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HUMAN SYSTEMS INTEGRATION GUIDANCE FOR UNMANNED AIRCRAFT SYSTEMS

Edition A, Version 1

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NORTH ATLANTIC TREATY ORGANIZATION

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NATO LETTER OF PROMULGATION

17 February 2022

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CHAPTER 1 INTRODUCTION

1.1 REFERENCES

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1.2 TERMS AND DEFINITIONS

1.2.1 Definitions

Throughout this document, terminology is used that may mean different things to different people. The definitions listed in Table 1-1 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 1-1: Definition of Terms Used in this Document

Traditionally Used Term	As Used in this Document	Definition
STANREC	STANREC	A STANREC is a NATO standardization document used exclusively in the materiel field of standardization that lists one or several NATO or non-NATO standards relevant to a specific Alliance activity unrelated to interoperability.
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 organization 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	The 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 organization 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.

1.2.2 Acronyms

Table 1-2: Acronyms Used in this Document

AOF	Acquisition Operating Framework
CBRN	Chemical, Biological, Radiological and Nuclear
COTS	Commercial Off the Shelf
C2	Command and Control
DoD	Department of Defense
DoDAF	Department of Defense Architectural Framework
EHFA	Early Human Factors Analysis
FINAS	Flight In Non-segregated Airspace
GCS	Ground Control Station
GOTS	Government Off the Shelf
HFE	Human Factors Engineering
HFI	Human Factors Integration
HFST	Human Factors Specialist Team
HMI	Human-Machine Learning
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
IPT	Integrated Project Team
JCGUAS	Joint Capability Group Unmanned Aircraft Systems
KSA	Knowledge, Skills, and Abilities
LASER	Light Amplification by Simulated Emission
MoD	Ministry of Defense
MOTS	Military Off the Shelf
NATO	North Atlantic Treaty Organization
NTSB	National Transportation Safety Board
SA	Situation Awareness
SME	Subject Matter Expert
SOP	Standard Operating Procedure
TAD	Target Audience Description
TLCM	Through-Life Capability Management
UAS	Unmanned Aircraft System
WG	Working Group
WHMIS	Workplace Hazardous Materials Information System

1.3 BACKGROUND

1. People are the key component of any defense system — and this is no less the case for unmanned aircraft systems (UASs), where, despite the term “unmanned,” much human involvement is required to achieve the 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 to gain a competitive advantage.

2. As various organizations 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 realization that there is much more than simply an aircraft in question. This understanding is formally captured in the US Unmanned Aircraft Systems development and standardization guide (United States Department of Defense [DoD], 2012, 2016), and other supporting documents. From a total system perspective, one should appreciate that a UAS is comprised of an unmanned aircraft, ground components, and other architectural elements, each with their attributes and which collectively interact to exhibit emergent system-level properties that are of value to various system stakeholders.

3. 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, including system safety. Also couched in this systems view is the acknowledgment 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 has not removed the human element from the system. Instead, UAS provides 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.

4. As in manned systems, the essential role of the human in a UAS is to provide contextually responsive command and control (C2) for the system with the overarching situation awareness (SA). To accomplish these functions, the human must interact with the system at some point in its operation and use some form of human-machine interface (HMI). Therefore, it is 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 Human Systems Integration (HSI) when developing, acquiring, and operating UAS. Figure 1-1 represents the main elements of HSI for an integrated system: people, technology, and work environment.

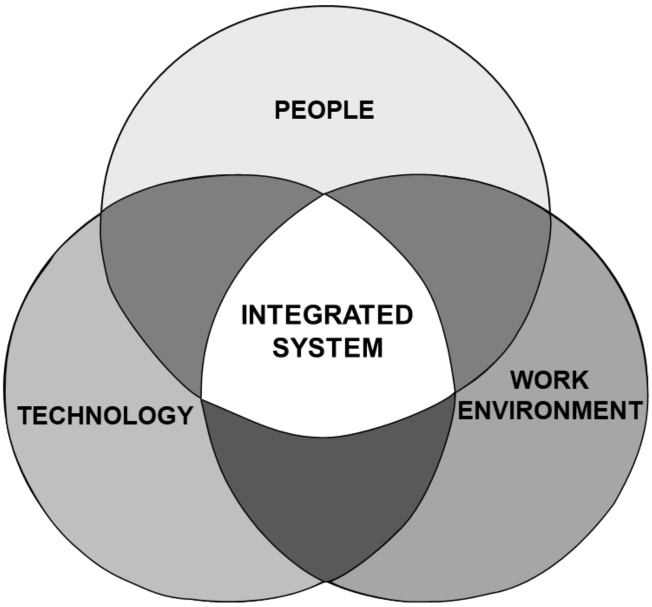

Figure 1-1: Main Elements of An Integrated System

5. 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 and interaction-centered design (Hou et al., 2014) perspective of systems increases productivity and safety while decreasing costs. According to the US Defense Acquisition Guidebook, HSI is defined as “a robust process by which to design and develop systems that effectively and affordably integrate human capabilities and limitations. HSI should be included as an integral part of a total system

approach to weapon systems development and acquisition….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" (Defense Acquisition University, 2010).

6. HSI involves the identification and trade-off of the human-related issues that could heavily impact system performance. To ensure that all issues are considered, these human-related issues are categorized into five main areas or domains, namely Manpower/Personnel, Training, Human Factors Engineering (HFE), Safety and Health, and Organizational and Social Characteristics. 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; instead, they need to be related to each other. Any decision in one of the domains almost certainly impacts on another domain.

7. For proponents of operating UAS within the world-wide airspace structure in a non-segregated fashion, such as the NATO Joint Capability Group 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 HMIs for 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 GCS design far less tractable. Rather, human factors engineering decisions need to be considered in light of the overall performance, safety, and cost-benefit 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.

8. To provide 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, this Standard Recommendation (STANREC) was prepared by the Human Factors Specialist Team (HFST) for the UAS Flight in Non-Segregated Airspace (FINAS) Working Group (WG), JCGUAS. It was the product of FINAS study number 4685, extracted the high-level process-related elements from the United Kingdom Ministry of Defence Standard 00-250, Human Factors for Designers of Systems (2008), that were applicable to a generic systems engineering framework for designing and procuring a UAS. This document represents the hard work and dedication of the HFST members whose service and efforts made this work possible. These individuals include:

Patrick Le Blaye (France), Daniel Hauret (France), Piet Hoogeboom (Netherlands), Ming Hou (Canada), Joe Geeseman (USA), Edgar Reuber (Germany), Ian Ross (UK), Roland Runge (Germany), Anja Schwab (Germany), Anthony Tvaryanas (USA), Eric Vorm (USA).

