Defence Research and Development Canada
Unmanned Aircraft Systems (UAS)
Human Systems Integration Support

UAS GCS HUMAN SYSTEMS INTEGRATION (HSI) GUIDANCE AND HUMAN FACTORS (HF) AIRWORTHINESS CONSIDERATIONS

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PWGSC Contract Number: W7711-088136/001/TOR

Contract Scientific Authority: Dr. Ming Hou, DRDC Toronto, 416-635-2063

Contract Report
DRDC-RDDC-2014-C212
July 2014

UNMANNED AIRCRAFT SYSTEM (UAS), GROUND CONTROL STATION (GCS)
HUMAN SYSTEMS INTEGRATION (HSI) GUIDANCE
AND
HUMAN FACTORS AIRWORTHINESS CONSIDERATIONS

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REVISION HISTORY

REVISION LETTER	DA NO.	PAGES AFFECTED	DATE
-	DA #	Initial Release Originator: A. Stewart	31 March, 2014

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1. PROJECT BACKGROUND

The Royal Canadian Air Force (RCAF) has established a Project Management Office (PMO) [Joint Unmanned Surveillance and Target Acquisition System (JUSTAS)] to define the requirements to procure a new Unmanned Aircraft System (UAS). Generally speaking, the UAS is comprised of an Air Vehicle, Ground Control Station (GCS), and the associated functionalities and communication links between the two.

Integral to the procurement of any new system, including a Military or Commercial Off-The-Shelf (MOTS/ COTS) system, consideration should be given to establishing a Human Systems Integration (HSI) program. The Off-The-Shelf nature of a MOTS/COTS procurement does not negate the requirement for an HSI program, rather an effective HSI program is even more important. It has been well established, and documented that, as a MOTS/ COTS acquisition does not permit the same level of influence over system design, more consideration needs to be given to how the chosen solution will affect the deployment concept; including the impact on human performance, safety, training requirements, organizational structure, and career progression (Greenley, 2008).

To support the effort identified above, the Director Technical Aerospace Engineering Support (DTAES) 6-7, with the support of Defence Research and Development Canada (DRDC) Toronto, requested the development of an HSI Guidance Document as part of the Statement of Work (SOW), under contract W7711-088136/001/TOR, 16 May 2013, UAS System Analysis and Human Systems Integration Guidance.

Subsequent to the issuance of the SOW, at the Initial Meeting (15 August, 2013), a clarification of the work activities was discussed. The results of the discussion are captured in the Record of Decisions (Document Number 1000-1593-1). In summary, discussions held during the meeting resulted in a reduced emphasis on HSI Guidance, and more prominence placed on establishing a Basis of Certification for the UAS Ground Control Station, focusing solely on the Human Factors requirements, in direct support of DTAES 6.

The impetus for this change in focus was directly influenced by the Department of National Defence`s (DND) Air Force (AF) 9000 process, requiring any procurement or modification project to establish a Technical Airworthiness Program and subsequently, as per the Technical Airworthiness Manual (TAM) and the Airworthiness Design Standards Manual (ADSM), establish a Basis of Certification (BoC) to which compliance may be shown prior to the Technical Airworthiness Authority (TAA) issuing a Technical Airworthiness Clearance (TAC), which is required prior to receiving the DND Type Certificate (TC).

2. HUMAN SYSTEMS INTEGRATION GUIDANCE

All cited references are included in the following section, and as such, Section 2.1 should be considered the master reference list for this document.

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2.2 Aim

The background material on the advent of HSI into a holistic, system-of-systems, sociotechnical approach to address all facets of human performance in the system lifecycle, and the associated impacts that must be considered in the advancement of complex technology-based capabilities, has been addressed by several authors (e.g., Beevis, 1999; Naislin, 1983).

For the purpose of this guidance material we will take at face value the etiology of HSI as a discipline, and the importance and interrelationships of its component sub-disciplines. In addition, the cost-benefit justification of HSI has also been well documented in the following references and as such this document will also take at face value the cost-benefit of performing an HSI program for developmental programs as well as MOTS/ COTS procurement programs (e.g., Burgess-Limerick (2010), Greenley (2008)).

The goal of this HSI guidance will be to provide a high level overview of:

- The Canadian perspective on HSI;
- HSI Definition
- Each Canadian HSI domain;
- The Canadian HSI Process;
- HSI guidance for MOPTS acquisition; and
- ”Lessons learned” with respect to HSI and Unmanned Aircraft Systems (UAS) from existing literature.

2.3 Canadian HSI Perspective

As Canada was becoming increasingly aware of the value of employing HSI programs during military procurement, for both developmental and off-the-shelf programs, a number of unique Canadian requirements were identified that were not necessarily addressed by the existing HSI constructs. As such Canada sought to establish and validate a HSI Program for the Canadian Department of National Defence (DND).

This realization led to a multi-year program to develop, demonstrate and validate an HSI approach for DND. The final report (Greenley, 2008) for this program outlines the position, as of 2008, of HSI within the DND. The report documents the evolution of the Canadian HSI program and details a HSI cost-benefit analysis justifying the implementation of this HSI Program within DND. In addition the report presents several case studies that provide further evidence supporting the value of HSI. This seminal body of work and the associated HSI Program have remained intact since it was completed.

This work effort (Greenley, 2008) established for DND, an applicable definition of HSI and its sub-disciplines to best suit the Canadian Defence community. The recommendations contained in the Canadian HSI Program were based on a review of HSI work completed by the North Atlantic Treaty Organization (NATO), United States military (Air Force HSI, Army Manpower and Personnel Integration (MANPRINT), and Navy Manning Affordability and HSI), and the Human Factors Integration program developed by the United Kingdom. The review of HSI programs was considered in conjunction with an assessment of the historical approaches applied to Canadian Defence programs, as well as the Defence Management System (DMS) itself.

Further to establishing a suitable definition of HSI and identifying appropriate sub-disciplines, the work completed by Greenley et al.(2008) established the core elements of an HSI program, technically integrating the HSI domains and formulating a recipe for integrating the technical activities with linked systems and capability engineering activities. The proposed HSI program was initiated by conducting a review of the established processes in the areas of Human Factors Engineering (MIL-HDBK-46855A), Training (Canadian Forces Individual Training and Education System (CFITES) in DND), Safety (MIL-STD-882D), and common processes used by DND personnel in the area of Personnel Analysis (within ADM[HR]) and Health Hazard Assessments (HHA) (in multiple areas across DND).

