



AFRL-RH-WP-TP-2012-0047

The NATO Unmanned Aircraft Systems Human Systems Integration Guidebook

**Anthony P. Tvaryanas, M.D, Ph.D, M.P.H.&T.M.
Rebecca Singer, Booz Allen Hamilton
Barbara Palmer, Booz Allen Hamilton**

April 2012

Technical Paper

Distribution A: Approved for public release; distribution is unlimited.

**AIR FORCE RESEARCH LABORATORY
711TH HUMAN PERFORMANCE WING HUMAN SYSTEMS
INTEGRATION DIRECTORATE WRIGHT-PATTERSON
AIR FORCE BASE, OH 45433-7320
AIR FORCE MATERIEL COMMAND**

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
<p>The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</p> <p>PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</p>					
1. REPORT DATE (DD-MM-YYYY) 30-11-2012		2. REPORT TYPE Technical Paper		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE Unmanned Aircraft System Human Systems Integration Guidebook				5a. CONTRACT NUMBER SP0700-03-D-1380	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Anthony P. Tvaryanas (711 HPW/HP) Rebecca Singer (BAH) Barbara Palmer (BAH)				5d. PROJECT NUMBER DO 324	
				5e. TASK NUMBER TAT 09-27	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) SURVIAC 46 TG/OL-AC/SURVIAC 2700 D STREET, Bldg 1661 Wright-Patterson AFB, OH 45433-7404				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Maj Donna Fox 711 HPW/HP 2510 Fifth Street, Bldg 840 Wright-Patterson AFB, OH 45433				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Distribution A: Approved for public release: distribution unlimited.					
13. SUPPLEMENTARY NOTES 88 ABW/PA Cleared 10/21/2013; 88ABW-2013-4442 SURVIAC is operated by Booz Allen Hamilton, 8283 Greensboro Drive, McLean, VA 22102					
14. ABSTRACT This guidebook was prepared by the HSI Specialty Team for the UAS Flight in Non-Segregated Airspace (FINAS) Working Group, NATO Joint Capability Group for UAS (JCGUAS). It provides guidance for consideration of the human component of UAS to decrease human performance-related accidents and incidents and improve safety, thereby facilitating routine flight of UAS in non-segregated airspace. It was the product of FINAS study number 4685, which baselined the United Kingdom Ministry of Defence Standard 00-250, Human Factors for Designers of Systems, and extracted the high-level process-related elements that were applicable to a generic systems engineering framework for designing and procuring UAS.					
15. SUBJECT TERMS Unmanned Aircraft Systems, Human Systems Integration, Manpower, Personnel, Training, Human Factors Engineering, Safety and Health, Organizational and Social, Human Views					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Anthony Tvaryanas
U	U	U	UU	59	19b. TELEPHONE NUMBER (Include area code) 937-938-3253

The NATO Unmanned Aircraft Systems Human Systems Integration Guidebook

*Pre-approval
(Nov 2012)*



*“A guide to the Human Systems Integration
process for the design and procurement of
better performing and safer Unmanned
Aircraft Systems”*

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Preface

This guidebook describes

- The importance Human Systems Integration (HSI) to the flight of Unmanned Aircraft System (UAS) in non-segregated airspace
- Activities that can help identify where the key human contributions to UAS performance and safety are likely to occur
- How to manage the HSI input into development of UAS
- Techniques that can be used to apply HSI

This guidebook is aimed at NATO and Industry personnel who need to address and resource the human issues/risks in the design, implementation, and operation of Unmanned Aircraft Systems





The processes specified in the guidebook are both goal and risk-based. Overarching HSI goals that must be satisfied in every UAS project are identified. Provided the goals are achieved, the means by which they are achieved can be tailored to the circumstances of individual UAS projects. As a consequence, the extent and depth of HSI activities should be tailored to the degree of project risk presented human-related considerations. In this way, the process supports the development of cost-effective UAS that are safer, have increased mission effectiveness and reliability, therefore meeting requirements for integration into non-segregated airspace.

The main users of this guidebook will be project managers designing, developing, and/or procuring UAS. This guidebook therefore addresses Human-Related considerations and HSI activities to allow managers to understand their relevance and importance to the systems engineering process as a whole. Nonetheless, all parties involved in UAS development, including the end-users of UAS, should find this guidebook relevant.

This guidebook was prepared by the HSI Specialty Team for the UAS Flight in Non-Segregated Airspace (FINAS) Working Group, Joint Capability Group for UAS (JCGUAS). The particular focus of the guidebook, which is part of the overall work package of FINAS, was the provision of guidance to improve consideration of the human component of UAS to decrease human performance-related accidents and incidents and improve safety, thereby facilitating routine flight of UAS in non-segregated airspace. It was the product of FINAS study number 4685, which baselined the United Kingdom Ministry of Defence Standard 00-250, *Human Factors for Designers of Systems* (2008), and extracted the high-level process-related elements that were applicable to a generic systems engineering framework for designing and procuring a UAS.

Reference.....PFP(NNAG-JCGUAV)D(2009)0002n

Version.....1

Date.....18 April 2012



HSI Specialty Team Members:

Doug Davis (USA), Sarah Harris (UK), Daniel Hauret (France), Piet Hoogeboom (Netherlands), Ming Hou (Canada), Patrick Le Blaye (France), Jean-Daniel Masson (France), Michael Mif ud (UK), Edgar Reuber (Germany), Stephen Rice (USA), Jan Joris Roessingh (Netherlands), Ian R ss (UK, BAE Systems), Michal Rottem-Hovev (Israel), Roland Runge (Germany), Anja Schwab (Germany), Rebecca Singer (USA, BAH), Jochum Tadema (Netherlands), Anthony Tvaryanas (USA).

Definition of Terms

Throughout this document, terminology is used that may mean different things to different people. The definitions listed in Table 1 are intended to clarify and standardize the terminology used

All of the definitions listed are referenced in ISO 15288:2008, *Systems and software engineering – System life cycle processes*. The first column provides the term as it may be used in other standards or references, the second column provides the term as it is used in this document, and the third column provides a definition of the term.

Table 1. Definition of Terms Used in this Document

Traditionally Used Term	As Used in this Document	Definition
Guidebook	Guidebook	A non-directive reference book of a particular subject or a compilation of factual data and instructional material not subject to frequent revision.
Human Systems Integration	HSI	A systematic process of identifying, tracking, and resolving human-related issues ensuring a balanced development of both technologies and human aspects of complex systems.
Life-cycle	Life-cycle	Evolution of a system, product, service, project or other human-made entity from conception through retirement in acquisition.
Stakeholder	Stakeholder	An individual or organisation having a right, share, claim, or interest in a system or in its possession of characteristics that meet their needs and expectations.
System	System	A combination of interacting elements organized to achieve one or more stated purpose(s) (a system may be considered as a product or the services it provides).
System Acquirer	Acquirer	Stakeholder that acquires or procures a product or service from a contract (e.g., Government or Industry).
System User	User	An individual or group that benefits or interacts with the system, i.e. operators, maintainers, and support personnel.
System Developer (Supplier, Solution Provider)	Contractor	An organisation or individual that enters into an agreement with the acquirer and develops a system or product.
Trade-off	Trade-off	Decision making actions that selects various requirements and alternative solutions on the basis of net benefit to the stakeholder.

Introducing Human Systems Integration

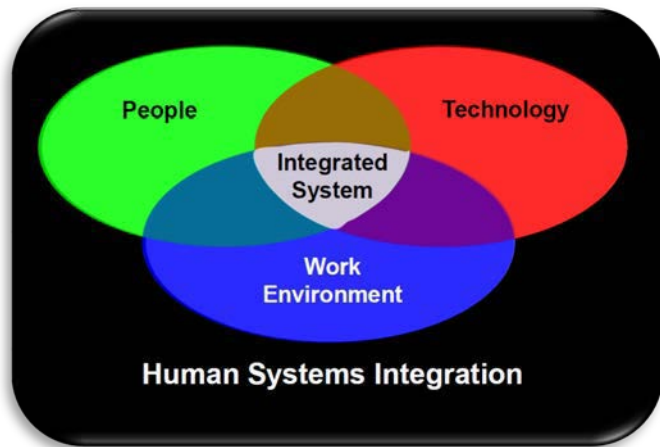
Why implement HSI in Unmanned Aircraft Systems?

People are the key component of any defence system — and this is no less the case for unmanned aircraft, where, despite the term “unmanned,” much human involvement is required to achieve desired mission effectiveness. The field of unmanned aircraft is clearly an emerging, high growth sector within aviation. As with any new area of innovation, the initial focus in unmanned aviation has centered on advancing the enabling technologies and developing the procedures for their operation so as to gain a competitive advantage.



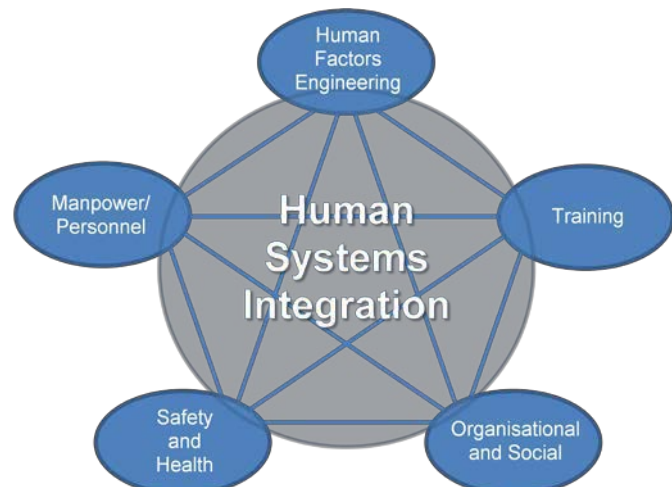
As various organisations have developed and employed increasingly sophisticated unmanned aircraft over the past decade, there has been a growing understanding of unmanned aircraft as complex, distributed systems rather than simply aircraft — that is, the realisation that there is much more than simply an aircraft in question. This understanding is formally captured in the current term of reference of *Unmanned Aircraft System (UAS)*. From a total system perspective, one should appreciate that a UAS is comprised of an unmanned aircraft, surface components, and other architectural elements, each with their own attributes and which collectively interact to exhibit emergent system-level properties that are of value to various system stakeholders.

Implicit in this systems view should be the comprehension that the Ground Control Station (GCS), inclusive of the human crewmembers, plays a significant role in determining the overall system-level properties of a UAS to include system safety. Also couched in this systems view is the acknowledgement that development of UAS needs to be coordinated through a systems engineering process. Even when a systems engineering approach is adopted, however, it is often constrained in scope to the technological system. This observation is a significant problem, because contrary to popular opinion, UAS have not removed the human element from the system. Instead, UAS provide the option for the human to no longer necessarily be co-located within the physically dynamic components of the system. Similarly, highly automated systems allow modification rather than elimination of the role of humans, such as by decreasing prerequisite skills and aptitudes or allowing increased span of control.