1.4 PURPOSE AND SCOPE

1. This STANREC describes:

   a. The importance of HSI to the flight of UAS in non-segregated airspace;

   b. Activities that can help identify where the key human contributions to UAS performance and safety are likely to occur;

   c. How to integrate HSI input into the development of UAS; and

   d. Techniques that can be used to apply HIS.

2. The processes specified in the STANREC 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 by human-related considerations. In this way, the process supports the development of cost-effective UAS that is safer, and has increased mission effectiveness and reliability, therefore meeting requirements for integration into non-segregated airspace.

1.5 TARGET AUDIENCE

This STANREC is aimed at NATO and Industrial personnel who need to address and resource the human issues/risks in the design, implementation, procurement, evaluation, and operation of UASs. The primary users of this STANREC will be an integrated project team (IPT) with all stakeholders, including project managers, designers, and developers who design, develop, and/ or procuring UASs. This STANREC addresses human-related considerations and HSI activities to allow the IPT members 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 STANREC relevant.

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CHAPTER 2 HUMAN SYSTEMS INTEGRATION DOMAINS

1. Human Systems Integration (HSI) involves the identification and trade-off of the human-related issues that could impact acquisition processes. These human-related issues are categorized into five main areas, or domains, which essentially form a checklist of issues that need to be considered. As illustrated in Figure 2-1, the five HIS domains are: Manpower/Personnel, Training, Human Factors Engineering (HFE), Safety and Health, and Organizational and Social Characteristics.

2. The human-related 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 program and conduct an Early Human Factors Analysis to identify the risks and tradeoff s in order to resolve these issues later in the project.

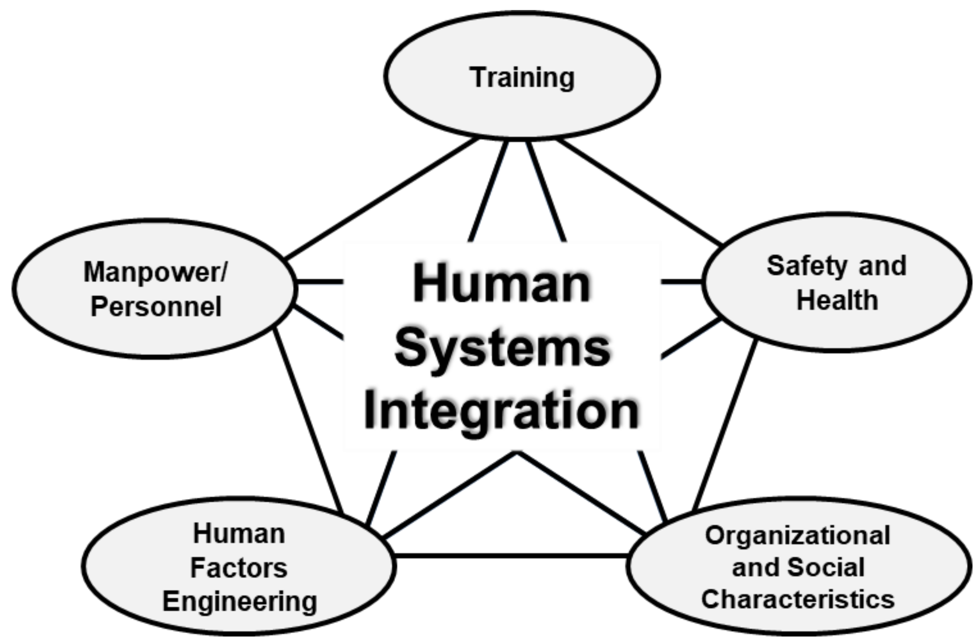

Figure 2-1: Five Human Systems Integration Domains

2.1 MANPOWER/PERSONNEL

1. The Manpower/Personnel domain concerns the number of men and women, military, civilians, and contractors, required and available to operate and maintain the UAS under consideration. It considers knowledge, skills, 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.

2. Some important HSI issues to consider within this domain are:

a. Wartime/peacetime manpower requirements;

b. Deployment considerations;

c. Operating strength;

d. Manning;

e. Personnel selection and classification;

f. Cognitive, physical and educational profiles;

g. Accession and attrition rates;

h. Qualified personnel when and where needed;

i. Individual differences/variability;

j. Supervision;

k. Manpower mix; and

l. Language aptitude.

2.2 TRAINING

1. Training embraces the specification and evaluation of the optimum combination of instructional systems; education; and on-the-job training required to develop the competencies (i.e., knowledge, skills, and abilities, such as social/team-building abilities and soft skills, etc.) 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.

2. Some important HSI issues to consider within this domain are:

a. Training pipeline flow;

b. Training tasks and training development methods;

c. Training needs and methodologies (e.g., individual vs collective and classroom-based vs blended);

d. Media, equipment, and facilities;

e. Operational tempo;

f. Continuity training, refresher training, and core competency-based training; and

g. Teamwork/crew resource management.

h. Balance of live flying training, embedded training, and simulator training

i. Licensing, certification, and recertification of individuals

j. Evaluation/quality assurance of training

2.3 SAFETY AND HEALTH

1. Safety and Health is the process of applying expertise to minimize 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 minimize 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, ionizing and non-ionizing radiation, and human factors issues that can create chronic disease and discomfort such as repetitive motion diseases. Human factors stresses that the risk of chronic disease and discomfort overlap with occupational health considerations. These issues directly impact crew morale.

2. Some important HSI issues to consider within this domain are:

a. Total system reliability and fault reduction/error tolerance;

b. Safety culture;

c. Occupational injuries and illnesses;

d. Health hazards induced by systems, environment, or task requirements;

e. Shift work, disturbed biological rhythms, and physiological fatigue; and

f. Telewarfare and sustained, in-garrison operations.

2.4 ORGANIZATIONAL AND SOCIAL CHARACTERISTICS

1. Organizational 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 organizations who need to collaborate on a distributed and temporary basis for effective operations. Consequently, organizational and social characteristics focus on the process of using all available tools and techniques drawn from relevant information and behavioral science disciplines. This process also enables people to adapt to a more open culture that requires greater sharing and trust between colleagues and coalition partners.

2. Some important HSI issues to consider within this domain are:

a. Distributed teams and shared SA (e.g., remote split operations);

b. Differences in cultural, spiritual, and ethical norms;

c. Trust and information sharing to include means and standards of communications;

d. Definition of roles, responsibilities, and authorities;

e. "Soft" interoperability;

f. Alternative organizational configurations;

g. Multi -national/multi -service interoperability; and

h. Language.

2.5 HUMAN FACTORS ENGNIEERING

1. Human Factors are the user's cognitive, physical, sensory, and team dynamic abilities required to perform UAS-specific operational, maintenance, and support job tasks. 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 maximize user effectiveness and efficiency while minimizing the risk of injury to personnel and others.