The HSI program went through several iterations based on feedback by the DND community, resulting in a methodology that was specifically targeted at the acquisition process (Defence Management System), while integrating with the Defence Materiel Acquisition and Support processes within ADM(Mat), and to link the HSI process with processes currently defined on the Acquisition Desktop (a web-based repository for the DND Materiel Acquisition community).

2.4 HSI Definition

With the goal of incorporating human performance considerations in the Materiel Acquisition and Support cycle, and contributing to effective systems operability, safety, reliability, maintainability, availability and survivability, Greenley et al.(2008), among others, defined HSI as:

> *The technical process of integrating the five HSI domains, Human Factors Engineering, Manpower and Personnel, Training, System Safety, and Health Hazards with a materiel system (the materiel lifecycle) to ensure safe, effective operability and supportability.*

The definition provided recognizes HSI as a multidisciplinary field of study which establishes human considerations as priority in systems design/acquisition. It is a systematic process of identifying, tracking and resolving human-related issues ensuring a balanced development of both technologies and human aspects of complex systems. Incorporating an HSI program during the Defence Materiel Acquisition process ensures human performance considerations are satisfactorily accounted for and can be better addressed early during the Acquisition Life Cycle process.

Furthermore, through an understanding of the human performance considerations (e.g., Human Factors issues, manpower requirements, required knowledge skills and abilities, and training implications), Materiel Acquisition can better identify, and obtain, the system with the best possible envisioned performance (equipment, human, and operational) while minimizing the system's life cycle costs (costs saved and costs avoided).

2.5 HSI Domains

The Canadian instantiation of HSI is defined by the contribution of five interrelated people oriented disciplines; Human Factors Engineering, Manpower/Personnel, Training, System Safety, and Health Hazards. A successful HSI program ensures that human considerations are properly accounted for in system engineering processes that encompass system design, development, operations and disposal. The following sections provide brief descriptions of each of the five Canadian HSI domains.

2.5.1 Human Factors Engineering

Human Factors Engineering is concerned with the integration of human characteristics into system definition, design, development, and evaluation to optimize human-machine performance under operational conditions.

This contribution of human characteristics, the capabilities and limitations of the potential user population, into the design lifecycle is typically accomplished by establishing a detailed repository of task information (physical and cognitive) and integrating it into system definition, design, development, and evaluation to ensure the system is optimized for human performance.

For descriptions of Human Factors methodologies see:

- NATO STANAG 3994, Application of Human Engineering to Advanced Aircrew Systems, Edition 3, 2007;
- MIL-STD-46855A, Human Engineering Requirements for Military Systems, Equipment, and Facilities, 24 May 2011; and
- Wilson, J., and Corlett, N. (2005), Evaluation of Human Work, 3rd Edition. Taylor and Francis Gourp, LLC.

The appropriate Human Factors methodologies and level of analysis required are typically dictated by specific project considerations and constraints. As such, tailoring of the work effort associated with a Human Factors program is appropriate, and often, essential. Appendix A of MIL-STD-46855A contains details associated with tailoring the human factors work effort. In summary, this appendix suggests that the military standard not be considered for use in contracts for parts, subassemblies, or units, but should be considered for use in contracts for sets, subsystems and systems, and for facilities. The tailoring guidance contained in Appendix A of MIL-STD-46855A can be applied equally well as guidance for the tailoring of the work effort detailed in NATO STANAG 3994.

A detailed description of the conceptual phase work activities associated with the Human Factors Engineering domain, with regard to procurement of a Long Endurance UAS, may be found in:

- UAV Operator System and Task Analysis Human Engineering Program Plan, CMC Document Number 1000-1562, dated 18 March 2013, and
- UAV Operator Information Flow and Cognitive Task Analysis Human Engineering Program Plan, CMC Document Number 1000-1564, dated 25 March 2013.

2.5.2 Manpower and Personnel

The Manpower and Personnel domain focuses on the personal characteristics (cognitive and physical capabilities) of the people required, versus those available (operating strength and location), to operate, maintain, and sustain complex systems; considering the context of peacetime, conflict, low intensity operations, and future employment requirements. The Manpower and Personnel domain is also concerned with identifying the characteristics required to train, and train for the employment of these materiel and information systems.

The primary sub-areas of Manpower and Personnel include:

- Force Structure;
- Availability;
- Phasing;
- Manpower Workload;
- Physical Personnel Factors;
- Cognitive Personnel Factors;
- Recruitment, Retention and Advancement;
- Cultural and Social Factors;
- Previous Experience and Training; and
- Human-Human Interaction.

2.5.3 Training

The Training domain is primarily focused on the requirements for the instruction, or education (academic or on-the-job) required to provide personnel with their essential job skills, knowledge, values and attitudes, required to maintain the required MOSID and QL levels required as per the Manpower and Personnel requirements. The Training domain is also concerned with requirements for, and the constraints regarding such training.

Training is required to bridge the gap between the target audience's existing level of knowledge and that required to effectively operate, deploy/employ, maintain and support the system. The primary sub-areas of training include:

- legacy transfer;
- type of training;
- availability of training; and
- frequency of training.

Training is particularly crucial in the acquisition and employment of a new system. New tasks may be introduced into a duty position; current processes may be significantly changed; existing job responsibilities may be redefined, shifted, or eliminated; and/or entirely new positions may be required. It is vital to consider the total training impact of the system on both the individuals and the organization as a whole. Clearly, the cost and considerations of system ownership include initial and sustainment training, that is both unit and institutional.

In the context of the Canadian military, the Chief of Military Personnel (CMP) and Human Resources Civilian (HR-Civ) own all training information for the enlisted and civilian portion of DND respectively. These groups are assisted by individual career managers and occupational advisors.

In accordance with the CFITES, a Training Needs Analysis (TNA) shall be conducted in the final stages of producing a Job Based Occupation Specification (JBOS). The JBOS contains a list of tasks expected of an operator within a given occupation. If new tasks are expected for an occupation, it is necessary to assess and recommend when occupational training should be given and how a JBOS should be segmented to facilitate its analysis by one or more Qualification Standards Board (QSB). The Occupational Specification Validation Board (OSVB) will typically perform this activity.

While conducting a TNA may not be the responsibility of project staff, they must provide information of sufficient detail, in the form of a needs assessment, to trigger the OSVB process. It may be sufficient to focus on providing a description of the training requirements beyond those expected of the MOSID, rank, and QL, for each position, as MOSID, rank, and QL provide the legal description of the training required to perform associated tasks.