As in manned systems, the essential role of the human in UAS is to provide the overarching situation awareness and contextually responsive command and control for the system. To accomplish these functions, the human must interact with the system at some point in its operation and use some form of system interface. It is therefore essential for both mission effectiveness and safety that the human be fully integrated into UAS starting at system conception. This requires attention to all elements of HSI when developing, acquiring, and operating UAS.

It is worthwhile to explicitly define here what is meant by HSI since many individuals view it narrowly as the interface of the human and the machine, synonymous with human factors engineering and traditional cockpit design. This view actually encompasses only a single element of HSI. Broadly, HSI is based on the understanding that people are the critical elements within systems and adopting a human-centric perspective of systems increases productivity and safety whilst decreasing costs. HSI involves the identification and tradeoff of the human-related issues that could impact heavily upon system performance. To ensure that all issues are considered, these human-related issues are categorized into five main areas or domains (see figure to the right); and a core principle of HSI is the necessity for those developing, acquiring, and operating systems to maintain a holistic perspective of these domains. No one domain should be considered in isolation — rather, they need to be related to each other. Any decision in one of the domains almost certainly impacts on another domain.



Safety and Airspace Integration

For proponents of operating UAS within the world-wide airspace structure in a non-segregated fashion, such as the NATO Joint Capability Group for Unmanned Aircraft Systems (JCGUAS), a significant area of interest is system safety. With the growing emphasis on UAS mishap investigation and analysis, human error (i.e., human performance failure) has been shown to be a significant contributor to UAS safety-related events. Based on the concept of HSI developed above, any effort to address UAS system safety must involve a holistic consideration of the other HSI domains, such as human factors engineering, manpower/personnel, and training. This assertion represents nothing new and holds equally true in the case of traditional, manned aviation. However, in manned aviation personnel and training are fairly tightly defined by existing regulations and standards, thereby allowing a relatively prescriptive approach to the human factors engineering of human-system interfaces in achieving desired system safety levels. In contrast, significantly greater variability presently exists in terms of personnel and training as they apply to UAS, making a prescriptive approach to the design of the GCS far less tractable. Rather, human factors engineering decisions need to be considered in light of the overall performance, safety, and cost trade space that exists between the human factors engineering, manpower/personnel, and training domains, among others. Consequently, a repeatable process solution to GCS design that explicitly considers this trade space is preferable so that potentially desirable innovation is not unnecessarily limited.

As a result of its first investigation of an accident involving an unmanned aircraft, the U.S. National Transportation Safety Board (NTSB) issued a total of 22 safety recommendations to address what NTSB Chairman Mark V. Rosenker said were "a wide range of safety issues involving the civilian use of unmanned aircraft." The safety recommendations stemmed from the April 25, 2006, accident in which a Predator B operated on a surveillance mission by the U.S. Customs and



Border Protection crashed in a sparsely populated residential area near Nogales, Arizona. The Safety Board determined that the probable cause of the accident was the pilot's failure to use checklist procedures when switching operational control from a console that had become inoperable due to a "lockup" condition, which resulted in the fuel valve inadvertently being shut off and the subsequent total loss of engine power, and a lack of a flight instructor in the Ground Control Station. At the Board meeting, the NTSB highlighted several areas of particular interest including: the design and certification of the unmanned aircraft system; pilot qualification and training; the integration of UAs into the air traffic management system; and audio records of all UA operations- related communications. (Homeland Security and Defense, October 17, 2007)

Introduction to Human Systems Integration Domains



**Manpower/
Personnel**

Training

**Human Factors
Engineering**

**Safety and
Health**

**Organisational
and Social**

Human Systems Integration Domains

Human Systems Integration involves the identification and tradeoff of the human-related issues that could impact acquisition processes. These human-related issues are categorised into five main areas, or domains, which essentially form a checklist of issues that need to be considered.

These issues are not prescriptive and the domains should not be considered as separate entities, rather they need to be related to each other. Any decision in one of the domains can easily impact another domain. Stakeholders from all the domains need to come together early in the programme and conduct an Early Human Factors Analysis to identify the risks and trade-offs in order to resolve these later in the project.



Manpower/Personnel

The Manpower/Personnel domain concerns the number of men and women, military, civilian, and contractors, required and available to operate and maintain the UAS under consideration. It considers the aptitudes, experience, and other human characteristics, including body size and strength, necessary to achieve optimum system performance. This domain also includes the necessary selection processes required for matching qualified personnel to the appropriate task.

Some important HSI issues to consider within this domain are:

- Wartime/peacetime manpower requirements
- Deployment considerations
- Operating strength
- Manning
- Personnel selection and classification
- Cognitive, physical and educational profiles
- Accession and attrition rates
- Qualified personnel when and where needed
- Individual differences/variability
- Supervision
- Manpower mix
- Language aptitude



Training

Training embraces the specification and evaluation of the optimum combination of instructional systems; education; and on-the-job training required to develop the knowledge, skills and abilities (e.g., social/team building abilities, soft skills, competencies) needed by the available personnel to operate and maintain the UAS under consideration to a specified level of effectiveness under the full range of operating considerations.

Some important HSI issues to consider within this domain are:

- Training pipeline flow
- Training tasks and training development methods
- Media, equipment and facilities
- Operational tempo
- Continuity training, refresher training, and core competency-based training
- Teamwork/crew resource management
- Balance of live flying training, embedded training, and simulator training
- Licensing and certification of individuals
- Evaluation/quality assurance of training



Human Factors Engineering

Human factors are the user's cognitive, physical, sensory, and team dynamic abilities required to perform UAS-specific operational, maintenance, and support job tasks. Human Factors Engineering (HFE) covers the comprehensive integration of human characteristics into UAS design, including all aspects of workstation and workspace design and system safety. The objective is to maximise user efficiency whilst minimising the risk of injury, to personnel and others.

Some important HSI issues to consider within this domain are:

- Compatibility of design with anthropometrics and biomedical criteria
- Workload, situational awareness and human performance reliability
- Human-Machine Interface (HMI)
- Effects of design on skill, knowledge, and aptitude requirements
- Design driven human performance
- Information processing
- Cognitive fatigue
- HMI supports trust in automation
- Employment of automation
- Implementation of decision-aiding
- Design to enable maintenance tasks
- Human error



Safety and Health

Safety and Health is the process of applying expertise to minimise safety risk to UAS users and bystanders occurring as a result of the system operating or functioning in either a normal or abnormal manner. UAS design features should serve to minimise the risk of injury, acute or chronic illness, and/or discomfort of personnel who operate, maintain, or support the system. Likewise, design features should mitigate the risk for errors and accidents resulting from degraded job performance. Prevalent safety and health issues include noise, chemical safety, vibration, ionising and non-ionising radiation, and human factors issues that can create chronic disease and discomfort such as repetitive motion diseases. Human factors stresses that create risk of chronic disease and discomfort overlap with occupational health considerations. These issues directly impact crew morale.

Some important HSI issues to consider within this domain are:

- Total system reliability and fault reduction/error tolerance
- Safety culture
- Occupational injuries and illnesses
- Health hazards induced by systems, environment, or task requirements
- Shift work, disturbed biological rhythms, and physiological fatigue
- Telewarfare and sustained, in-garrison operations



Organisational and Social

Organisational complexity is a key feature of networked enabled capabilities typified by modern UAS. Networked enabled capabilities necessitate building trust and confidence between people in separate organisations who need to collaborate on a distributed and temporary basis for effective operations. Consequently, Organisational and Social is the process of using all available tools and techniques drawn from relevant information and behavioural science disciplines to enable people to adapt to a more open culture that requires greater sharing and trust between colleagues and coalition partners.

Some important HSI issues to consider within this domain are:

- Distributed teams and shared situation awareness (e.g., remote split operations)
- Differences in cultural, spiritual, and ethical norms
- Trust and information sharing to include means and standards of communications
- Definition of roles, responsibilities and authorities
- “Soft” interoperability
- Alternative organisational configurations
- Multi-national/multi-service interoperability
- Language



Human Systems Integration Process



HSI is about mitigating risk, managing safety, improving performance, and ensuring the satisfaction and well-being of personnel operating, maintaining, and supporting a UAS. To do this successfully, HSI activities must be related to the overall systems engineering approach used in acquisition. Figure 1 illustrates how key HSI activity stages map to the system engineering life-cycle stages. This figure is further broken out in the following sections of Pre-Development Decision HSI Activities and Post-Development Decision HSI Activities.

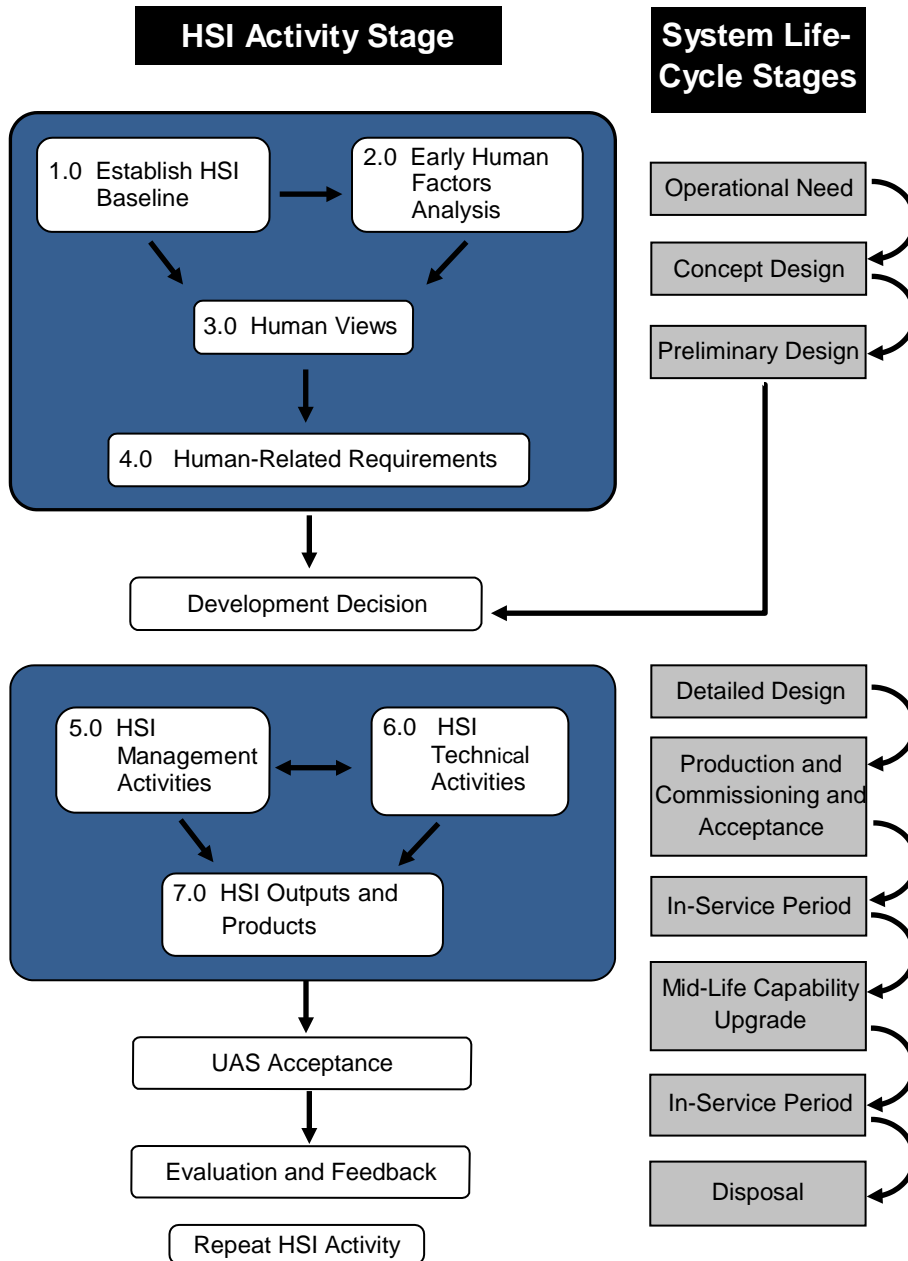


Figure 1. HSI activity stages mapped to the system engineering life-cycle stages
(Adapted from UK MoD Defence Standard 00-250)