2. Some important HSI issues to consider within this domain are:

a. Compatibility of design with anthropometrics and biomedical criteria;

b. Workload, SA, and human performance reliability;

c. HMI;

d. Effects of design on skill, knowledge, and aptitude requirements;

e. Design-driven human performance;

f. Information processing;

g. Cognitive fatigue;

h. HMI supports trust in automation/autonomy;

i. Employment of automation/autonomy;

j. Implementation of decision aid;

k. Design to enable maintenance tasks; and

l. Human error.

CHAPTER 3 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 the acquisition. Figure 3-1 illustrates how key HSI activity stages are mapped 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.

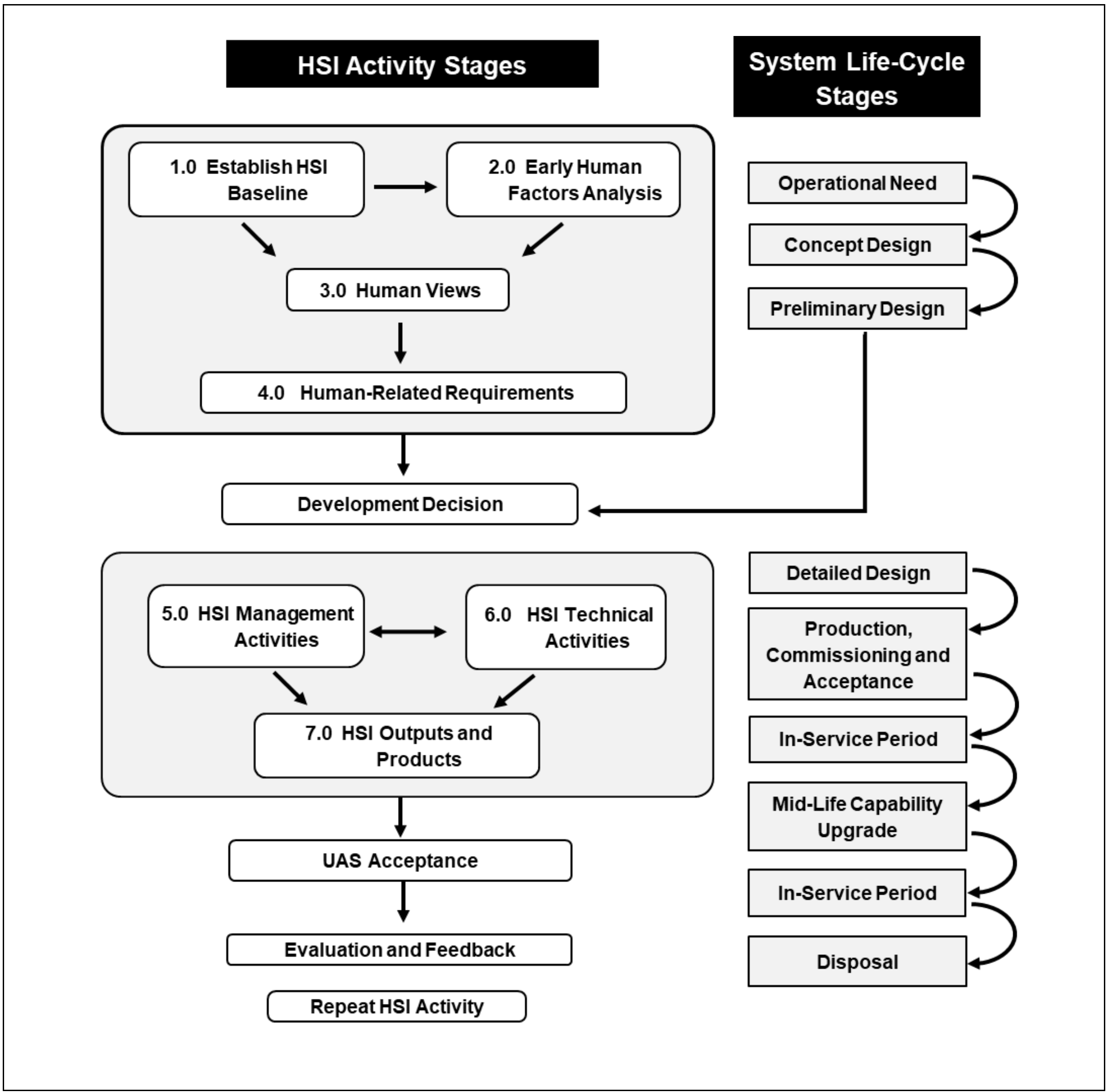

Figure 3-1: HSI activity stages mapped to the systems engineering life-cycle stages (Adapted from UK Ministry of Defence [MoD] Defence [Def] Standard [Stan] 00-250)

3.1 HSI PROCESS GOALS

1. 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 itemized goals.

a. Planned and managed consideration of systems and human-related considerations (including risks, issues, constraints, assumptions, etc.) from the very outset of a UAS project, and subsequently throughout the life-cycle.

b. Systematic treatment of systems and human-related considerations through the life of the UAS, including the early stages of in-service operations and final disposal.

c. Systematic, rigorous and formal capture, specification and management of human-related requirements necessary to provide the required UAS capability.

d. The adoption of a user-centered design (UCD) approach as defined in ISO 9241-210:2010, or an interaction-centered design (ICD) approach as defined in Hou, et al. (2015), or an agreed variant where such is decided to be more appropriate to the UAS project strategy.

e. The use of established systems engineering principles, accepted best practice, and suitable methods tools and techniques and data.

f. Design to match the Context of Use.

g. Design to match User Characteristics.

h. Design to match Organization characteristics.

i. Design to meet user needs.

j. Adoption of a multi-disciplinary approach.

k. Involvement of users in system and equipment design and evaluation.

l. The iteration of design solutions to optimize the solution against human-related requirements and human-related constraints.

m. Formal scrutiny, assessment and acceptance of systems aspects of the solution.

2. These high-level goals can be viewed as a hierarchical set, achieved through a series of sub-goals, activities, and data in-feeds. Figure 3-2 illustrates this hierarchy. When each of the individual goals, sub-goals and high-level goals have been satisfactorily addressed, a project may claim that HSI has been satisfactorily achieved.