A detailed description of the work activities associated with the Training domain, with regard to procurement of a Long Endurance UAS, may be found in:

- UAV Operator Training Needs Analysis Human Engineering Program Plan, CMC Document Number 1000-1565, dated 15 March 2013.

2.5.4 System Safety

The System Safety domain is primarily charged with identifying safety risks occurring throughout the full system's lifecycle (e.g., packaging, transport, set-up, use, maintenance, dismantling). As a discipline, System Safety Engineering employs specialized knowledge and skills in applying scientific and engineering principles, criteria, and techniques to identify hazards and then to eliminate the hazards or reduce the associated risks when the hazards cannot be eliminated.

It is within the scope of the Systems Safety domain to examine a system's design features and/or its operating characteristics to minimize the potential for human or machine failures that cause injurious accidents. The requirements associated with system safety are extremely specific with the inputs required from safety experts. MIL-STD-882E provides a list of proposed System Safety tasks:

- System Safety Program Plan;
- Hazard Management Plan;
- Hazardous Materials Management Plan;
- Preliminary Hazard List;
- Preliminary Hazard Analysis;
- Functional Hazard Analysis;
- Preliminary System Safety Assessment;
- Operating and Support Hazard Analysis;
- Health Hazard Analysis;
- Health Hazard Assessment;

- Personnel Impact Assessment Report;
- System Safety Case;
- System Hazard Analysis;
- Safety Compliance Assessment Report;
- Hazard Management Assessment Report; and
- Explosives Hazard Classification Data.

2.5.5 Health Hazards

The Health Hazards domain aims to identify short, and long term hazards to health, occurring as a result of normal operation of the system. Health Hazards also seeks to mitigate exposure by identifying the requirements for protective clothing and/or equipment.

The goal of a Health Hazard Assessment is to incorporate biomedical knowledge and principles early in the design of a system to eliminate or mitigate potential exposure to health hazards. Health hazards may include acoustic energy, biological substances, chemical substances, oxygen deficiency, radiation energy, shock, temperature extremes, humidity, trauma, vibration, and other hazards. Health hazards include those areas that could cause death, injury, illness, disability or a reduction in job performance.

The primary sub-areas of Health Hazards include:

- Noise and vibration;
- Hazardous substances (contact, inhalants, etc.);
- Electrical equipment;
- Mechanical equipment;
- Nuclear, biological, or chemical hazards;
- Musculoskeletal hazards;
- Heat or cold stress;
- Optical hazards; and
- Electromagnetic sources.

In the context of military acquisition, most new systems are comprised of some baseline of existing technology already in use by the intended user community; as such it may be acceptable to focus Health Hazard efforts on innovative or significantly updated systems. This does not, however, suggest the risks associated with existing technologies should be overlooked. It is just that such risks are comparatively better understood and likely do not require further Health Hazards Assessment.

The authority within DND for Health Hazards and Workplace Safety is the Director of General Safety (D Safe G). Two D Safe G documents, the General Safety Program (Ref. 3) and the DND/CF Hazardous Occurrence Investigator’s Guide (Ref. 1), should be considered as primary reference materials.

2.6 HSI Process

2.6.1 Integration of HSI with the Defence Acquisition Process

Within the Acquisition Phase of the Canadian Defence Acquisition Process there are four parts: Identification, Options Analysis, Definition and Implementation. These parts of the process can be linked to the five domains of HSI as shown graphically in Figure 1 (drawn from Greenley et al.(2008). It illustrates the concept, which involves the conduct of activities within the standard processes of each domain (horizontal axis of the matrix) at the different phases of the defence acquisition life cycle (vertical axis of the matrix). This results in a number of shared analyses or variables of common interest. It is recognized that there are opportunities across these areas for the linkage of activities, tools, and techniques within an HSI approach that improves the quality of analyses, while also saving time and effort.

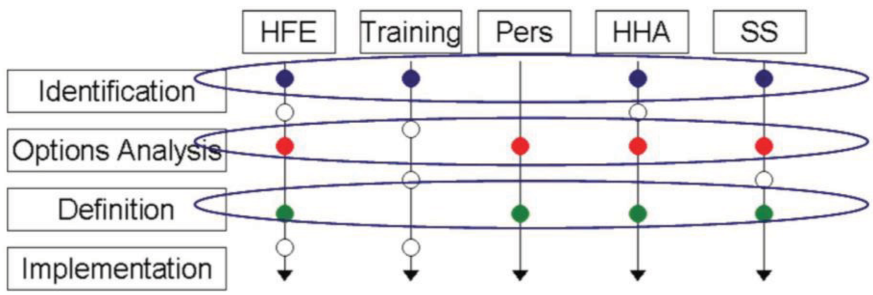

Figure 1: Integration of HSI Domains throughout the Defence Acquisition Process

2.6.2 Canadian HSI Process

Through the application of case studies, Greenley et al.(2008), was able to refine early concepts of the proposed HSI process. Through this effort, and coordination with the Directorate of Materiel Acquisition and Support Program Office, the work culminated in a final version (Version 3) that best represents an attempt to integrate HSI into the MA&S process within the ADM(Mat) Materiel Acquisition and Support community. Version 3 of the HSI process is depicted in Figure 2 below; for a detailed explanation of the process refer to Annex F of Greenley et al.(2008).