HSI Process Goals

In all UAS acquisition projects, the following HSI goals shall be fully pursued to achieve satisfactory outcomes. All HSI activities that are undertaken shall relate to and support one or more of the itemised goals.

- Planned and managed consideration of Human-Systems and People-Related considerations (including risks, issues, constraints, assumptions, etc.) from the very outset of a UAS project, and subsequently throughout the life cycle.
- Systematic treatment of Human-Systems and People-Related considerations through the life of the UAS, including the early stages of In-Service operations and final disposal.
- Systematic, rigorous and formal capture, specification and management of People-Related Requirements necessary to provide the required UAS capability.
- The adoption of a User-centred design approach as defined in ISO 9241-210:2010, or an agreed variant where such is decided to be more appropriate to the UAS project strategy.
- The use of established Human-Systems principles, accepted best practice, and suitable methods tools and techniques and data.
- Design to match the Context of Use.
- Design to match User Characteristics.
- Design to match User Organisation characteristics.
- Design to meet User needs.
- Adoption of a multi-disciplinary approach.
- Involvement of Users in system and equipment design and evaluation.
- The iteration of design solutions so as to optimise the Solution against People-Related Requirements and People-Related constraints.
- Formal scrutiny, assessment and acceptance of Human-Systems aspects of the Solution.

These high-level goals can be viewed as a hierarchical set, achieved through a series of sub-goals, activities and data in-feeds. Figure 2 illustrates this hierarchy. When each of the individual goals, sub-goals and high-level goals have been satisfactorily addressed, a project may claim that HFI has been satisfactorily achieved.



Figure 2. Overarching HSI Goal Structure (Adapted from Def Stan 00-250)

Pre-Development Decision HSI Activities

This section provides a functional decomposition of the Pre-Development Decision HSI Activities. Figure 3 illustrates the decomposition of the steps required in these activities and should be referenced in the following sections: 1) Establishing the HSI Baseline, 2) Early Human Factors Analysis, 3) Human Views,[†] and 4) Human-Related Requirements.

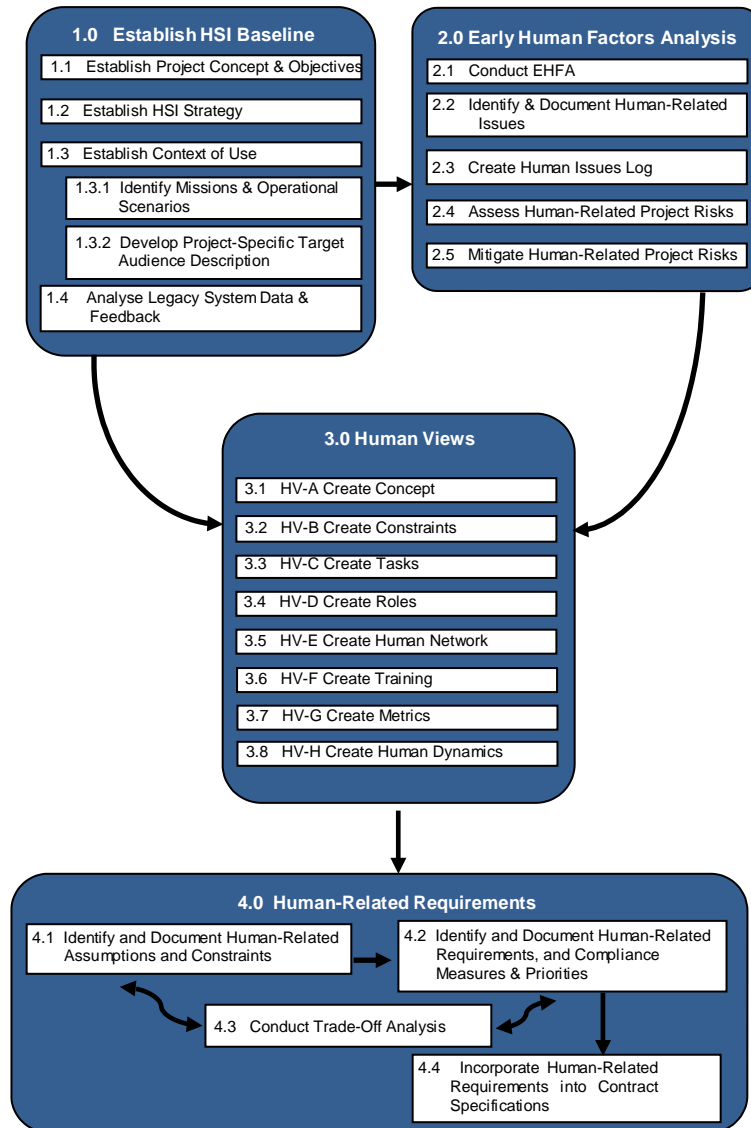


Figure 3. Decomposition of pre-development decision HSI activities
(Adapted from UK MoD Defence Standard 00-250)

[†] The NATO Human View (HV) is a supplementary view to existing architectures, providing an additional set of eight products that augment the DoDAF (or similar) systems architecture products required of systems engineers. The purpose of the HV is to capture human requirements and to inform on how humans interact with systems (NATO Human View Quick Start Guide).

1.0 Establish HSI Baseline

The objective of this activity is to collate the information necessary to form a baseline description of the key HSI-related considerations that will be assessed during an Early Human Factors Analysis. Depending on the life-cycle stage of the UAS project, differing levels of baseline are possible.

1.1 Establish Project Concept and Objectives

During this initial step, collect any documents or known assumptions that may have an influence on the human component of the emerging UAS-related capability. This would include identifying all material defining the baseline, such as the fixed inputs, background, objectives and scope of the UAS project as well as relevant standards. When reviewing these materials, emphasis should be on identifying content relevant to the HSI domains and determining what is 'core' to HSI; identifying what is known about human-related issues; determining what is 'fact' and what is 'assumption' and document both; note any likely HSI distinctions between options under consideration; and identify areas where there is no information on HSI matters and decide where to fill the gaps (HFI Practical Guidance for IPTs, 2001).

1.2 Establish HSI Strategy

The HSI Strategy shows how the key goals of the HSI effort help achieve overall UAS project goals. It is based on a clarified and quantified understanding of the main HSI issues and risks in the context of the specific UAS acquisition strategy. The issues will also direct the Early Human Factors Analysis (EHFA), which is both a management approach and technical activity (UK MoD HFI Process Handbook, 2007).

The development of an HSI Strategy should be initiated early in the UAS acquisition process when the need for a new UAS capability or improvements to an existing UAS is first established. It should describe the technical and management approach for meeting HSI parameters in the capabilities documents and identify and provide ways to manage any HSI-related cost, schedule, or performance issues that could adversely affect UAS programme execution (US DoD Defense Acquisition Guide, 2011).

The aim of the HSI Strategy is to ensure that the human element of the UAS is fully considered when generating and developing user requirements and the system requirements document.

1.3 Establish Context of Use

Context of Use is defined as the users, tasks, equipment (hardware, software, and materials), and the physical and social environments in which a UAS is used (ISO 9241-11:2000). Successful HSI requires the contractor to demonstrate that the UAS design is based on a systematic analysis and understanding of the expected context of use for the UAS capability (UK MoD Def Stan 00-250, 2008).

The purpose of the Context of Use is to clarify and communicate the user characteristics and tasks, and identify the technical, organisational, and physical environment.

Understanding the Context of Use guides and informs early design decisions, provides a firm basis for more detailed equipment design decisions, and provides a basis for evaluation of the resulting UAS. This understanding is required for new UAS as well as upgrades and capability enhancements to existing UAS, where available context of use information may need to be checked and validated.

Context of Use information embraces many dimensions. These include physical factors, organisational factors and social and psychological factors such as:

- Physical environment
- Cultural and social environment (e.g., work practices, attitudes, organisational structure)
- Attributes of the wider technical environment
- Legal and regulatory environment
- Shared situational awareness
- Trust and information sharing
- Alternative organisational configurations
- Existing user roles, responsibilities, and work management hierarchies.

1.3.1 Identify Missions and Operational Scenarios

Operational scenarios form one element of the capability requirement. Scenarios specify conditions under which the capability must be provided. Mission and scenario descriptions underpin much HSI work – from EHFA through the ‘person in the loop’ simulation (UK MoD Def Stan 00-250, 2008).

Mission analysis is a contributor to the Context of Use analysis process, providing operational scenarios that feed the EHFA process and other processes that require Context of Use information needed to establish the ‘baseline’. From the baseline, the designer can then assess the impact of the human-related risks.

1.3.2 Develop Project-Specific Target Audience Description

The Target Audience Description (TAD) is a living document, started early in and becoming more specific throughout a UAS project lifecycle. It describes the capabilities, limitations and characteristics of personnel who will operate, maintain and support the UAS being designed and developed. It integrates material from various “owners” who must be considered as stakeholders and included fully in the review process (UK MoD HFI Process Handbook, 2007). When establishing the TAD, HSI practitioners should verify whether there are any recruitment or retention trends or demographic changes that could alter the characteristics of the user population

over the life of the UAS. HSI analysts should consult with the personnel community and verify whether there are new personnel policies that could significantly alter the scope of the user population (US DoD Defense Acquisition Guidebook, 2011). The TAD includes information such as (UK MoD HFI Process Handbook, 2007):

- Which service/branch users will be drawn from
- The range of ranks and specialist areas involved
- Body size/strength
- Physical skills
- Knowledge/mental skills
- Personal attributes
- Educational background
- Experience
- Training objectives
- Career progression
- Summary of key tasks personnel will need to perform
- Description of the environment personnel will operate in.