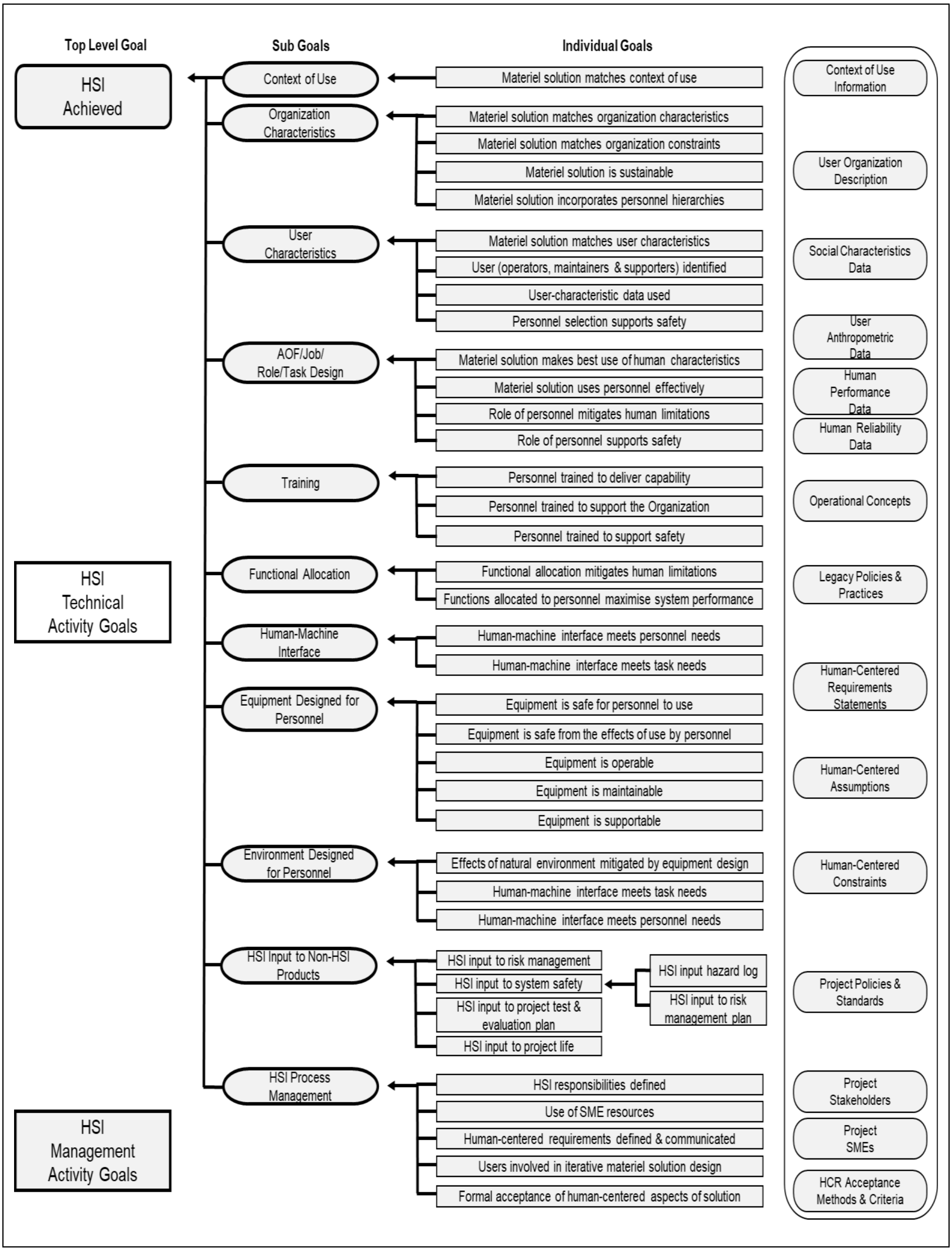

Figure 3-2: Overarching HSI Goal Structure (Adapted from UK MoD Def Stan 00-250)

3.2 PRE-DEVELOPMENT HSI ACTIVITIES

This section provides a functional decomposition of the Pre-Development Decision HSI Activities. Figure 3-3 illustrates the decomposition of the steps required in these activities and should be referenced in the following sections:

a. Establishing the HSI Baseline;

b. Early Human Factors Analysis (EHFA);

c. Human Views; and

d. Human-Related Requirements.