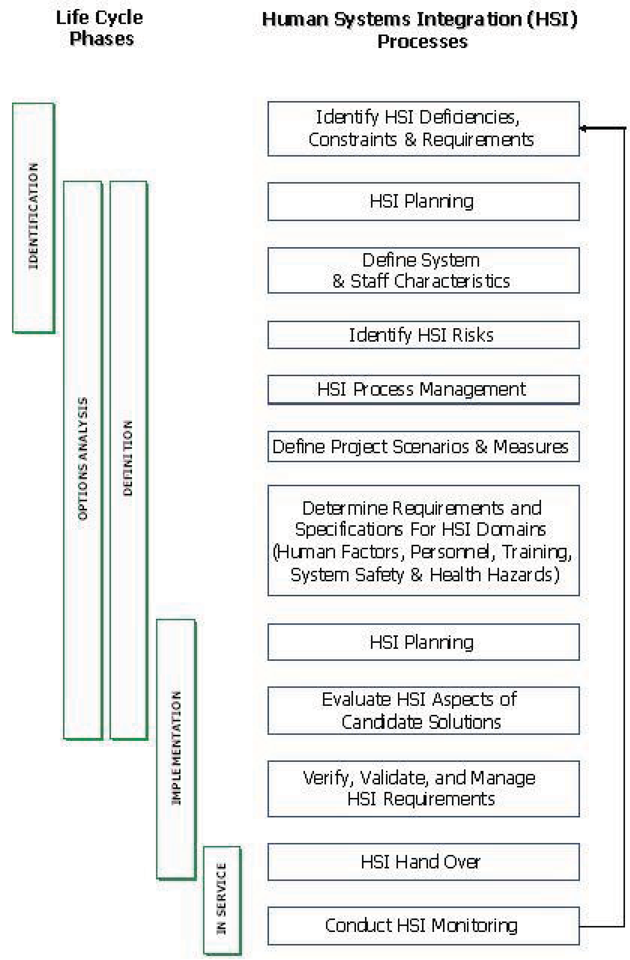

Figure 2: Project Life Cycle and HSI Process Elements

2.7 HSI Guidance for MOTS Acquisition

Increasingly, there appears to be a desire for defence acquisition programs to acquire COTS/ MOTS products, presumably under the notion that the product design is complete and fielding the article will be faster than a developmental program with detailed technical requirements. This assumption, while intuitively valid, does not reduce the need for a comprehensive HSI program. Rather the contrary has been shown to be true.

The concept of COTS/ MOTS procurements, evaluating products, or technical and performance-based specifications, to identify and select a “fits best” solution, may streamline the acquisition process, however, DND is still left with the task of integrating the product into the Canadian Forces operational context, doctrine, procedures, staffing, and training. The HSI construct has been iterated and implemented to address just such issues.

Greenley et al.(2008) provided several key conclusions in this regard based on their use case work. Some of their key conclusions are repeated below:

- The HSI process needs to be followed by both government and industrial participants in a MOTS acquisition;
- The difference between a MOTS procurement, and a Developmental procurement, is that the industrial team does not develop the design during the implementation phase

as the product already exists. As a result, HSI considerations cannot “drive” the design during Implementation;

- The remainder of the HSI analyses required to answer the core HSI question regarding safe and effective use of the future system apply equally to either a MOTS or a Developmental acquisition project. The government acquisition team still needs to determine which MOTS solution will fit best into the doctrinal, organizational, and procedural environment, and what the impact of the chosen MOTS solution will be on doctrine, organizational structure, staffing, procedures, human performance and safety.
- In many cases an effective HSI Program is even more important on a MOTS acquisition, since a MOTS acquisition does not permit the Government to influence the design of the system. Therefore, the Government can only influence the deployment concept which includes the full consideration of the impact of the chosen solution on human performance, safety, skill levels, training requirements, organizational structure and roles, and the impact on the career progression of personnel. Properly managing these impacts becomes a focus for DND on a MOTS acquisition, and therefore the role of HSI is elevated on these programs.

2.8 HSI - UAS Lessons Learned; A Brief Literature Review

In order to provide DND with information that is topical to HSI efforts relating to the fielding of Canada’s next Long Endurance UAS, a review was made of available literature to locate related Lessons Learned. The documents and associated Lessons Learned are listed in APPENDIX B.

3. BASIS OF CERTIFICATION – UAS GCS

The goal of this portion of the work package was to establish a baseline set of airworthiness requirements for which DTAES 6-7 specialists may request participation in providing recommendations regarding the Human Factors aspects of UAV GCS airworthiness certification. Also, this work was extended to identify appliance level Human Factors requirements that could help define Human Factors definitions or evaluations requirements of air vehicle level requirements.

The first step in this process was to identify the most appropriate source of UAS certification requirements directly applicable to the envisioned JUSTAS platform. Through a review of envisioned platform characteristics, and relevant certification sources, it was identified that NATO STANAG 4671, Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR) was the most applicable source of certification requirements. The USAR contains a set of technical airworthiness requirements intended primarily for the airworthiness certification of fixed-wing military UAV Systems with a maximum take-off weight between 150 and 20,000 kg that intend to regularly operate in non-segregated airspace. The intention of this document is to correspond as closely as practicable to a comparable minimum level of airworthiness for fixed-wing aircraft as embodied in documents such as 14 CFR Part 23 and EASA CS-23 (from which it is derived) whilst recognising that there are certain unique features of UAV Systems that require particular additional requirements or subparts.

It should be noted that the USAR acknowledges that the requirements contained therein may not be sufficient for the certification of UAV Systems with unconventional, novel or extremely complex features. Additionally, the USAR may be insufficient for UAV Systems with a design usage spectrum significantly different from that of General Aviation. It should also be noted that UAV Systems (including block upgrades to legacy systems) designed prior to the approval of the USAR document may not comply with these requirements.

The following areas are not covered by the USAR (see USAR page 3):

- Control station security;
- Security of the command and control data link from willful interference;
- Airspace integration and segregation of aircraft (including “sense and avoid”);
- The competence, training and licensing of UAV system crew, maintenance and other staff;
- Approval of operating, maintenance and design organizations;
- The type of operation;
- Vehicle Management and Navigation requirements;
- Frequency spectrum allocation;
- Noise, emission, and other environmental certification;
- Launch/landing equipment that is not safety critical and which does not form part of the Type;
- Certification Basis;
- Operation of the payload (other than its potential to hazard the aircraft);

- Carriage and release of weapons, pyrotechnics and other functioning or non-functioning stores designed for release during normal operations;
- Non-deterministic flight, in the sense that UAV flight profiles are not pre-determined or UAV;
- Actions are not predictable to the UAV crew;
- Sea-basing;
- Piloting from an external or internal control box; and
- Supersonic flight.

The USAR states that it expects that the areas identified above will be subject to other forms of approval by a Certifying Authority in order to ensure a total aviation safety approach.

3.1 NATO STANAG 4671 USAR – Human Factors Requirements

In effort to support DTAES 6-7, a thorough review of STANAG 4671 USAR was undertaken to identify requirements that had a Human Factors implication. Once identified, a subsequent review was undertaken to identify those requirements where a Human Factors Specialist (DTAES 6-7) would most likely need to participate in the certification finding, versus where Human Factors input may only be required to assist another specialty make a finding of compliance. This effort provides a comprehensive set of USAR requirements with a Human Factors implication. The identified Human Factors subset of USAR requirements is further classified into: a baseline set of Human Factors requirements for DTAES 6-7 to use as a starting point in establishing their level of participation in certification efforts, and a baseline set of requirements where Human Factors input could be of assistance to other certification specialties.