1.4 Analyse Legacy System Data and Feedback

Analysing predecessor systems — manned or unmanned — provides insight into both positive and negative aspects of a system design, providing the data needed to establish Lessons Learned. Much effort will be directed to identifying, assembling and analysing information which may include briefings, equipment failure reports, and safety logs. Managing information voids may be a major part of this effort. Information may not always be available in documentary form and may need to be obtained from users and subject matter experts. Precursor activities will be to define the scope of the predecessor system(s) under consideration and to define the scope of their Context of Use information that is relevant to the current project. Analysis techniques, applied to predecessor system(s), that are useful for supporting development of Context of Use for the current project include the following:

- Mission Analysis
- Function Analysis
- Design Scenario Analysis
- Operational Scenario Description
- Mission-critical Task Identification
- Operability Criteria Definition
- Information flows.

2.0 Early Human Factors Analysis

Early Human Factors Analysis (EHFA) is a key HSI tool and an essential component of initial UAS project development activities. Its purpose is to identify human-related issues and risks. HSI activity planning should be based on the results of EHFA.

Ideally, EHFA is conducted early in a UAS project lifecycle. However, the primary consideration in EHFA is that it must embrace the whole UAS, even if full or in-depth analysis is not possible in every area due to immaturity in a system design. Early in the lifecycle, human issues are often

missed but there can be high gains if they are caught. Conducting an EHFA should never be omitted on the basis that “it is now too late”.

The greatest value is obtained by the early involvement of HSI specialists. Although tools have been developed to assist with EHFA, the nature of the approach requires an open, questioning, free-thinking and possibly intuitive exploration of human-related issues rather than the application of a prescriptive or mechanistic process (UK MoD Def Stan 00-250, 2008).

2.1 Conduct Early Human Factors Analysis

The EHFA process comprises a simple three-stage approach which focuses effort and produces an output in support of HSI planning. These stages include: a) Establish the HSI Baseline (discussed in detail in section 1.0), b) Identify the HSI issues and record in a HSI Issues Log, and c) Assess the HSI issues and plan mitigation. The EHFA output forms the basis for the project HSI Strategy and Plan and provides the information needed to develop a Target Audience Description.

The level of detail in the analysis depends on the information available; EHFA is particularly suited to situations where limited information is available. The analysis is based upon the provision of baseline information which will be formed from the definition of the emerging concept options to the project and details of the operational requirement.



EHFA doesn't need to be complex or require significant resources. The level of effort needed will depend on the size and complexity of the UAS project, the expected role of the human in the UAS, and the quality and ease of access to suitable information sources. Where limited resources are available, particularly with smaller projects, the technique can be undertaken effectively by one person with both the appropriate analysis skills and the awareness of the potential scope of human issues. However, experience has shown that getting the correct stakeholders together can greatly speed the process and achieve better coverage of the potential human-related risks to the project (UK MoD Acquisition Operating Framework).

2.2 Identify and Document Human-Related Issues

Humans form a key component of operational capabilities. Whether a system is generally regarded as ‘unmanned’ or is thought to be ‘fully automated’, humans perform key roles. Human roles may involve supporting and maintaining equipment and also making final operational decisions such as weapons deployment, targeting, etc.

Including humans in an otherwise technology-centric system will generate ‘human-related issues.’ A human-related issue is considered to be anything that requires the attention or input from stakeholders, and decisions, choices or trade-offs between competing requirements to be made. For a satisfactory UAS design solution, all human-related issues need to be addressed and resolved to the satisfaction of stakeholders (UK MoD Def Stan 00-250, 2008).



The best way to identify the human-related issues is to conduct a focus group meeting with as many of the stakeholders as possible. Using the HSI domains as a prompt for areas where human-related issues/risks are likely to exist, capture the issues in a brainstorming fashion. At this stage, analysis is not necessary, the point is to not dismiss any comments or suggestions made by the stakeholders. Since there will likely be a lot of uncertainty, many assumptions will need to be made. These should be as explicit as possible and recorded in a Human Systems Integration Issue Log (UK MoD Acquisition Operating Framework).

2.3 Create HSI Issue Log

For effective UAS project management, all human-related issues, including assumptions, constraints, user needs, risks, associated mitigations, opportunities and outcomes that arise during the design of the UAS must be recorded. The human-related issues should be maintained throughout the duration of the contract and should form part of the contract deliverables. An acceptable vehicle for recording such issues is a HSI Issue Log, which may be presented in tabular form or more usually, in a spreadsheet or database form. This should be submitted to the acquirer for concurrence early in the contract (UK MoD Def Stan 00-250, 2008).

2.4 Assess Human-Related Project Issues

Once the human-related issues have been captured in the HSI Issue Log they need to be evaluated and assessed for likelihood and impact. This can be achieved by using a risk management matrix (or suitable national substitute) to determine the relative importance of each issue (see EUROCONTROL’s *The Human Factors Case: Guidance for Human Factors Integration* for an example human-related issue management matrix). If an issue is determined to have potentially adverse consequences, it is qualified as a risk. Typically, the top ten issues account for 80% of the HSI risk on any particular project.

2.5 Mitigate Human-Related Project Risks

This section provides a list of possible methods for mitigating the human-related risks that will help frame the HSI Strategy for a UAS project. The issues to be addressed by research, studies,

and/or data collection will form the basis of the Human Systems Integration Plan (HSIP). Possible mitigation strategies include (UK MoD Acquisition Operating Framework):

- Modify performance requirements
- Request demonstrations or HSI analysis from bidders
- Provide project funds for additional research/studies/data collection
- Highlight areas of concern in a Statement of Work and Business Case
- Produce a HSI data requirements list.

3.0 Human Views

The design of UAS requires collaboration between a diverse range of disciplines to embrace all areas of system design. One approach to dealing with such complexity is the use of Architecture Frameworks. UAS often operate as part of distributed environments and collaborative settings. They require the specification not only of the information systems, but also the social, organisational, task, and skill structures that support complex information flows and information sharing.



The NATO Human View (HV) (NATO TR-HFM-155: Human Systems Integration for Network Centric Warfare, 2010) enables an understanding of the human role in systems/enterprise architectures. It provides a basis for decisions by stakeholders by providing a structured linkage from the engineering community to the manpower, personnel, training, and human factors engineering communities. It provides a way to integrate HSI into the mainstream acquisition and systems engineering process by promoting early consideration of human roles. It provides early coordination of task analysis efforts by both systems engineering and human factors engineering teams. By capturing the necessary decision data in the HV and integrating this view with the rest of the architecture framework, the improved framework provides a complete set of attributes of the system data.



The purpose of the NATO HV in UAS projects is to capture human requirements and to inform on how humans interact within the systems. The HV is a supplementary view to existing architectures, providing an additional set of eight products that augment existing Architecture Frameworks required of systems engineers (Figure 4).

An architecture framework defines a common approach for development,

presentation and integration of architecture descriptions. The application of a framework enables architectures to contribute more effectively to building interoperable systems. The framework products capture multiple aspects of a complex system. These products can then be integrated together to evaluate the relationship and impact of the corresponding variables. These products should be considered as living documents and need to be iteratively updated as the system design matures.

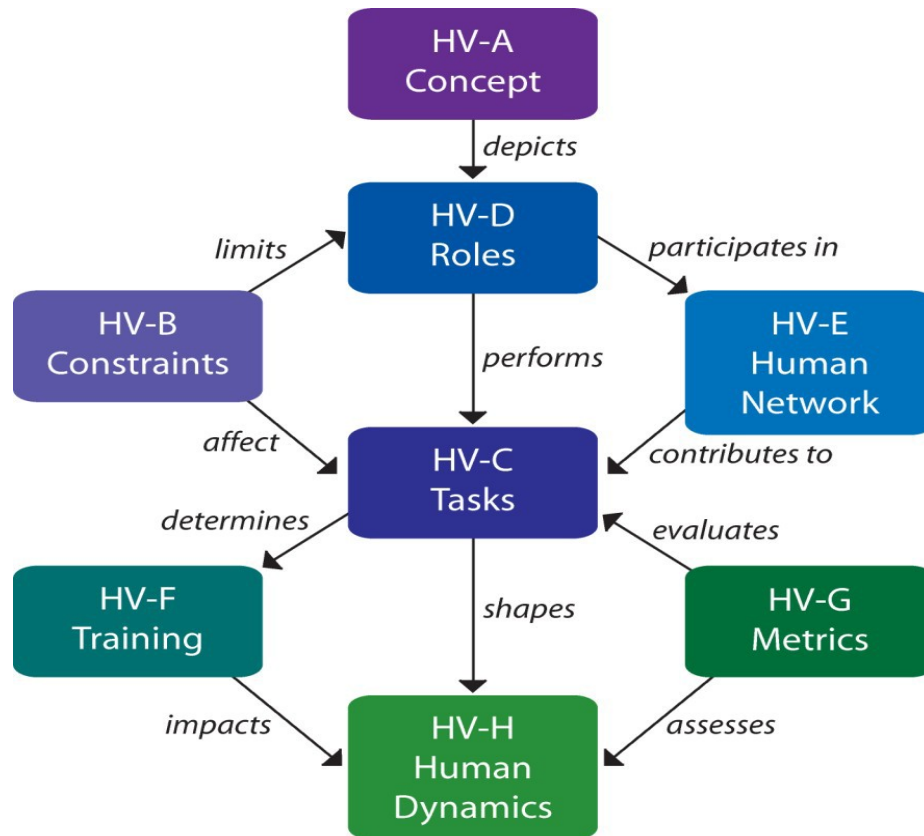


Figure 4. NATO Human View products overview
(NATO HSI for Network Centric Warfare)

3.1 Create HV-A: Concept

The HV-A is a conceptual, high-level representation of the human component of the enterprise architecture framework. Its purpose is to visualize and facilitate understanding of the human dimension in relation to operational demands and system components. It serves as both the single point of reference and departure to depict how the human will impact performance (mission success, survivability, supportability, and cost) and how the human will be impacted by the system design and operational context (personnel survivability, skill demands, training requirements, workload and well-being).

Information requirements may include:

- Pictorial depictions of the system and its human component
- High level indicators of where human system interactions may occur
- Textual descriptions of the overall human component of the system
- Use cases which describe the human process.