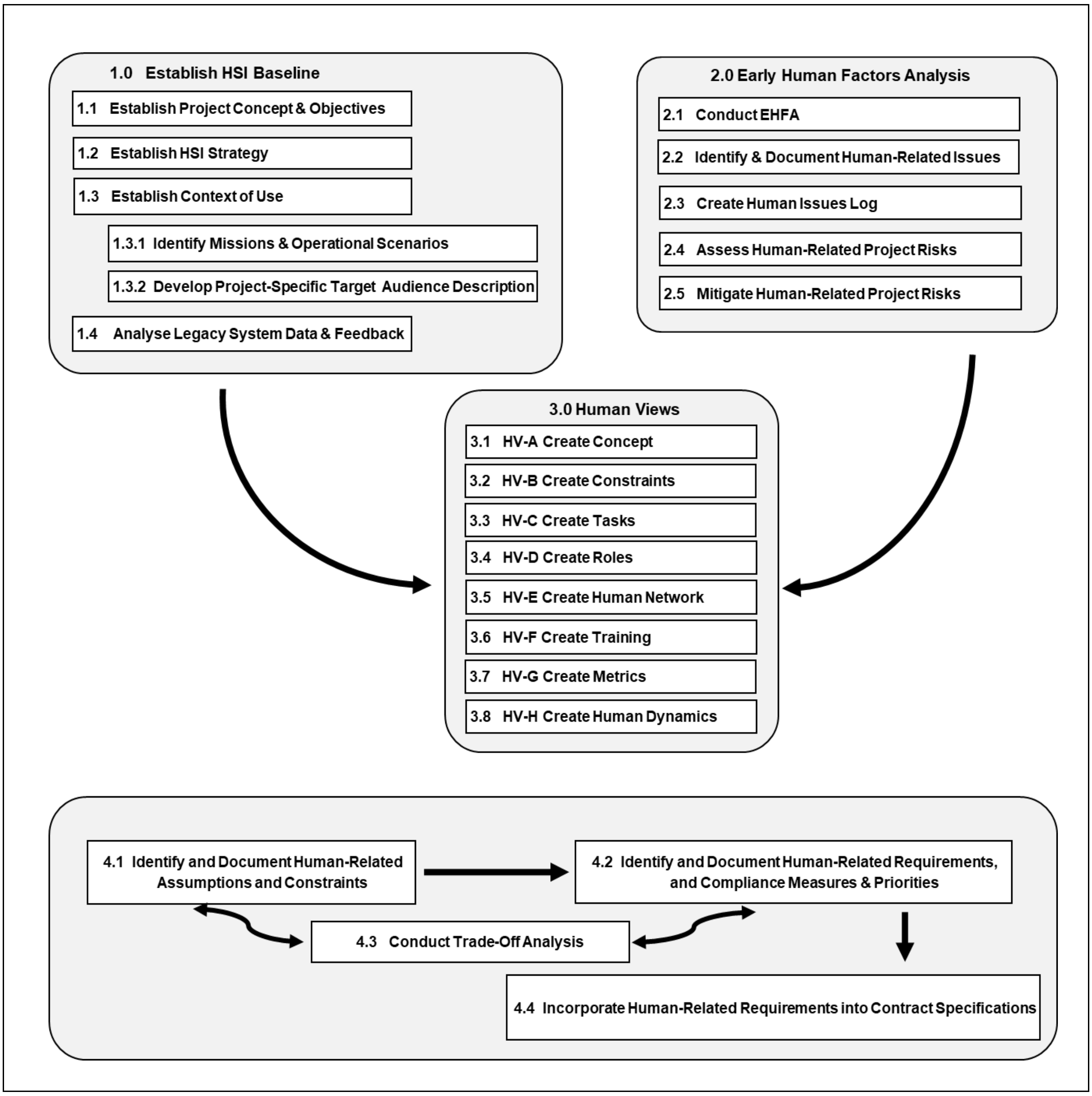

Figure 3-3: Decomposition of Pre-development Decision HSI Activities

3.2.1 HSI Baseline Establishment

This activity aims to collate the information necessary to form a baseline description of the key HSI-related considerations that will be assessed during an EHFA. Depending on the life-cycle stage of the UAS project, differing levels of the baseline are possible.

3.2.1.1 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).

3.2.1.2 Establish HSI Strategy

1. 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).

2. 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 program execution (US DoD Defense Acquisition Guidebook, 2010).

3. 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.

3.2.1.3 Establish Context of Use

1. 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 924111:2000). 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).

2. The purpose of the Context of Use is to clarify and communicate the user characteristics and tasks, and identify the technical, organizational, 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 the available context of use information may need to be checked and validated.

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

a. Physical environment;

b. Cultural and social environment (e.g., work practices, attitudes, organizational structure);

c. Attributes of the wider technical environment;

d. Legal and regulatory environment;

e. Shared SA;

f. Trust and information sharing;

g. Alternative organizational configurations; and

h. Existing user roles, responsibilities, and work management hierarchies.

3.2.1.3.1 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 'human-in-the-loop' (HITL) simulation (UK MoD Def Stan 00-250, 2008).

Mission analysis contributes 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.

3.2.1.3.2 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 life-cycle. 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 STANREC, 2008). The TAD includes information such as (UK MoD HFI Process Handbook, 2007):

a. Which service/branch users will be drawn from;

b. The range of ranks and specialist areas involved;

c. Body size/strength;

d. Physical skills;

e. Knowledge/mental skills;

f. Personal attributes;

g. Educational background;

h. Experience;

i. Training objectives;

j. Career progression;

k. Summary of key tasks personnel will need to perform; and

l. Description of the environment personnel will operate in.

3.2.1.4 Analyze Legacy System Data and Feedback

Analyzing predecessor systems — manned or unmanned — provides insight into both positive and negative aspects of system design, providing the data needed to establish Lessons Learned. Much effort will be directed at identifying, assembling, and analyzing information that 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 (SMEs). 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 relevant to the current project. Analysis techniques applied to the predecessor system(s) that are useful for supporting the development of Context of Use for the current project include the following:

a. Mission Analysis;

b. Functional Analysis;

c. Design Scenario Analysis;

d. Operational Scenario Description;

e. Mission-critical Task Identification;

f. Operability Criteria Definition; and

g. Information flows.

3.2.2 Early Human Factors Analysis

1. 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.

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

cycle, human-related 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".

3. The greatest value is obtained by the early involvement of HSI specialists. Although tools have been developed to assist with EHFA, 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 00250, 2008).

3.2.2.1 Conduct Early Human Factors Analysis

1. The EHFA process comprises a simple three-stage approach that 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.

2. 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 that will be formed from the definition of the emerging concept options to the project and details of the operational requirement.

3. EHFA does not need to be complicated or require significant resources. The level of effort required 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-related 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).

3.2.2.2 Identify and Document Human-Related Issues

1. 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 making final operational decisions such as weapons deployment, targeting, etc.

2. 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).

3. The best way to identify the human-related issues is to conduct a focus group meeting with as many 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 not to 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).

3.2.2.3 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).

3.2.2.4 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.

3.2.2.5 Mitigate Human-Related Project Issues

This section provides a list of possible methods for mitigating the human-related risks to 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):

a. Modify performance requirements;

b. Request demonstrations or HSI analysis from bidders;

c. Provide project funds for additional research/studies/data collection;

d. Highlight areas of concern in a Statement of Work and Business Case; and

e. Produce a HSI data requirements list.

3.2.3 Human Views

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

2. 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 stakeholders' decisions 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 offers 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.

3. The purpose of the NATO HV in UAS projects is to capture human requirements and to illustrate how humans interact within the systems. The HV is a supplementary view of existing architectures, providing an additional set of eight products that augment existing Architecture Frameworks required of systems engineers (Figure 3-4).

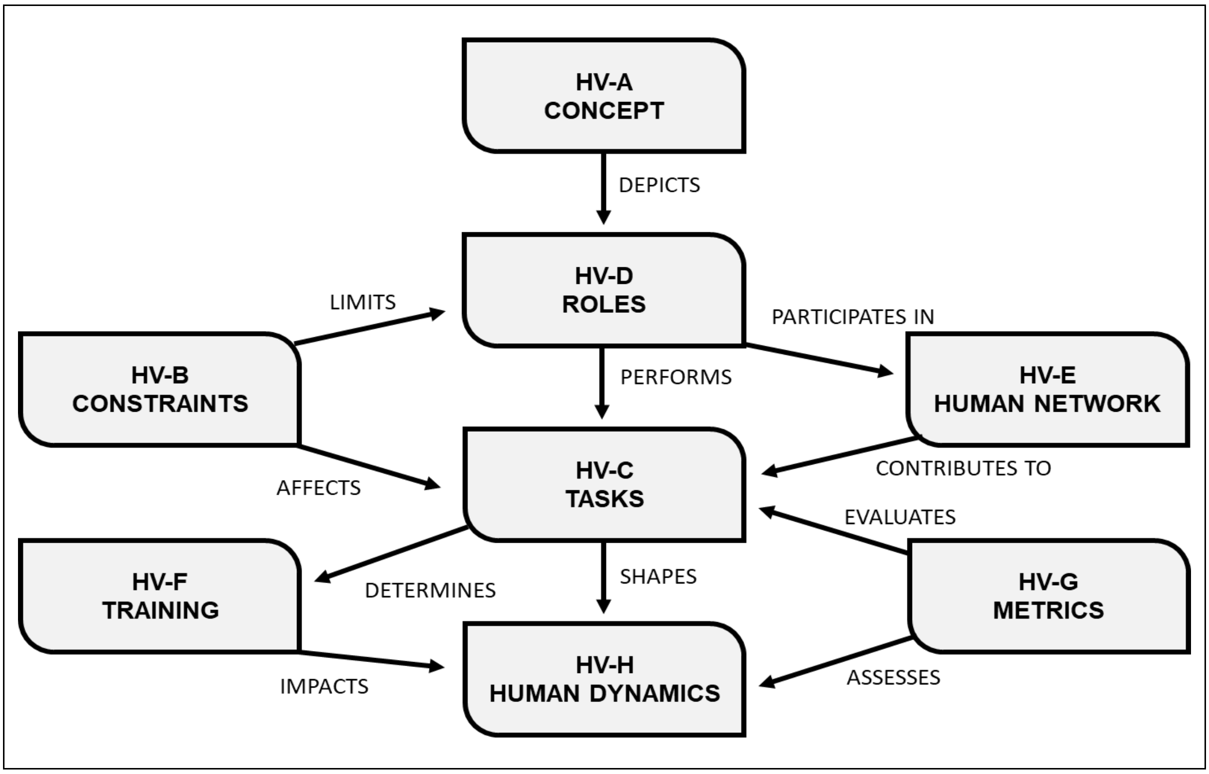

Figure 3-4: NATO Human View Products Overview (NATO HSI for Network Centric Warfare)