The baseline set of Human Factors requirements, constituting the Human Factors Basis of Certification for UAS GCS, are identified at APPENDIX C. In addition, a categorization of the Human Factors area of concern (usability; advisory, caution, and warning; situation awareness; reach, vision, and clearance; workload; intended function; and environmental assessment) is also provided.

The requirements that have been identified as having a Human Factors implication, but that may not require DTAES 6-7 certification input, are identified at APPENDIX D.

3.2 Technical Standard Order

In order to inform some of the potential aspects of the Human Factors areas of concern identified in the Human Factors Basis of Certification, a review of potentially applicable Technical Standard Order (TSO) documents was performed. A TSO may contain appliance level requirements itself, or it may evoke another document that contains a set of Minimum Operational Performance Specifications (MOPS).

In similar fashion to the USAR review, effort was taken to identify Human Factors requirements, either in the TSO itself, or in the MOPS, that can serve as a baseline set of requirements that may help inform the scope of Human Factors analysis required to show compliance to the USAR.

As the MOPS are copy right protected, only the paragraph number identifying Human Factors requirements are provided. However, a derived set of Human Factors analysis is provided.

The derived set of Human Factors analysis are identified at APPENDIX D.

4. HUMAN FACTORS GUIDANCE

During the conduct of the work, discussions were held where it was expressed that specific Human Factors guidance would be of assistance to DTAES 6-7. The intent of the following sections is to provide guidance, based on the contractor's Human Factors expertise, regarding Human Factors considerations for anthropometry, room layout, and Human Views. Specific methodologies are not discussed.

4.1 Anthropometry

4.1.1 Anthropometric Data Sources

As Human Factors practitioners are aware, selecting the appropriate anthropometric survey is important to ensure the best accommodation of a specific population, as human variability can be observed depending on the age, sex, ethnicity, and occupation of the source population. In addition, if possible, recent data should be given preference if applicable as we know populations change over time due to secular trend.

Anthropometric data applicable to the Canadian Forces can be found in:

- 1998 Anthropometric Survey of the Land Forces;
- 1988 Anthropometric Survey of U.S. Army Personnel (NATICK TR-89/044);
- 1988 Anthropometric Survey of U.S. Army Personnel (NATICK TR-91/040) (Army Pilots); and
- 1985 Anthropometric Survey of Canadian Forces Aircrew.

Due to secular trend implications, it could be suggested that the 1998 Anthropometric Survey of the Land Forces may be the most appropriate, currently available, anthropometric data applicable to Canadian Forces population. However, it should be noted that there is currently an anthropometric survey being conducted to gather anthropometric data on 2200+ Canadian Forces personnel. When complete, the 2012 Canadian Forces Anthropometric Survey (CFAS) should be considered to replace the 1985 Anthropometric Survey of Canadian Forces Aircrew and 1998 Anthropometric Survey of the Land Forces with an updated set of un-encumbered body dimensions as well as state-of-the-art 3D models able to contribute to continued studies of encumbered (clothed) anthropometry.

4.1.2 Use of Anthropometric Data

The first step in using anthropometric data effectively in design is to fully appreciate and understand the design problem and design constraints. This understanding will help determine the relevant body characteristics integral to accommodate the user population.

Given that design problems are usually multivariate in nature, and given that anthropometric measurements typically have weak correlation between each other, selecting the appropriate anthropometric dimensions to incorporate will have perhaps the most significant impact on the success of the design.

4.1.3 Special Considerations when applying Anthropometric Data

Anthropometric measurements are usually collected as semi-nude measures. This has implications if the measurements are used without taking into account clothing and protective equipment (e.g., work boots, helmet, gloves, night vision goggles, winter clothing). Every attempt should be made to identify the impact of clothing and ancillary equipment on the anthropometric measurements prior to design. For example, standing height may need to be adjusted to account for both work boot sole thickness and depth of protective headgear.

4.1.4 Selecting the appropriate type of measurement

Anthropometric measurements generally fall into two categories; structural and functional. Structural measures are taken with the body in a standard and still position (Figure 3), while functional measures are taken when the body adopts working postures (Figure 4). Selecting the appropriate type of anthropometric measurement will need to be determined on a case by case basis given the nature of the design problem.

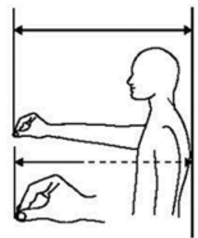

Figure 3: Structural Anthropometric Measurement

Figure 4: Functional Anthropometric Measurement

4.1.5 Selecting the appropriate anthropometric measurements

Zehner, in his paper Prediction of Anthropometric Accommodation in Aircraft Cockpits (2001), proposed 6 critical anthropometric dimensions that should be incorporated into any evaluation of cockpit accommodation (Sitting Height, Eye Height Sitting, Acromion Height Sitting, Arm Span, Buttock-Knee Length, and Knee Height Sitting). These measures were originally selected based on an in-depth understanding of the design problem; considering the person(s), the task(s), and the environment. The 6 critical dimensions directly reflect measurements that assess specific aspects of the operational environment and, in combination, provide a means to assess the population's ability to perform the functions required in the given operational context. It should be noted that these measures are appropriate for cockpit accommodation of the given context Zehner was considering. As his paper suggests, other dimensions may also be important to consider given the specifics of a particular design problem.

While this paper is widely referenced, it is important that the Human Factors practitioner have a good understanding of the design problem (person, task, environment) before selecting critical anthropometric dimensions for their specific context. An example is provided below that identifies critical anthropometric dimensions for a notional seated workstation (shared office environment).

4.1.6 Example: Anthropometric Data and Workstation Design

Consider a seated workstation; the following could be considered critical anthropometric dimensions for each aspect of the design problem:

- Eye height sitting – impacts view over height and display layout;
- Elbow rest height (above seat pan) – impacts work surface height and control placement;
- Thumb tip reach – impacts control placement;
- Popliteal height – impacts seat adjustability;
- Thigh clearance – impacts clearance under work surface;
- Buttock-knee length – impacts clearance required under work surface;
- Buttock-popliteal length – impacts seat pan depth; and
- Functional leg length – impacts clearance required under workstation.

In practice, these measures need to be applied in conjunction with an understanding of the design problem to ensure anthropometric accommodations can be met.