3.2 Create HV-B: Constraints

The human is the most important and unique component within a UAS, but they can also potentially be the weakest link or highest risk component when the system design fails to account for human constraints. However, the latter issue can be mitigated when deliberate attention is given to accommodating human constraints during system design. Therefore expressing the capabilities and limitations of the human in the UAS is required. HV-B contains the set of data elements that are used to adjust the expected roles and functions. It acts as a repository for different sets of constraints that may affect parameters of different views impacting the total system. If a UAS requires a human-machine interface, then the system must be designed to accommodate the human in such a way as to account for the human limitations, and to support/maintain the human to at least a minimum acceptable level.

The HV-B has six sub views:

1) Manpower Projections (HV-B1) – illustrates predicted manpower requirements for supporting present and future projects that contribute to larger capabilities.

Information requirements may include:

- Understand manpower forecasting to allow initial adjustments in training, recruiting, professional development, assignment and personnel management
- Anticipate impacts (and timeframe) related to number(s) of personnel, personnel mix, military occupation/trades structure, rank/level distribution, and postings/relocation(s) of personnel
- Ensure sufficient number of personnel with necessary Knowledge, Skills, and Abilities (KSA) are ‘ready and able’ to support fielding of future programme.

2) Career Progression (HV-B2) – illustrates career progression as well as the essential tasks, skills, and knowledge (and proficiency level) required for a given job.

Information requirements may include:

- Impacts of alternative system and capability designs on career progression
- Jobs available given an individual’s current job and occupation
- Competencies required for each individual job
- Availability of individuals with necessary competencies.

3) Establishment Inventory (HV-B3) – defines current number of personnel by rank and job within each establishment.

Information requirements may include:

- Forecast of trained effective strength
- Number of people that must be trained, recruited, etc. to fill gaps required for future years.

4) Personnel Policy (HV-B4) – personnel policy ensures that personnel are fairly considered, properly treated, well looked after and supported in a legal, moral and ethical manner.

Information requirements may include:

- Department policies dealing with (governing) human resource issues
- Human resource documents, such as policies, doctrine, laws, benefits, pay, Standard Operating Procedures (SOPs), etc.

5) Health Hazards (HV-B5) – considers the design features and operating characteristics of a UAS that can create significant risks of illness, injury or death.

Information requirements may include (CCOHS, 2009; PSEPC, 2005):

- System, material, environmental or task hazard assessment
- Air quality control assessment
- Noise/vibration pollution evaluation
- Impact force, shock, LASER protection
- Workplace Hazardous Materials Information System (WHMIS) identification, classification, and evaluation of the materials or chemicals used for tasks
- Chemical, Biological, Radiological, and Nuclear (CBRN) protection
- Extremes of temperature, etc.

6) Human Characteristics (HV-B6) – considers the characteristics of an operator and movement capabilities and limitations of that operator under various operating conditions.

Information requirements may include:

- Aspects such as anthropometric/medical data; reach data; range of motion data; physical strength data; human sensory (e.g., visual, auditory, tactile, proprioceptive, etc) assessment; speed or duration of activity data; cognitive workload; working memory capacity; ability to be security cleared; personality; motivation; etc.

3.3 Create HV-C: Tasks

The HV-C describes the human-specific activities, i.e., the tasks that have been assigned to the humans in a UAS over its entire life cycle. It also considers how the functions are decomposed into tasks and the dependencies between tasks.

Information requirements may include:

- Human-related functions in a UAS
- Allocation of functions between humans and technology
- Decomposition of functions into tasks
- Task descriptions in terms of various criteria and the KSA requirements
- Depiction of inter-dependencies between different tasks
- The tools required to accomplish a task
- Human-machine interface design guideline on the basis of task requirements.

3.4 Create HV-D: Roles

The HV-D describes the roles that have been defined for the humans interacting with the UAS. A role represents a job function defining specific behaviour within the context of an organisation, with some associated semantics regarding the authority and responsibility conferred to the person in the role, and competencies required to do the job.

Information requirements may include:

- Responsibility – accountability and commitment
- Permissions – access ability of an individual to perform a specific task
- Competencies – the quality of being able to perform; a combination of knowledge, skills, and abilities
- Multiplicity – a role may be performed by a human or by multiple humans at the same time.

3.5 Create HV-E: Human Network

The HV-E captures the human-to-human communication patterns that occur as a result of ad hoc or deliberate team formation, especially teams distributed across space and time.

Information requirements may include:

- Role groupings or teams formed, including the physical proximity of the roles and virtual roles included for specific team tasks
- Type of interaction – i.e., collaborate, coordinate, supervise, etc.
- Team cohesiveness indicators – i.e., trust, sharing, etc.
- Team performance impacts – i.e., synchronisation (battle rhythm), level of engagement (command directed)
- Team dependencies – i.e., frequency/degree of interaction between roles.

3.6 Create HV-F: Training

The HV-F is a detailed accounting of how training requirements, strategy, and implementation will impact the human. It illustrates the instruction or education and on-the-job or unit training required to provide personnel their essential tasks, skills, and knowledge to meet the job requirements.

Information requirements may include:

- As is training resources, availability, and suitability
- Risk imposed by to-be operational and system demands
- Cost and maturity of training options for tradeoff analysis
- Training required to obtain necessary knowledge, skills, and ability to support career progression
- Differentiation of basic, intermediate, or advance job training; operational vs. system specific training; and individual vs. team training.

3.7 Create HV-G: Metrics

There is a wide range of human-related metrics currently in use and different approaches to human-systems performance measurement may be adopted for a particular UAS project. The HV-G provides a repository for human-related values, priorities and performance criteria, and maps measures to other HV elements. It maps high-level (qualitative) values to quantifiable performance metrics and assessment targets and maps measurable metrics to human functions. It provides the basis for human factors assessments that underpin human-system performance assessments or for requirements tracking and certification.

Information requirements may include:

- Qualitative human factors value definitions
- Quantitative human performance metrics (what is to be measured)
- Target values (what quantifiable value is acceptable)
- Human task-to-metrics mapping
- Value definition links
- Value to design element mapping
- Methods of compliance.

3.8 Create HV-H: Human Dynamics

The HV-H captures dynamic aspects of human system components defined in other views. These are dynamic aspects in the sense that states, conditions, or performance parameters may change over time, or as a result of triggering events. It pulls together definitions from across the Human View to be able to communicate high level system behaviour. It provides inputs to human behaviour and executable models that may be supported by simulation tools. There are many different human models and simulations that can be used to develop dynamic models; this view can provide stimuli and design aspects for these models.

Information requirements may include:

- States (e.g., snapshots) and State Changes:
 - Organisational/team structure
 - Task/Role assignments to people
 - Team interaction modes
 - Demands on collaboration load (e.g., need to spend effort in building shared awareness, consensus-finding, communicating)
 - Task switches/interruptions
- Conditions (e.g., triggering events or situations; scenarios)
 - Critical / frequent / representative / typical scenarios
 - Operational constraints (e.g., extensive heat stress)
 - Time conditions: sequence, duration, concurrency
- Performance outcomes (observed or predicted), e.g.,
 - Workload
 - Decision speed
 - Team interaction/collaboration style
 - Trust in commanders intent
 - Quality of shared awareness/coordination/implicit communication.

4.0 Human-Related Requirements (HRRs)

Human-related requirements derive from the use of humans as part of a system that delivers a capability. Their purpose is to provide an effective means of coupling human issues into the systematic framework for managing requirements during acquisition. HRRs are organized under the following three major headings:

1. **Overarching HRRs** which are system requirements that arise because humans are part of a UAS. For example, they address the need to design visual displays in accordance with human performance capabilities and limitations.

2. **Service-specific HRRs** which are system requirements that arise because a particular group of military personnel are part of the system (e.g., Army, Navy or Air Force). For example, they address the need to conform to current Air Force organisational hierarchies in the manning solution.
3. **Capability-specific HRRs** which are system requirements that arise because the particular group of military personnel must achieve certain functions as part of the system. For example, they address the need for equipment users to locate and identify targets or achieve a specified rate of fire (UK MoD Def Stan 00-250, 2008).

4.1 Identify and Document Human-Related Assumptions and Constraints

The contractor must ensure that all human-related assumptions and constraints recorded in an HSI Issue Log are validated at agreed stages in the contract. The process of validation must confirm the continued applicability of each constraint and the assessed impact on UAS design (UK MoD Def Stan 00-250, 2008).

4.2 Identify and Document Human-Related Requirements, and Compliance Measures and Priorities

As with any other type of requirement, an acceptance process must be in place to determine whether or not a HRR has been met. The contractor needs to identify and propose appropriate means of demonstrating compliance with each requirement in the contract and submit them to the acquirer for agreement; areas of non-compliance must also be indicated. Acceptable means of demonstrating compliance may include, but not be limited to: compliance with a published standard, conformity to an agreed process, measurement or inspection of solution characteristics, static test, dynamic test, behavioural test, functional test, physical modeling prototyping or trial use under defined conditions. The contractor must demonstrate that the extent and quality of evidence of compliance to be provided is commensurate with:

- The degree to which each particular requirement impacts the UAS design
- The complexity of the relevant UAS component(s) or subsystem(s)
- The degree of project risk presented by the requirement.

Tests involving humans are more costly than conventional equipment testing and are subject to practical and ethical constraints; however, they are a necessary part of the overall process of evaluation and acceptance of systems. Cost-effective approaches to contract acceptance of HRRs are described in Table 2.



Table 2. Means of Accepting Compliance with a Requirement.

Type	Description
Consensus based on Judgement	Formal agreement by stakeholder based on subjective judgement that lower-level requirements, and/or design detail will cause the requirement to be met.
Consensus based on Evidence	Formal agreement by stakeholders that evidence presented (from analysis, modeling, experiment, survey, or comparability) justifies the belief that a design will meet the requirement, or that a solution does meet the requirement.
Design Inspection	Formal scrutiny of descriptions of a materiel solution at an appropriate level of detail or abstraction, to check for conformance with a requirement or specification. In this context, the term ‘design’ is not confined to low-level detail. It may apply to any materiel solution description that embodies design decisions, even if the decisions are represented by lower-level ‘requirements’.
Functional Demonstration	Formal demonstration that equipment performs the functions in a requirement or specification.
Task Walkthrough	Formal presentation of task-support facilities to representative users, sequentially as if the task(s) were being performed, with criteria based upon their adequacy and comprehensibility, together with qualitative measures of user acceptability.
Operability Trial	Formal, controlled, structured trials, with tasks performed by representative users, and criteria based on user performance plus subjective user reaction.

4.3 Conduct Trade-off Analysis

A trade-off is a decision-making action that selects various requirements and alternative solutions on the basis of net benefit to the stakeholder. Successful HSI requires the contractor to demonstrate that the UAS design has resulted from an iterative process that has involved stakeholders, Subject Matter Experts (SMEs), user representatives and operators from the acquirer’s organisation. The contractor must create and maintain records of such trade-off decision-making processes as part of the provision of traceability records. These records should form part of the contract deliverables (UK MoD Def Stan 00-250, 2008).