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 systems design matures.

3.2.3.1 Create HV-A Concept

1. 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).

2. Information requirements may include:

a. Pictorial depictions of the system and its human component;

b. High-level indicators of where human-system interactions may occur;

c. Textual descriptions of the overall human component of the system; and

d. Use cases which describe the human information process.

3.2.3.2 Create HV-B: Constraints

The human is the most important and unique component within a UAS. Still, they can also 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 following subviews:

3.2.3.2.1 Manpower Projections (HV-B1)

1. Manpower projections Illustrate predicted manpower requirements for supporting present and future projects that contribute to larger capabilities.

2. Information requirements may include:

a. Understand manpower forecasting to allow initial adjustments in training, recruiting, professional development, assignment, and personnel management;

b. 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; and

c. Ensure sufficient number of personnel with necessary Knowledge, Skills, and Abilities (KSA) are ‘ready and able’ to support fielding of the future program.

3.2.3.2.2 Career Progression (HV-B2)

1. Career progression illustrates career progression as well as the essential tasks, skills, and knowledge (and proficiency level) required for a given job.

2. Information requirements may include:

a. Impacts of alternative system and capability designs on career progression;

b. Jobs available given an individual's current job and occupation;

c. Competencies required for each individual job; and

d. Availability of individuals with necessary competencies.

3.2.3.2.3 Establishment Inventory (HV-B3)

1. Establishment inventory defines current number of personnel by rank and job within each establishment.

2. Information requirements may include:

a. Forecast of trained effective strength, and

b. The number of people that must be trained, recruited, etc. to fill gaps required for future years.

3.2.3.2.4 Personnel Policy (HV-B4)

1. Personnel policy ensures that personnel are fairly considered, properly treated, well looked after, and supported in a legal, moral, and ethical manner.

2. Information requirements may include:

a. Department policies dealing with (governing) human resource issues;

b. Human resource documents, such as policies, doctrine, laws, benefits, and pay; and

c. Standard Operating Procedures (SOPs), etc.

3.2.3.2.5 Health Hazards (HV-B5)

1. Health Hazards considers the design features and operating characteristics of a UAS that can create significant risks of illness, injury, or death.

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

a. System, material, environmental, or task hazard assessment;

b. Air quality control assessment;

c. Noise/vibration pollution evaluation;

d. Impact force, shock, LASER protection Workplace Hazardous Materials Information System (WHMIS) identification, classification, and evaluation of the materials or chemicals used for tasks;

e. Chemical, Biological, Radiological, and Nuclear (CBRN) protection; and

f. Extremes of temperature, etc.

3.2.3.2.6 Human Characteristics (HV-B6)

1. Human characteristics consider the characteristics of an operator and movement capabilities and limitations of that operator under various operating conditions.

2. 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.

3.2.3.3 Create HV-C: Tasks

1. 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.

2. Information requirements may include:

a. Human-related functions in a UAS;

b. Allocation of functions between humans and technology;

c. Decomposition of functions into tasks;

d. Task descriptions in terms of various criteria and the KSA requirements;

e. Depiction of inter-dependencies between different tasks;

f. The tools required to accomplish a task; and

g. HMI design guidelines on the basis of task requirements.

3.2.3.4 Create HV-D: Roles

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

2. Information requirements may include:

a. Responsibility – accountability and commitment;

b. Permissions – access ability of an individual to perform a specific task;

c. Competencies – the quality of being able to perform; a combination of KSA; and

d. Multiplicity – a role may be performed by a human or by multiple humans at the same time.

3.2.3.5 Create HV-E: Human Network

1. The HV-E captures the human-to-human communication patterns resulting from ad hoc or deliberate team formation, especially teams distributed across space and time.

2. Information requirements may include:

a. Role groupings or teams formed, including the physical proximity of the roles and virtual roles included for specific team tasks;

b. Type of interaction – i.e., collaborate, coordinate, supervise, etc.;

c. Team cohesiveness indicators – i.e., trust, sharing, etc.;

d. Team performance impacts – i.e., synchronization (battle rhythm), level of engagement (command directed); and

e. Team dependencies – i.e., frequency/degree of interaction between roles.

3.2.3.6 Create HV-F: Training

1. The HV-F is a detailed account of how training requirements, strategy, and implementation will impact humans. It provides the instructions and the unit training required to provide personnel with their essential tasks and KSA to meet the job requirements.

2. Information requirements may include:

a. As is training resources, availability, and suitability;

b. Risk imposed by to-be operational and system demands;

c. Cost and maturity of training options for trade-off analysis;

d. Training required to obtain the necessary knowledge, skills, and ability to support career progression; and

e. Differentiation of basic, intermediate, or advanced job training; operational vs. system specific training; and individual vs. team training.

3.2.3.7 Create HV-G: Metrics

1. 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-machine system performance assessments or for requirements tracking and certification.

2. Information requirements may include:

a. Qualitative human factors value definitions;

b. Quantitative human performance metrics (what is to be measured);

c. Target values (what quantifiable value is acceptable);

d. Human task-to-metrics mapping;

e. Value definition links;

f. Value to design element mapping; and

g. Methods of compliance.

3.2.3.8 Create HV-H: Human Dynamics

1. The HV-H captures dynamic aspects of human 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 behavior. It provides inputs to human behavior 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.

2. Information requirements may include:

1) States (e.g., snapshots) and State Changes:

a. Organizational/team structure;

b. Task/Role assignments for people;

c. Team interaction modes;

d. Demands on collaboration load (e.g., need to spend effort in building shared awareness, consensus-finding, and communicating); and

e. Task switches/interruptions.

2) Conditions (e.g., triggering events or situations; scenarios):

a. Critical / frequent / representative / typical scenarios;

b. Operational constraints (e.g., extensive heat stress); and

c. Time conditions: sequence, duration, and concurrency.