- Design eye position.
  - Design eye position = seat height + eye height sitting
- Work surface (at elbow height)
  - Work surface = seat height + elbow height sitting
- Thigh clearance
  - Thigh clearance = seat height + thigh clearance + clothing and equipment
- Reach to controls
  - Reach to controls = thumb tip reach (from chair backrest)
- Knee/foot room
  - Knee room = buttock-popliteal length (from chair backrest)
  - Foot Room = functional leg length (from chair backrest)

4.2 Room Layout Considerations – GCS

4.2.1 Purpose

The purpose of the room layout process is to provide scientific rigor to the generation of a layout design that allows the operators within the space, in combination with the installed systems and equipment, to safely and efficiently perform all of the functions required in the space. Key considerations for optimization through this process include:

- Communications, both inter-personnel and personnel-equipment;
- Accessibility, including ingress, egress, traffic flow, maintenance, and all related anthropometric considerations;
- Safety, regarding both injury prevention and personnel comfort; and
- Security, including control of access to the space and control of access to information within the space.

Optimization of individual workstation design is generally considered separately from the room layout process (i.e., the workstation designs are an input to the process), but the design of the workstation(s) does have an impact on the room layout so it is beneficial for the two design problems to be considered in parallel.

4.2.2 Process

From McKay et.al. 2013, we learn effective room layout design process will generally be similar to the process described in ISO 11064. This process can be tailored as required for the particular domain or space being considered; see Figure 5 for an example of a tailored process map.

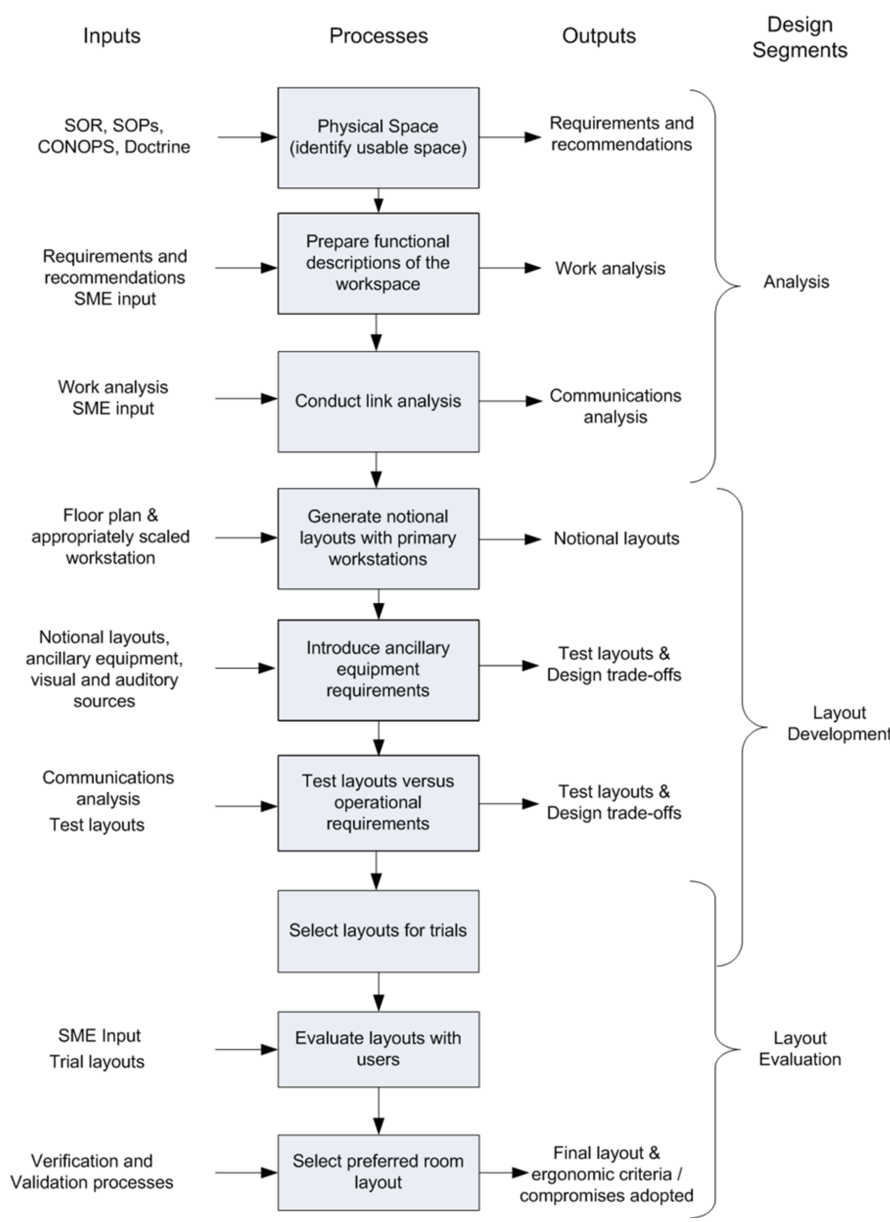

Figure 5: Tailored ISO 11064 Room Layout Design Process

It should be noted that this process is intended to be iterative, as shown in

Figure 6; this allows for appropriate consideration of any effects resulting from new or updated information uncovered during the later stages of the process.

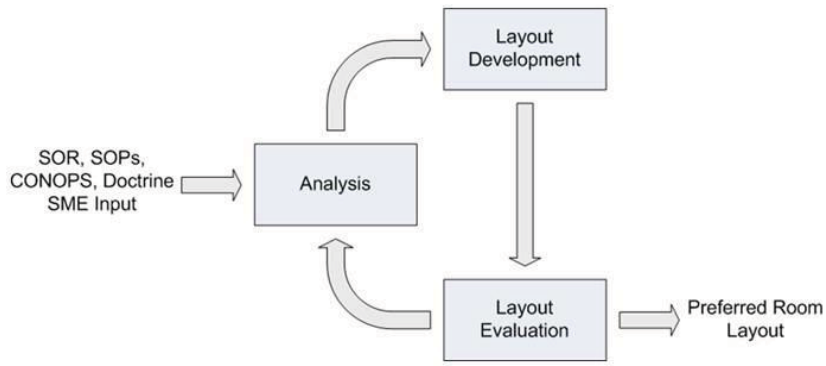

Figure 6: Iterative Room Layout Process

As shown in Figure 5 and Figure 6, there are three main segments in the room layout process: analysis, layout development, and layout evaluation.