4.4 Incorporate Human-Related Requirements into Contract Specifications

This stage involves accepting the UAS design detailed in the contractor’s specification and ensure it is supported by tests and trials to provide evidence of the HRRs. For HRRs that relate to human performance, the aim is to ensure that suitable tests are included along with equipment performance tests. For any HRRs that have not been subjected to such tests, and refer to

intangibles, the equipment specification is not sufficient. There must be an accompanying contractual requirement for how the contractor will engage with stakeholders, and what types of evidence must be produced to support stakeholder acceptance ensuring the non-testable HRRs are met by the UAS design.

The evidence may take the form of practical results from trials under realistic conditions of use or documented stakeholder consensus. Such HRRs must be worded in a way that a contractor understands what is required and can engage with stakeholders.

Acceptance of a delivered UAS is matched against the contract specification, which will contain testable criteria already accepted to represent the requirements in the document of system requirements (e.g., System Requirement Document). If there are any intangible HRRs, then the System Acquirer will seek consensus among the relevant stakeholders that supporting evidence presented in accordance with the contract has demonstrated compliance. The contractor should seek to gain this consensus as early as possible during the contract period and plan activities accordingly. (UK MoD Def Stan 00-250, 2008)



Post-Development Decision HSI Activities

HSI Activity Planning is the next stage of the HSI Process. This stage is divided into Management and Technical activities, which should run alongside each other and can be tailored to suit specific project requirements. HSI Management Activities relate to planning what to do and when, whilst Technical Activities relate to doing HSI. Together the activities of HSI provide a framework for ensuring the human element of a UAS is considered early in acquisition and that the required level of HSI maturity is reached before the development of a system. To do this, adequate resources are needed to ensure that the necessary HSI activities are budgeted for, scheduled and managed as part of the acquisition process.

This section provides a decomposition of HSI Activity Planning including key HSI outputs and products. Figure 5 illustrates the decomposition of the steps required and should be referenced in the following sections: 1) Management Activities, 2) Technical Activities and 3) HSI Outputs and Products. Recognising these activities is important because HSI may have common goals and requirements with other areas of systems engineering – e.g., safety and Integrated Logistics Support. Aligning activities or sharing information could reduce effort – e.g., the same task analysis data could underpin human-machine interface design, training needs analysis and safety assessments (UK MoD Through Life Capability Management [TLCM] Handbook, 2010).

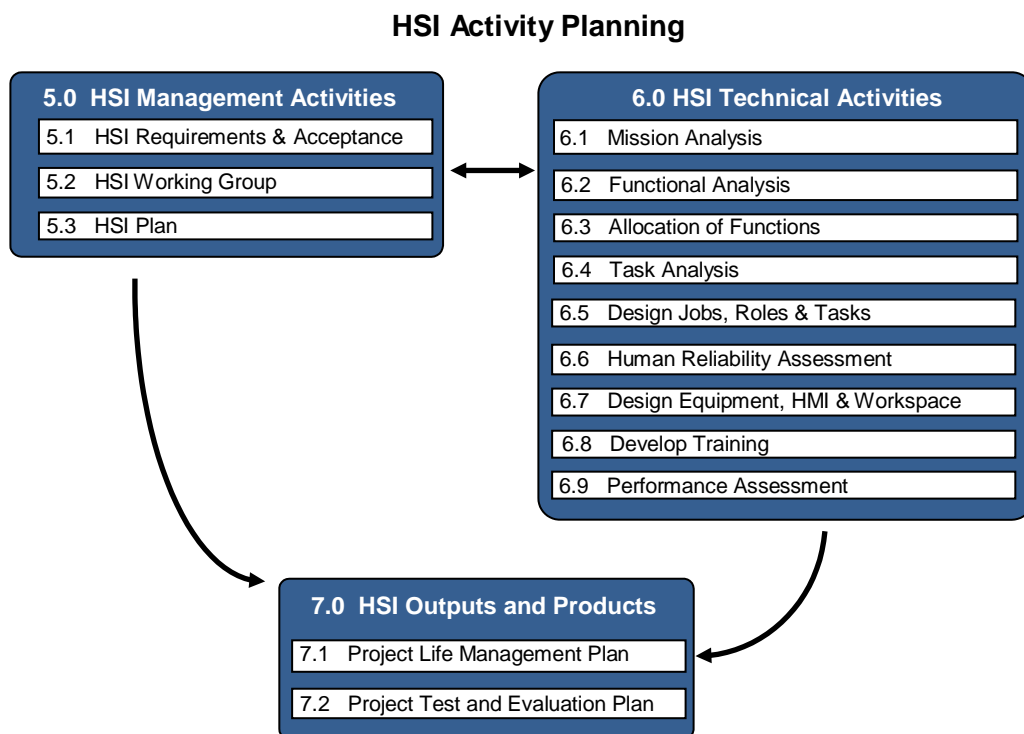


Figure 5. Decomposition of post-development decision HSI activities

5.0 Management Activities

The management of HSI needs to be implemented very early in a UAS project lifecycle. HSI follows a defined process, with clear activities, inputs and deliverables throughout the project lifecycle. The size or criticality of these inputs will depend on the extent and severity of HSI issues and risks identified for a project (UK MoD HFI Process Handbook, 2007).

5.1 HSI Requirements and Acceptance

Requirements. Most UAS are critically dependent on human-related requirements so HSI must identify requirements where people are or might be involved via User Requirements. In some UAS projects they will need to be included as a top-level item, in others they can be aggregated with other concerns. HSI contributions to the requirements might include human functions, human support functions, user and organisational constraints and measures of effectiveness (UK MoD HFI Process Model, 2007).

- **Human-Related Contribution to Requirements.** It is essential that human performance concerns are reflected in high-level capability requirements to provide the “hooks” for follow-on detailed requirements. Since it is people working with the procured equipment that deliver the desired capability, requirements must address all aspects that impact the ability of people to effectively work with the equipment as well as any overarching legal or moral obligations to people.

The system requirement, supplied to contractors, focuses mainly on the equipment and is formulated in terms of the following types of requirements: 1) *functional* (i.e., what the equipment must do), 2) *nonfunctional* (i.e., how well it must do it), and 3) *constraints* (i.e., limits on the solution).

A subtype of nonfunctional requirements, HSI requirements are specified using two additional types of requirements: 1) *human performance* (i.e., how well the user must perform the tasks using the equipment and 2) *process* (i.e., things the contractor must do). Making human performance requirements explicit is critical to ensuring they are tested and considered as part of the equipment acceptance decision. Process requirements are often used when functional or performance requirements cannot be clearly specified. HSI should contribute requirements at a comparable level of detail to those from other areas (Harrison & Forster, 2003).

- **Human-Machine Interface Requirements.** In general, the largest set of HSI-related requirements deals with the human-machine interface since the interface mediates much of the equipment’s impact on the user. For information-rich systems, it may be prudent to develop the human-machine interface requirements prior to the main functional requirements through an interactive requirements prototyping exercise with users (Harrison & Forster, 2003).
- **Human Systems Integration Process Requirements.** Requirements for conducting HSI have an important role in defence contracts. Mandating processes to generate evidence about human aspects of the UAS can reduce risk by enabling better coupling of contractor results with the procuring authority’s own internal HSI processes and programme. In addition, since the cost of HSI-related work can be a significant part of a contractor’s budget, mandating key evidence-producing activities ensures all competitor’s proposals are

comparable. It is also sensible to require contractors to demonstrate how proposed UAS designs have been influenced by HSI considerations (Harrison & Forster, 2003).

Acceptance. The most critical check on whether requirements are appropriate is whether acceptance criteria have been sufficiently identified. Some typical types of HSI acceptance tests include design inspection, functional demonstration, task walkthroughs, and operability trials (previously defined in Table 2, Section 4.2). The aim during HSI acceptance is to properly test attributes of the equipment for which the contractor is responsible, including the ability to integrate with the human component of the UAS. Early defined requirements and acceptance criteria should ensure that contractors provide more effective equipment and systems that fully meet the operational requirements.

Acceptance must specify how contractors will be assessed against the HSI requirements and constraints in terms of the characteristics of the UAS (including conformance to standards) and performance. HSI acceptance criteria tend to take two forms: those dealing with design characteristics and those dealing with human performance as a function of system performance.

In the early stages, HSI requirements may not be specified in any detail and the requirement may actually be to carry out requirements definition studies in the HSI domains. Gradually a set of derived HSI requirements should be produced that are based upon the evolving design (UK MoD HFI Process Handbook, 2007).

5.2 HSI Working Group

A HSI Working Group (HSIWG) serves as a forum for interchange of ideas and information and also helps resolve conflicts between different specialist requirements. This forum is important for coordination between HSI stakeholders so it is necessary to establish it as soon as possible. The next steps are to define the terms of reference, obtain support from the Acquirer with a clear line of reporting to them, include user representatives/other technical areas of the project, and include stakeholders with an interest in human-related aspects of the UAS. The HSIWG functions to proactively resolve issues and conflicting requirements; when an impasse occurs, the working group brings the issue to the attention of the Acquirer leadership for decision. Ideally, the HSIWG should run throughout the project and should retain a reasonably stable membership. Sustaining the group during fielding of the UAS will allow for coordination of feedback from UAS users, such as operators and maintainers, on gaps and opportunities.



5.3 Human Systems Integration Plan

Because each UAS is unique, individual programmes will naturally emphasize some domain areas more than others. Human Systems Integration Plan (HSIP) content will depend upon the nature of the particular UAS being developed. Consequently, an organisation may tailor the HSIP to their particular circumstance and better satisfy the specific organisational needs. The HSIP is best submitted as an evolutionary and continuous product in conjunction with the UAS

engineering plan and system lifecycle management plan (or national equivalent plans); however, the HSIP can also be developed as a stand-alone document.

Type of Information in a HSIP:

- HSI issues
 - HSI constraints
 - HSI studies, actions and mitigation strategies for each significant issue
 - Organisational chart
 - Dependencies between organisations and project activities in conducting HSI activities
 - Key milestones, deliverables and timescales
 - Extent of need for user (i.e., operator) participation
 - Method for including HSI in system level trade-offs
 - Method for monitoring and controlling progress against the plan
-

The HSIP should support HSI throughout the life cycle of the UAS, taking into consideration programme needs from capability planning. The HSIP should be updated and refined annually with the UAS engineering plan to account for evolving risks and improvement initiatives. If it is not possible to update yearly, it should at least be refined at important system development points. If possible, a full HSIP should be included as an annex in the UAS engineering plan, but as previously mentioned, it can be developed as a stand-alone plan. Regardless, it is fundamentally important for those responsible for HSI on a project to develop a HSIP for the success of the UAS (United States Air Force, 2008).

