective, affordable and safe capability.

Definitions:

Human Factors Integration (HFI)

UK Defence Standard 00-250, 2008

"HFI is a systematic process for identifying, tracking and resolving human-related issues ensuring a balanced development of both technological and human aspects of capability."

Human Systems Integration (HSI)

US DoDI 5000.02 (Enclosure 8)

"The goal of HSI is to optimize total system performance, minimize total ownership costs, and ensure that the system is built to accommodate the characteristics of the user population that will operate, maintain, and support the system."

USCG COMDTINST M5000.10

"Human Systems Integration (HSI) incorporates knowledge of human capabilities and limitations into systems to make them more efficient, effective and safe. During system acquisition, HSI seeks to balance human capabilities and limitations with the affordances and constraints presented by system technology in order to accomplish system objectives. HSI considers all human roles in the system such as the operator, maintainer, trainer, designer, etc. HSI offers a unique value proposition to the Coast Guard by systematic consideration of the human as an element of total systems performance, providing program managers with the information to improve human-technology integration when design changes are most cost effective."

HFI and HSI Domains:

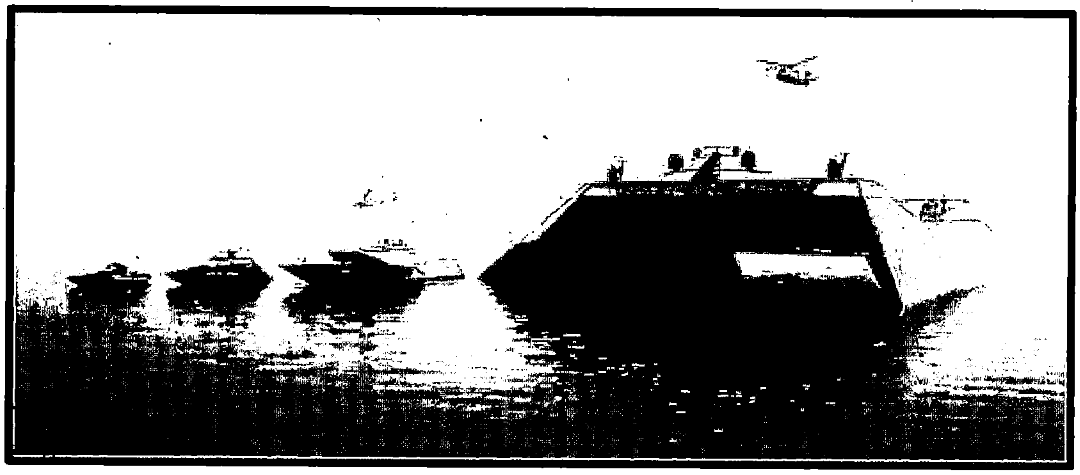
Both HFI and HSI involve the identification and trade-off of human-related aspects that could impact capability development and delivery. To ensure all relevant factors are considered each of the initiatives comprise a framework of domains, some of which are common while others differ in their focus.

Recognising the value that an HFI/HSI approach offers, other nations, specific military services and non-defence industries have adopted and tailored the initiatives such that a number of variations in the domains now exist, see Table A1.1 below.

Due to the fundamental similarities of the various initiatives, and their shared overall goal, the terms HFI and HSI have been used interchangeably for the purposes of the HSC HFE Design Guide.

UK MOD HFI Domains JSP 912	**US DOD HSI Domains** DOD 5000	**USCG HSI Domains** COMDTINST M5000.10
Human Factors Engineering	Human Factors Engineering	Human Factors Engineering
Manpower	Manpower	Manpower
Personnel	Personnel	Personnel
Training	Training	Training
System Safety	Safety & Occupational Health	System Safety
Health Hazard Assessment	Survivability	Performance
Social & Organisational	Habitability	

Table A1.1 Similarities and Variations in HFI / HSI Domains



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