The analysis process should include both a work analysis and a communications analysis. There are a variety of techniques that can be used while conducting both of these analyses (e.g., Mission, Function, Task Analysis (MFTA), Work Domain Analysis (WDA), and Hierarchical Goal Analysis (HGA)). The primary consideration is that the selected techniques must ensure complete coverage of all activities required in the space, allow for a sufficiently detailed analysis to determine and analyze the communication requirements of the space, and facilitate validation by Subject Matter Experts (SMEs) who may not be experts in the techniques. Outputs of the analysis process should include:

- Possible operational conditions of the space (e.g., normal, abnormal, emergency);
- The size of the space and any construction features (e.g. doors, windows, etc.);
- A manning concept for the space;
- A list of equipment required to carry out the functions of the space;
- Any specific ingress/egress requirements for the space;
- A determination of the appropriate population anthropometric measures to be used in the layout development;
- A complete list of the intended functions of the space;
- For each intended function, details such as the importance, frequency, and information flow/communication requirements; and
- For each communication requirement, details such as the communication type, importance, frequency, any angular or distance constraints, and the effect of noise masking.

The layout development process should consider all of the requirements of the space, as identified through the analyses. Therefore, the outputs of the analyses, along with SME input and best practices from guidance documents (e.g., Annex A of ISO 11064), should be used to generate notional layouts for the space. In general, some of the requirements of the space will place conflicting demands on the room layout, and design trade-offs between the conflicting requirements will need to be carefully considered to optimize the overall performance of the space. Considerations when assessing design trade-offs include (but are not limited to):

- The importance of the affected top-level intended function;
- The criticality of the task, goal, or communication link to the success of the top-level intended function;
- The degree of functional association (i.e., the number of other functions, tasks, goals, or communication links affected);
- The frequency of the task, goal, or communication link; and
- The duration of the task, goal, or communication link.

For example, the need to provide accessibility for maintenance tasks can have an impact on the performance of operational functions; if this is the case, it may be desirable to consider layout designs that provide sub-optimal accessibility for one or more maintenance tasks in order to improve operational performance. However, design solutions that significantly impact frequent or important maintenance tasks are unlikely to be desirable. To ensure overall optimization of the layout design, it is generally advantageous to create several notional layouts that reflect different compromises between conflicting requirements, which can then be further examined as part of the layout evaluation.

The evaluation of the notional layouts can be carried out at varying levels of fidelity throughout the iterative process (e.g., starting with paper mockups or drawings, progressing to 3D models, and finally to a full-scale physical mock-up). Each evaluation should include participation from SMEs to ensure that operational considerations are appropriately addressed. Outputs from the layout evaluations can then be used to improve the notional layouts and/or to select between multiple layout options.

4.2.3 Additional Information & References

For further information regarding room layout, refer to:

- International Organization for Standardization, Ergonomic dressing of control centres, ISO 11064, 2000.
- McKay, P., Coates, C., Stewart, A., Perlin, M., & Wang, W., Human Factors Analysis and Layout Guideline Development for the Canadian Surface Combatant (CSC) Project, DRDC Toronto CR 2013-043, 2013.
- Coates, C. & Perlin, M., Control Space Optimization. Presented at the 2009 14th International Ship Control Symposium, Ottawa, Canada, September 2009.

4.3 Human Views

As reported in Coates et al.(2013), Allied defence communities have been adopting and developing architectural approaches as a structure for the development of a systems architecture, or enterprise architecture. They note that while international architecture frameworks evolve to include new concepts in System Engineering, the portrayal of the human as a unique part of the system has not been addressed; an explicit representation of the unique implications humans bring to, and impose on, the system design is required. To that end, they worked to define a set of Human Views, which leverage Human System Integration principles, for the purpose of capturing the human requirements and inform on how the human interacts within the system.

Human Views, as developed for Canada, are a theoretical concept for incorporating human considerations (data) into an architecture framework. They were developed, in part, from the NATO Human Views Handbook and reorganized under Canadian HSI domains with a particular focus on acquisition. Although the introduction of Human Views into the Canadian Forces Architecture Framework (DNDAF) is still at an early stage, the Human Factors contents are still important for making (facilitating) acquisition decisions.

To date, the data elements of the Human Views have not been incorporated into DNDAF. While desirable to have the required elements in the architecture framework, this should not preclude an acquisition project from undertaking the work identified in the Human Views as it has been established as providing a structured, organized view of Human Factors data from which procurement staff can make informed HSI decisions affecting their project.

The following table, adapted from Coates et al. (2013) shows the linkages between HSI domains and the Human Views.

Table 1: HSI Domain - Human View Linkages

HSI Domain	Sub Category	DNDAF HV
Overview	Overview	HV-1 Concept
Manpower and Personnel	Force structure	HV-2 Establishment
	Human Interaction	HV-3 Organization
	Availability	HV-4 Manpower projection
	Previous experience and training	Not Applicable
	Cognitive and physical personnel factors	HV-5 Personnel Characteristics
	Recruitment, retention, advancement	Not Applicable
Training	Training	HV-6 Training Needs
System Safety	Systems Safety	HV-7 System Safety
Health Hazards	Health Hazards	HV-8 Health Hazards
Human Factors	Operator roles, functions, and tasks	HV-9 Human Tasks
	Operator roles, functions, and tasks	HV-10 Communications
	Environment	Not Applicable
	Workload	Not Applicable

For more information regarding the development and methodology for Human Views see:

- Coates, C., Stewart, A., Wang, W. (July 2013). Canadian Human Views Handbook. Defence Research and Development Canada, DRDC-CR-2013-041.
- Coates, C., Stewart, A. (July 2013). Development of a Core Set of Canadian Human Views – Acquisition Focused, The Human View in DNDAF - Final Report. Defence Research and Development Canada, DRDC-CR-2013-TBD.