6.0 Technical Activities

This section will introduce the HSI Technical Activities that may be carried out during a UAS project. Many of these Technical Activities will require specialist input. However, it is also necessary for those managing HSI to have some understanding of the need for function and output of these activities as part of the HSI Management process. HSI Technical Activities ensure ‘designing for use’ objectives can be met. Additionally, HSI is an integral part of systems engineering and so should support other specialist technical activities.

The EHFA forms a starting point by allowing key HSI risks, issues, assumptions and constraints to be identified. The previous work on Human Views (section 3.0) will inform the Technical Activities, and the results of the activities should be used to update applicable Human Views. Although the Technical Activities are sequentially described here, the execution of these activities is iterative. Iteration is not only appropriate but also expected. New information is created by individual Technical Activities, and typically this information takes the form of questions with respect to requirements, analysed risks or opportunities. Such questions should be resolved by reapplication of Technical Activities. Appendix A provides a Cross-Walk matrix and Justification table mapping each Technical Activity with applicable Human Views.

HSI Technical Activities draw upon a range of specialist methods and tools generally used by qualified practitioners. It is important from the HSI Management perspective to be familiar with the types of design and evaluation activities that should occur.

6.1 Mission Analysis

Mission Analysis is important in deciding what the human does. The operational scenario provides information that supports EHFA and enables generation of human–system assumptions. It also contributes support to manning and personnel requirements. Such scenarios are likely to form the basis of future acceptance testing for fitness of purpose, including calculations and assessment of human performance and workload, etc. They must be based on a comprehensive understanding of operators' other tasks (not related to the equipment/capability in question) and of service doctrine and training expertise (UK MoD HFI Process Handbook, 2007). [Relevant HVs: HV-A Concept, HV-B Constraints, HV-C Tasks, HV-D Roles, and HV-G Metrics].

6.2 Functional Analysis

Functional analysis is the analysis of UAS functions. Functions describe relatively broad activities that may be implemented by personnel alone (e.g., deploy equipment), by equipment alone (e.g., self-test/equipment circuitry), or, as in most cases, by some combination of both (e.g., pre-flight checks). Functions can be instantaneous (e.g., fire missile) or prolonged (e.g., monitor radar), simple (e.g., start engines) or complex (e.g., assess tactical situation). At a certain level of detail, functions become indistinguishable from tasks; there are no clear-cut rules for making this distinction (UK MoD Def Stan 00-250, 2008). [Relevant HVs: HV-A Concept, HV-C Tasks, and HV-D Roles].

6.3 Allocation of Functions

Function Allocation refers to the task of deciding the distribution of functions between the operator and equipment. Considered one of the most important human-centred design principles, these design decisions determine the extent to which a given job, task, function or responsibility is to be automated or assigned to human performance.

The decisions are based on many factors, such as relative capabilities and limitations of humans versus technology in terms of reliability, speed, accuracy, strength, flexibility of response, financial cost, the importance of successful or timely accomplishment of tasks and user well-being. They should not simply be based on determining which functions the technology is capable of performing and then simply allocating the remaining functions to users, relying on their flexibility to make the system work. The resulting human functions should form a meaningful set of tasks. Users should always be involved in these decisions as described in the user-centred design process (ISO 13407:1999). [Relevant HVs: HV-C Tasks and HV-D Roles].

6.4 Task Analysis

A comprehensive view and clear understanding of the users' typical tasks and cognitive processes are fundamental to most aspects of HSI and feeds into many other system design activities. The scope of what the operators and maintainers are required to do is captured in a task description (which is intimately



linked with the operational requirement). Task analysis then explores the implications of these tasks in terms of the operator's ability to undertake them. For systems where human functions are predominantly "cognitive", the methods of analysis captures this essential human activity. Analytical methods such as mission function task analysis, cognitive task analysis, cognitive work analysis, and hierarchical goal analysis can provide the user interface communication, visual display and control requirements needed for system design. They also provide the means to capture more detailed knowledge from subject matter experts for embedding in a knowledge-based system (Banbury, et al., 2007; Hou, et al., 2011; UK MoD HFI Process Handbook, 2007; UK MoD TLCM Handbook, 2010). [Relevant HVs: HV-A Concept, HV-C Tasks, HV-D Roles, and HV-F Training].

6.5 Design Jobs, Roles, and Tasks

Job analysis is the process of systematically investigating and evaluating the attributes of a job in terms of tasks, procedures, and responsibilities and personal attributes. Job design involves deciding what tasks will be performed by which personnel, how tasks will be grouped together and allocated, and how individuals will relate to each other so that their work can be coordinated. This ensures that tasks and roles allocated to a job are appropriately structured and achievable (UK MoD HFI Process Handbook, 2007; TLCM, 2010). [Relevant HVs: HV-A Concept, HV-B Constraints, HV-C Tasks, HV-D Roles, HV-E Human Network, and HV-F Training].

6.6 Human Reliability Assessment

Human Reliability Assessment (HRA) is a specialist activity, using knowledge about the expected UAS design and its likely failures to define causal chains showing what factors would combine to create particular hazards. HRA identifies the likelihood of human error in UAS designs and the impact of such errors (UK MoD HFI Process Handbook, 2007). [Relevant HVs: HV-B Constraints and HV-H Human Dynamics].



6.7 Design Equipment, HMI, and Workspace

This is concerned with the design of operational equipment including displays (visual and auditory), controls, human-computer interfaces, alarms and warnings, user manuals and operational facilities within workspaces. It also addresses hand tools, work clothing, and selection of Commercial Off the Shelf (COTS), Military Off the Shelf (MOTS) or Government Off the Shelf (GOTS) – i.e., preexisting – equipment. The design of workspaces should be concerned with meeting the functional needs of the system and personnel whilst minimising stress and maintaining optimal levels of performance (UK MoD TLCM Handbook, 2010). [Relevant HVs: HV-A Concept, HV-G Metrics, and HV-H Human Dynamics].

6.8 Develop Training

Training Needs Analysis assesses training requirements arising as a result of new equipment procurement, doctrinal change, organisational change, or changes to policy. It generally includes a comparison of different training methods and equipment with a view to recommending

the optimum training system (UK MoD TCLM Handbook, 2010). [Relevant HVs: HV-C Tasks, HV-D Roles, HV-F Training, and HV-G Metrics].

6.9 Performance Analysis

Human performance related issues and risks, such as usability, error, situation awareness, workload, and team coordination should be addressed in analyses to ensure that the intended users will be able to use the system in an operational environment and achieve required standards of task performance. A wide range of techniques for predicting and measuring aspects of human performance are available. Access to intended users may need to be provided to support 'person in the loop' performance trials. Computer modeling can be a cost-effective way of predicting human performance. The data from this type of analysis will consequently inform and aid decisions about human-machine interface design, allocation of functions, etc. (UK MoD TCLM Handbook, 2010). [Relevant HVs: HV-A Concept, HV-B Constraints, HV-C Tasks, HV-D Roles, HV-E Human Network, HV-G Metrics, and HV-H Human Dynamics].

7.0 HSI Outputs and Products

To ensure HSI aspects are fully considered as part of broader UAS project management and technical development, it is important to include a human component in other project activities and their documentation. Two key examples are a Project Life Management Plan and a Project Test and Evaluation Plan.

7.1 Project Life Management Plan

A Project Life Management Plan gives a whole life perspective on UAS project objectives, assumptions, plans and resources. It draws upon a set of documents including the following HSI examples:

- HSI Management Plan and Strategy
- Key HSI decisions
- HSIWG constitution and responsibilities
- Division of responsibility for HSI activities
- HSI testing and evaluation plans and results
- Procedures for managing/sharing HSI data
- HSI audit results following introduction to service
- HSI management strategy for upgrades
- HSI risks, issues, assumptions and constraints.

7.2 Project Test and Evaluation Plan

A Project Test and Evaluation Plan defines how the project will ensure that the required UAS is being produced and then confirm that it has been produced. Those aspects of the UAS that relate to integration between human and equipment elements require HSI input to the Project Test and Evaluation Plan. Such input may be integrated within the plan or developed as a standalone section. It should include the following:

- HSI Management Plan
- HSI acceptance processes and procedures (including specifying appropriate military/user participants for trials)
- HSI Testing and Evaluation Plan results
- Outputs from HSIWG meetings.

Conclusion

Human Systems Integration (HSI) is a robust process integral to systems engineering by which to design and develop UAS designs that effectively and affordably address human capabilities and limitations. It involves the identification and tradeoff of the human-related issues that could impact acquisition processes. Its major value is the integration of five individual domains consisting of Manpower and Personnel, Training, Human Factors Engineering, Safety and Health, and Organisational and Social. HSI integrates and facilitates the trade-offs among these five domains and between the domains and the other performance requirements without replacing individual domain activities.

HSI must be applied during development and acquisition of UAS and related equipment to integrate personnel (operator, user, or maintainer) effectively into the design of the system. The total system includes not only the prime mission equipment, but also the people who operate, maintain and support the system; the training and training devices; and the operational and support infrastructure.

UAS technology continues to rapidly evolve in the face of relatively static human performance capabilities and limitations, increasing the potential for mismatches between people and technology. System developers need to ensure that UAS are designed to take human considerations into account, thereby allowing them to push the technology, human, and other support resources to their collective limit in pursuit of mission capability. Given humans continue to have significant impacts on the operational effectiveness of UAS, they must be viewed as a central component of UAS.

Appendix A

Table 3. Technical Activity and Human View Cross-Walk

HSI Technical Activity								
Mission Analysis								
Functional Analysis								
Allocation of Functions								
Task Analysis								
Design Jobs, Roles, and Tasks								
Human Reliability Assessment								
Design Equipment, HMI, and Workplace								
Develop Training								
Performance Analysis								
Human View								
HV-A Concept – A high-level representation of the human component of the enterprise architecture framework. Its purpose is to visualize and facilitate understanding of the human dimension in relation to operational demands and system components (NATO 2010).	X		X		X	X		X
HV-B Constraints – These are sets of characteristics that are used to adjust the expected roles and tasks based on the capabilities and limitations of the human in the system (NATO 2010).	X			X	X			X
HV-C Tasks – Describes the human activities that are assigned to the human in the system with information requirements including human-related functions in a system, allocation of functions between humans and machines and decomposition of functions into tasks (NATO 2010).	X	X			X	X	X	X
HV-D Roles – Describes the roles that have been defined for the humans interacting with the system with information requirements including the access ability of an individual to perform a specific task and the quality of being able to perform – a combination of knowledge, skills, and attributes (NATO 2010).	X	X			X	X	X	X
HV-E Human Network – Captures the human to human communication patterns that occur as a result of ad hoc or deliberate team formation, especially teams distributed across space and time (NATO 2010).	X				X			
HV-F Training – A detailed accounting of how training requirements, strategy, and implementation will impact the human. It illustrates the instruction or education and on-the-job training required to provide personnel their essential tasks, skills, and knowledge to meet the job requirements (NATO 2010)			X		X	X		
HV-G Metrics – Provides a repository for human-related values, priorities and performance criteria. It may map high-level (qualitative) values to quantifiable performance metrics and assessment targets or it may map measurable metrics to human performance specifications (NATO 2010).	X	X	X					X
HV-H Human Dynamics – Captures dynamic aspects of human system components. These are dynamic in the sense that states, conditions, or performance parameters may change over time, or as a result of triggering events (NATO 2010)	X		X	X				

Justification of Mapping

Mission Analysis

Mission Analysis is important in deciding what the human does. It considers a comprehensive set of operational mission profiles. Each mission profile is divided into a number of phases and related operating modes. Each mode is then divided into task steps which are categorized in terms of frequency, criticality, demands, etc. For each identified task the associated system functions are identified. This constitutes the allocation of the task to the system component, human component, or sharing of the function between the two.