3) Performance outcomes (observed or predicted), such as:

a. Workload;

b. Decision speed;

c. Team interaction/collaboration style;

d. Trust in the commander's intent; and

e. Quality of shared awareness/coordination/implicit communication.

3.2.4 Human-Related Requirements

Human-Related Requirements (HRRs) 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 organizational hierarchies in the manning solution.

3) Capability-specific HRRs 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).

3.2.4.1 Identify 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).

3.2.4.2 Identify Human-Related Requirements and Compliance Measures Priorities

1. 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, behavioral 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:

a. The degree to which each particular requirement impacts the UAS design;

b. The complexity of the relevant UAS component(s) or subsystem(s); and

c. The degree of project risk presented by the requirement.

2. 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 evaluation and acceptance of systems. Cost-effective approaches to contract acceptance of HRRs are described in Table 3-1.

Table 3-1. Means of Accepting Compliance with A Requirement

HRR TYPE	DESCRIPTION
Consensus based on Judgment	Formal agreement by stakeholder based on subjective judgment that lower-level requirements and/ or design detail will cause the condition to be met.
Consensus based on Evidence	Formal agreement by stakeholders that evidence presented (from analysis, modeling, experiment, survey, or comparison) 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, and structured trials with tasks performed by representative users, and criteria based on user performance plus subjective user reaction.

3.2.4.3 Conduct Trade-off Analysis

A trade-off is a decision-making action that selects various requirements and alternative solutions based on 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 organization. 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).

3.2.4.4 Incorporate Human-Related Requirements into Contract Specifications

1. 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 UAS design meets the non-testable HRRs.

2. 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 so that a contractor understands what is required and can engage with stakeholders.

3. Acceptance of a delivered UAS is matched against the contract specification, containing 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)

3.3 POST-DEVELOPMENT DECISION HSI ACTIVITIES

1. 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, while 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 the 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.

2. This section provides a decomposition of HSI Activity Planning, including key HSI outputs and products. Figure 3-5 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. Recognizing 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 HMI design, training needs analysis, and safety assessments (UK MoD Through Life Capability Management [TLCM] Handbook, 2010).

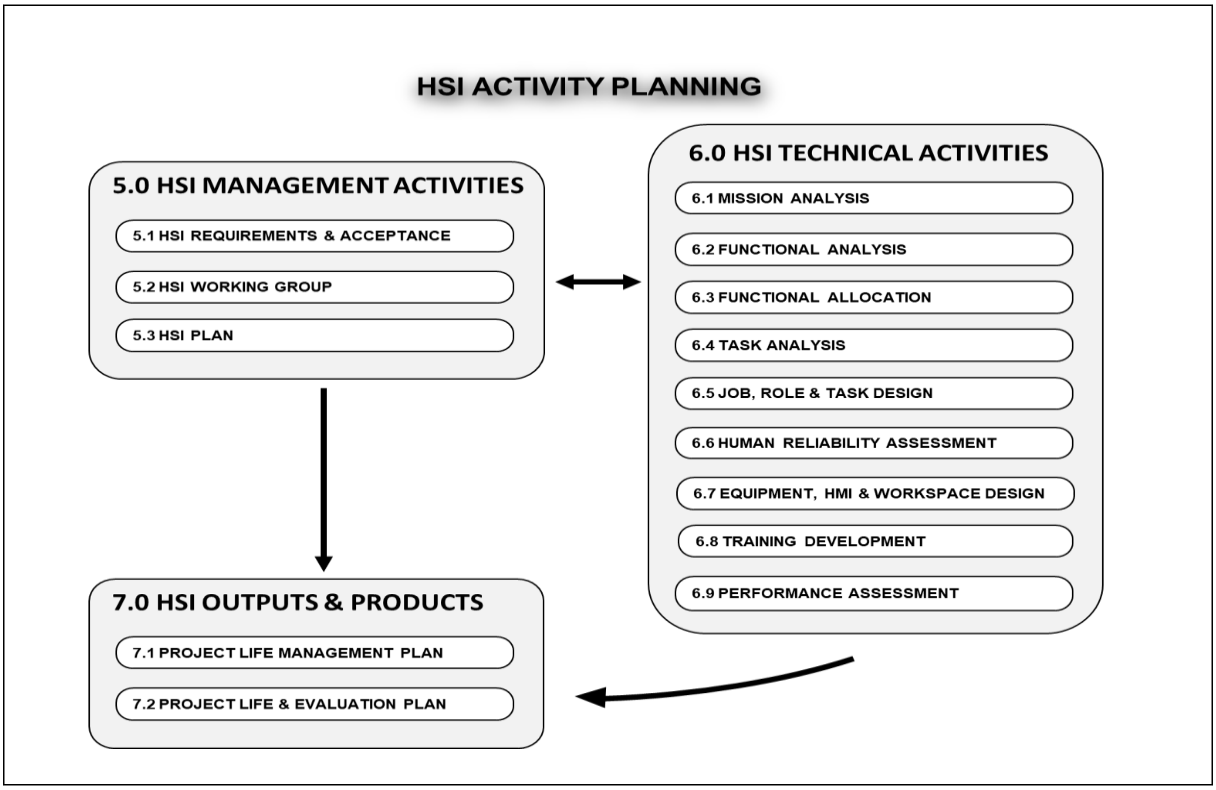

Figure 3-5: Decomposition of Post-development Decision HSI Activities

3.3.1 Management Activities

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

3.3.1.1 HSI Requirements and Acceptance

1. Requirements: most UAS are critically dependent on HRRs, 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 organizational constraints, and measures of effectiveness (UK MoD HFI Process Model, 2007).

2. 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 (Hou et al., 2014). 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 part of the equipment acceptance decision. Process requirements are often used when functional or performance requirements cannot be specified. HSI should contribute requirements at a comparable level of detail to those from other areas (Harrison & Forster, 2003).

3. 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. It may be prudent for information-rich systems to develop the human-machine interface requirements before the main functional requirements through an interactive requirements prototyping exercise with users (Harrison & Forster, 2003).

4. Human Systems Integration Process Requirements. Requirements for conducting HSI have an essential role in defense 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 program. 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 competitors' proposals are comparable. It is also sensible to require contractors to demonstrate how proposed UAS designs have been influenced by HSI considerations (Harrison and Forster, 2003).

3.3.1.2 Acceptance

1. 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.

2. 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.

3. In the early stages, HSI requirements may not be specified in any detail, and the requirement may 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).

3.3.2 HSI Working Group

A HSI Working Group (HSIWG) serves as a forum for the interchange of ideas and information and also helps resolve conflicts between different specialist requirements. This forum is vital 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 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.