Human View	Justification
HV-A Concept	A high-level representation of the human component of the enterprise architecture framework. Its purpose is to visualize and facilitate understanding of the human dimension in relation to operational demands and system components.
HV-B Constraints	These are sets of characteristics that are used to adjust the expected roles and tasks based on the capabilities and limitations of the human in the system.
HV-C Tasks	Describes the human activities that are assigned to the human in the system with information requirements including human-related functions in a system, allocation of functions between humans and machines and decomposition of functions into tasks.
HV-D Roles	Describes the roles that have been defined for the humans interacting with the system with information requirements including the access ability of an individual to perform a specific task and the quality of being able to perform – a combination of knowledge, skills, and attributes.
HV-G Metrics	Provides a repository for human-related values, priorities and performance criteria. It may map high-level (qualitative) values to quantifiable performance metrics and assessment targets or it may map measurable metrics to human performance specifications.

Functional Analysis

Functional Analysis is the analysis of UAS functions. Functions describe relatively broad activities that may be implemented by personnel alone, by equipment alone, or by some combination of both. Functions can be instantaneous (e.g., fire missile), prolonged (e.g., monitor radar), simple (e.g., start engine), or complex (e.g., asses tactical situation).

Human View	Justification
HV-A Concept	A high-level representation of the human component of the enterprise architecture framework. Its purpose is to visualize and facilitate understanding of the human dimension in relation to operational demands and system components.
HV-C Tasks	Describes the human activities that are assigned to the human in the system with information requirements including human-related functions in a system, allocation of functions between humans and machines and decomposition of functions into tasks.
HV-D Roles	Describes the roles that have been defined for the humans interacting with the system with information requirements including the access ability of an individual to perform a specific task and the quality of being able to perform – a combination of knowledge, skills, and attributes.

Allocation of Functions

Allocation of Functions refers to the task of deciding the distribution of functions between the operator and the equipment. Design decision determine the extent to which a given job, task, function, or responsibility is to be automated or assigned to human performance.

Human View	Justification
HV-C Tasks	Describes the human activities that are assigned to the human in the system with information requirements including human-related functions in a system, allocation of functions between humans and machines and decomposition of functions into tasks.
HV-D Roles	Describes the roles that have been defined for the humans interacting with the system with information requirements including the access ability of an individual to perform a specific task and the quality of being able to perform – a combination of knowledge, skills, and attributes.

Task Analysis

Task Analysis techniques are used to understand and represent human and system performance in a particular task or scenario. The scope of what the operators and maintainers are required to do is captured in a task description (which is linked with the operational requirement). Task Analysis then explores the implications of the tasks in terms of the operator's ability to undertake them.

Human View	Justification
HV-A Concept	<p>A high-level representation of the human component of the enterprise architecture framework. Its purpose is to visualize and facilitate understanding of the human dimension in relation to operational demands and system components.</p>
HV-C Tasks	<p>Describes the human activities that are assigned to the human in the system with information requirements including human-related functions in a system, allocation of functions between humans and machines and decomposition of functions into tasks.</p>
HV-D Roles	<p>Describes the roles that have been defined for the humans interacting with the system with information requirements including the access ability of an individual to perform a specific task and the quality of being able to perform – a combination of knowledge, skills, and attributes.</p>
HV-F Training	<p>A detailed accounting of how training requirements, strategy, and implementation will impact the human. It illustrates the instruction or education and on-the-job training required to provide personnel their essential tasks, skills, and knowledge to meet the job requirements.</p>

Design Jobs, Roles, and Tasks

Job analysis is the process of systematically investigating and evaluating the attributes of a job in terms of tasks, procedures, and responsibilities and personal attributes. Job design involves deciding what tasks will be performed by which personnel, how tasks will be grouped together and allocated, and how individuals will relate to each other so that their work can be coordinated.

Human View	Justification
HV-A Concept	A high-level representation of the human component of the enterprise architecture framework. Its purpose is to visualize and facilitate understanding of the human dimension in relation to operational demands and system components.
HV-B Constraints	These are sets of characteristics that are used to adjust the expected roles and tasks based on the capabilities and limitations of the human in the system.
HV-C Tasks	Describes the human activities that are assigned to the human in the system with information requirements including human-related functions in a system, allocation of functions between humans and machines and decomposition of functions into tasks.
HV-D Roles	Describes the roles that have been defined for the humans interacting with the system with information requirements including the access ability of an individual to perform a specific task and the quality of being able to perform – a combination of knowledge, skills, and attributes.
HV-E Human Network	Captures the human to human communication patterns that occur as a result of ad hoc or deliberate team formation, especially teams distributed across space and time.
HV-F Training	A detailed accounting of how training requirements, strategy, and implementation will impact the human. It illustrates the instruction or education and on-the-job training required to provide personnel their essential tasks, skills, and knowledge to meet the job requirements.

Human Reliability Assessment

Human Reliability Assessment must be considered whenever the human component in a system contributes to system safety or system reliability. This may occur when operator actions are required to maintain safety or when operator performance can directly influence overall system performance. HRA identifies the likelihood of human error in UAS design and the impact of such errors.

Human View	Justification
HV-A Concept	A high-level representation of the human component of the enterprise architecture framework. Its purpose is to visualize and facilitate understanding of the human dimension in relation to operational demands and system components.
HV-H Human Dynamics	Captures dynamic aspects of human system components. These are dynamic in the sense that states, conditions, or performance parameters may change over time, or as a result of triggering events.

Design Equipment, HMI, and Workspace

This is concerned with the design of operational equipment including displays (visual and auditory), controls, human-computer interfaces, alarms and warning, user manuals and operational facilities within workspaces. The design of workspaces should be concerned with meeting the functional needs of the system and personnel whilst minimising stress and maintaining optimal level of performance.

Human View	Justification
HV-B Constraints	These are sets of characteristics that are used to adjust the expected roles and tasks based on the capabilities and limitations of the human in the system.
HV-G Metrics	Provides a repository for human-related values, priorities and performance criteria. It may map high-level (qualitative) values to quantifiable performance metrics and assessment targets or it may map measurable metrics to human performance specifications.
HV-H Human Dynamics	Captures dynamic aspects of human system components. These are dynamic in the sense that states, conditions, or performance parameters may change over time, or as a result of triggering events.

Develop Training

Training Needs Analysis is to identify the skills and knowledge that users require to perform their jobs. It assesses training requirements arising as a result of new equipment procurement, doctrinal change, organisational change, or changes to policy. It generally includes a comparison of different training methods and equipment with a view to recommending the optimum training system.

Human View	Justification
HV-C Tasks	Describes the human activities that are assigned to the human in the system with information requirements including human-related functions in a system , allocation of functions between humans and machines and decomposition of functions into tasks.
HV-D Roles	Describes the roles that have been defined for the humans interacting with the system with information requirements including the access ability of an individual to perform a specific task and the quality of being able to perform – a combination of knowledge, skills, and attributes.
HV-F Training	A detailed accounting of how training requirements, strategy, and implementation will impact the human. It illustrates the instruction or education and on-the-job training required to provide personnel their essential tasks, skills, and knowledge to meet the job requirements.
HV-G Metrics	Provides a repository for human-related values, priorities and performance criteria. It may map high-level (qualitative) values to quantifiable performance metrics and assessment targets or it may map measurable metrics to human performance specifications.

Performance Analysis

Human performance-related issues and risks, such as usability, error, situation awareness, workload, and team coordination should be addressed in analyses to ensure that the intended users will be able to use the system in an operational environment and achieve required standards of task performance. Computer modeling can be a cost-effective way of predicting human performance. The data from this type of analysis will consequently inform and aid decisions about human-machine interface design, allocation of functions, etc.

Human View	Justification
HV-A Concept	A high-level representation of the human component of the enterprise architecture framework. Its purpose is to visualize and facilitate understanding of the human dimension in relation to operational demands and system components.
HV-B Constraints	These are sets of characteristics that are used to adjust the expected roles and tasks based on the capabilities and limitations of the human in the system.
HV-C Tasks	Describes the human activities that are assigned to the human in the system with information requirements including human-related functions in a system , allocation of functions between humans and machines and decomposition of functions into tasks.
HV-D Roles	Describes the roles that have been defined for the humans interacting with the system with information requirements including the access ability of an individual to perform a specific task and the quality of being able to perform – a combination of knowledge, skills, and attributes.
HV-E Human Network	Captures the human to human communication patterns that occur as a result of ad hoc or deliberate team formation , especially teams distributed across space and time.
HV-G Metrics	Provides a repository for human-related values, priorities and performance criteria. It may map high-level (qualitative) values to quantifiable performance metrics and assessment targets or it may map measurable metrics to human performance specifications.
HV-H Human Dynamics	Captures dynamic aspects of human system components. These are dynamic in the sense that states, conditions, or performance parameters may change over time, or as a result of triggering events.

Acronyms

C

CBRN Chemical, Biological, Radiological and Nuclear
COTS Commercial Off the Shelf

D

DoD Department of Defense
DoDAF Department of Defense Architectural Framework

E

EHFA Early Human Factors Analysis

F

FINAS Flight in Non-Segregated Airspace

G

GCS Ground Control Station
GOTS Government Off the Shelf

H

HFE Human Factors Engineering
HFI Human Factors Integration
HMI Human-Machine Interface
HRA Human Reliability Assessment
HRR Human-Related Requirement
HSI Human Systems Integration
HSIP Human Systems Integration Plan
HSIWG Human Systems Integration Working Group
HV Human View

J

JCGUAS Joint Capability Group for Unmanned Aircraft Systems

K

KSA Knowledge, Skills, and Abilities

M

MoD Ministry of Defence
MOTS Military Off the Shelf

N

NATO North Atlantic Treaty Organisation
NTSB National Transportation Safety Board

S

SME Subject Matter Expert
SOP Standard Operating Procedure

T

TAD Target Audience Description
TLCM Through-Life Capability Management

U

UAS Unmanned Aircraft System

W

WG Working Group
WHMIS Workplace Hazardous Materials Information System

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