3.3.3 Human Systems Integration Plan

1. Because each UAS is unique, individual programs will naturally emphasize some domain areas more than others. Human Systems Integration Plan (HSIP) content will depend upon the particular UAS being developed. Consequently, an organization may tailor the HSIP to their specific circumstance and better satisfy the specific organizational needs. The HSIP is best submitted as an evolutionary and continuous product in conjunction with the UAS engineering plan and system life-cycle management plan (or national equivalent plans); however, the HSIP can also be developed as a stand-alone document.

Type of Information in a HSIP includes:

a. HSI issues;

b. HSI constraints;

c. HSI studies, actions, and mitigation strategies for each significant issue;

d. Organizational chart;

e. Dependencies between organizations and project activities in conducting HSI activities;

f. Key milestones, deliverables, and timescales;

g. Extent of need for user (i.e., operator) participation;

h. Method for including HSI in system-level trade-offs; and

i. Method for monitoring and controlling progress against the plan.

2. The HSIP should support HSI throughout the life-cycle of the UAS, taking into consideration program 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 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).

3.3.4 Technical Activities

1. HSI Technical Activities 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 understand 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.

2. 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. Individual Technical Activities create new information, and typically this information takes the form of questions with respect to requirements, analyzed risks or opportunities. Such questions should be resolved by the reapplication of Technical Activities. Appendix A provides a Cross-Walk matrix and Justification table mapping each Technical Activity with applicable Human Views.

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

3.3.4.1 Mission Analysis

Mission Analysis is important in deciding what the human does. The operational scenario provides information that supports EHFA and enables the 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].

3.3.4.2 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 the 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].

3.3.4.3 Functional Allocation

1. Functional Allocation refers to the task of deciding the distribution of functions between the operator and equipment. Considered one of the most important human-centered design or interaction-centered 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.

2. 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-centered design or interaction-centered design process (ISO 13407:1999; Hou, et al., 2014).

3.3.4.4 Task Analysis

A comprehensive view and clear understanding of the users' typical tasks and cognitive processes are fundamental to most aspects of HSI and feed 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 (Hou, et al., 2015; 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].

3.3.4.5 Job, Role, and Task Design

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 and allocated, and how individuals will relate to each other so that their work can be coordinated. This ensures that tasks and roles assigned 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].

3.3.4.6 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].

3.3.4.7 Equipment, HMI, and Workspace Design

This is concerned with operational equipment design, 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., pre-existing – equipment. The design of workspaces should be concerned with meeting the functional needs of the system and personnel whilst minimizing 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].

3.3.4.8 Training Development

Training Needs Analysis assesses training requirements arising from new equipment procurement, doctrinal change, organizational change, or changes to the 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].

3.3.4.9 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 the '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].

3.3.5 HSI Outputs and Products

To ensure HSI aspects are fully considered as part of broader UAS project management and technical development, it is essential 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.

3.3.5.1 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:

a. HSI Management Plan and Strategy;

b. Key HSI decisions;

c. HSIWG constitution and responsibilities;

d. Division of responsibility for HSI activities;

e. HSI testing and evaluation plans and results;

f. Procedures for managing/sharing HSI data;

g. HSI audit results following introduction to service;

h. HSI management strategy for upgrades; and

i. HSI risks, issues, assumptions, and constraints.

3.3.5.2 Project Test and Evaluation Plan

A Project Test and Evaluation Plan defines how the project will ensure that the required UAS is 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 stand-alone section. It should include the following:

a. HSI Management Plan;

b. HSI acceptance processes and procedures (including specifying appropriate military/ user participants for trials);

c. HSI Testing and Evaluation Plan results; and

d. Outputs from HSIWG meetings.

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CHAPTER 4 CONCLUSION

1. Human Systems Integration (HSI) is a robust process, integral to systems engineering, to design and develop UASs that effectively and affordably address human capabilities and limitations. Its major value is the integration of five individual domains consisting of Manpower and Personnel, Training, Human Factors Engineering, Safety and Health, and Organizational and Social Characteristics. HSI integrates and facilitates the trade-offs among these five domains as well as between the domains. HSI also integrates and facilitates other performance requirements without replacing individual domain activities.

2. HSI must be applied during the 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 primary mission equipment but also the people who operate, maintain and support the system; the training and training devices; and the operational and support infrastructure.

3. 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.

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ANNEX A. JUSTIFICATION OF TECHNICAL ACTIVITY AND HUMAN VIEW CROSS-WALK MAPPING

This section elaborates on the various components that impact the machine and the human interaction. The tables illustrated below explain related concepts, analysis and their interrelationships.

TABLE A-1. TECHNICAL ACTIVITY AND HUMAN VIEW CROSS-WALK

HUMAN VIEW	Performance Analysis	Training Development	Equipment, HMI & Workspace Design	Human Reliability Assessment	Job, Role & Task Design	Task Analysis	Functional Allocation	Functional Analysis	Mission Analysis
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 concerning 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 requirement, 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.	✓	✓	✓						✓
HV-H Human Dynamics - Captures dynamic aspects of human system components. These are dynamic in th esense that states, conditions, or performance parameters may change over time, or as a result of triggering events.	✓		✓	✓					

1. 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.

TABLE A-2. JUSTIFICATION OF MAPPING FOR MISSION ANALYSIS

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 concerning 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**.

2. 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).

TABLE A-3. FUNCTIONAL ANALYSIS

HUMAN VIEW	JUSTIFICATION
HV-A Concept	A high-level representation of the human component of the enterprises architecture framework. **Its purpose is to visualize and facilitate understanding of the human dimension concerning 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.

3. FUNCTIONAL ALLOCATION

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

TABLE A-4. FUNCTIONAL ALLOCATION

HUMAN VIEW	JUSTIFICATION
HV-C Tasks	Describes the human activities 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.

4. 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.

TABLE A-5. TASK ANALYSIS

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 concerning 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.
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.

5. JOB, ROLE, AND TASK DESIGN

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.

TABLE A-6. JOB, ROLE, and TASK DESIGN

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 concerning 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.

6. 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.

TABLE A-7. HUMAN RELIABILITY ASSESSMENT

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 concerning 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**.

7. EQUIPMENT, HMI, AND WORKSPACE DESIGN

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 minimizing stress and maintaining an optimal level of performance.

TABLE A-8. EQUIPMENT, HMI, and WORKSPACE DESIGN

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.

8. TRAINING DEVELOPMENT

Training Needs Analysis needs to conduct first to identify the competencies, including KSAs that users require to perform their jobs. It assesses training requirements and strategies arising as a result of new equipment procurement, doctrinal change, organizational change, or changes to the policy. It generally includes a comparison of different training methods and equipment to recommend the optimum training system. Then training contents and delivery methods can be developed.

TABLE A-9. TRAINING DEVELOPMENT

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 map measurable metrics to human performance specifications**.

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. 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.

TABLE A-10. PERFORMANCE ANALYSIS

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 concerning 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 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.

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