APPENDIX A – Acronyms

ADSM ..... Airworthiness Design Standards Manual
AF ..... Air Force
BoC ..... Basis of Certification
CF ..... Canadian Forces
CFAS ..... Canadian Forces Anthropometric Survey
CFITES ..... Canadian Forces Individual Training and Education System
CMC ..... Canadian Marconi Company
CMP ..... Chief of Military Personnel
COTS ..... Commercial Off-The-Shelf
D Safe G ..... Director of General Safety
DMS ..... Defence Management System
DND ..... Department of National Defence
DNDAF ..... Department of National Defence Architecture Framework
DRDC ..... Defence Research and Development Canada
DTAES ..... Director Technical Aerospace Engineering Support
EASA ..... European Aviation Safety Agency
GCS ..... Ground Control Station , Ground Control Station
HGA ..... Hierarchical Goal Analysis
HHA ..... Health Hazard Assessment
HR-CIV ..... Human Resources Civilian
HSI ..... Human Systems Integration
ISO ..... International Organization for Standardization
JBOS ..... Job Based Occupationa Specification
JUSTAS ..... Joint Unmanned Surveillance and Target Acquisition System
MA&S ..... Materiel Acquisition and Support
MFTA ..... Mission, Function, and Task Analysis
MIL-HDBK ..... Military Handbook
MIL-STD ..... Military Standard
MOPS ..... Minimum Operational Performance Specification
MOSID ..... Military Occupational Structure Identification Code
MOTS ..... Military Off-The-Shelf
NATO ..... North Atlantic Treaty Organization
OSVB ..... Occupational Specification Validation Board
PMO ..... Project Management Office
QL ..... Qualification Level
QSB ..... Qualification Standards Board
RCAF ..... Royal Canadian Air Force
SME ..... Subject Matter Expert
SOW ..... Statement of Work
STANAG ..... Standardization Agreement
TAA ..... Technical Airworthiness Authority
TAC ..... Technical Airworthiness Clearance
TAM ..... Technical Airworthiness Manual
TC ..... Type Cirtificate
TNA ..... Training Needs Analysis
TSO ..... Technical Standard Order
UAS ..... Unmanned Aircraft System
UAV ..... Unmanned Aerial Vehicle
USAR ..... Unmanned Aerial Vehicles Systems Airworthiness Requirements
WDA ..... Work Domain Analysis

APPENDIX B – UAV HSI Lessons Learned

Hudson, J. A., Zehner, G. H., Parakkat, J, and Choi, H. J. (2007). ***A Methodology for Evaluating Advanced Operator Workstation Accommodation****, Air Force Research Laboratory, Human Effectiveness Directorate, Warfighter Interface Division, Collaborative Interfaces Branch.*

(Noted in Section 2.1 as reference 20)

- While the Human Systems Engineering process is wide and varied during system development, part of it must seek to maximize mission effectiveness through experimentation and analysis in two areas:
    - 1) physical layout – to ensure the widest physical accommodation range of operator body size and proportion;
    - 2) reduction of performance-reducing fatigue (Page 1)
- Controlled experiments should be conducted for assessing mission effectiveness when causal factors, normally associated with fatigue, are varied. (Page 1)
- Digital Human Models… are not considered replacements for live human subject testing in mock-ups. (Page 6)
- Postural fixity is a real risk factor that needs to be addressed. (Page 9)
- Preferred postures during reach should be taken into account when defining the AOW workstation layout. (Page 9)
- The AOW layout should not only be based on minimum anthropometric dimensions to reach controls, but also include consideration for the relationship between maximum reach area and comfort zone, particularly for the smallest subjects. (Page 10)
- When designing the workstation layout, handedness of the target population should be considered such that tasks with heavy loads or requiring fine motor skill could be easily accessed by the operators' dominant hand side without causing awkward postures. (Page 11)

*U.S. Air Force Human Systems Integration Handbook, **Planning and Execution of Human Systems Integration**, Directorate of Human Performance Integration, Human Performance Optimization Division, undated.*

(Noted in Section 2.1 as reference 51)

- HSI is integral to program development. It provides benefits throughout the system life-cycle, from initial implementation to retirement.
- It is important to integrate human concerns into the system design early in the development process. In doing so LCCs are significantly lowered, which can increase financial savings and decrease potential safety concerns.
- It is important for the HSI team to include SMEs from all pertinent domains.
- Work closely with teams and program management to identify HSI high value areas that may impact critical programmatics, especially performance. (Page 25)
- Do not let the human aspects get overshadowed by technology needs. (Page 29)
- Be explicit regarding the consequences - monetary and life cycle - of planned trade-offs so that good decisions can be made. (Page 29)
- Work with the user on all trade-off decisions. (Page 29)
- Require in SOW/SPEC for offerers to substantiate HSI claims as part of their proposal. (Page 43)
- require contractor to develop an HSIP, including plans for test and evaluation, and usability. (Page 43)
- Evaluate the first technical incremental demonstration for HSI considerations as early as possible. (Page 45)
- Continue this practice with each consecutive increment and implement mitigation strategies as necessary. (Page 45)
- Work closely with HPTs and IPTs to identify, establish and refine/update constraints and requirements in all the HSI domains that
    - could impact system design and capability, and
    - will achieve effective human-system interfaces. (Page 46)
- Coordinate with appropriate points of contact for program management, systems engineering, training, fielding, program scheduling, testing, logistics, and documentation. (Page 48)
- Obtain baseline of human performance with the equipment in its current context of use. (Page 50)
- Predict performance degradation or enhancement due to the proposed changed context of use. (Page 50)
- Identify the need for modifications, additional items, changes to other systems, procedural work-arounds, modified training or additional skills needed to guarantee the required performance of the human component of the proposed equipment. (Page 50)
- Identify feasibility of any required changes to the organization and manning needed to ensure adequate performance of the human component. (Page 50)
- COTS does not eliminate the need for good HSI. (Page 51)
- Test and evaluate the system as early as possible. (Page 52)
- Ensure that HSIP, TEMP, and DT&E/OT&E Plans mandate testing and evaluation by typical users (operators, maintainers, support personnel, and trainers). (Page 52)
- Use knowledge derived from testing and usability evaluation for system training development; and
- Training SME should have results of early functional analysis such as human task allocations. (Page 52)

Hobbs, A. and Herwitz, S. R. (2005) ***Human Factors in the Maintenance of Unmanned Aircraft****, Unmanned Aerial Vehicles Human Factors, Program Review FY05, Office of the Chief Scientist for Human Factors, Federal Aviation Administration.*

(Noted in Section 2.1 as reference 18)

- Operators reported that transport and handling damage “ramp rash” are significant issues due to the need to move and assemble UAVs.
- Careful attention needs to be directed to battery charging/discharging cycles. In addition, some types of batteries (e.g., lithium polymer) can be dangerous if correct procedures are not followed.
- UAVs tend to make extensive use of composite materials. Repair of these materials may require special expertise and equipment to deal with hazardous materials.
- In contrast to conventional aircraft, the payload on board a UAV is more likely to be integrated with the UAV structure and power supply. Maintainers may be expected to support the payload as well as the aircraft.
- Non-consumable UAV parts that can be removed and repaired generally do not have part numbers. Tracking the maintenance history of these components may become problematic, and may increase the risk of maintenance errors.
- Given the importance of computer components, several UAV owners require maintenance personnel to have an understanding of software and the capability to make software updates. Human-computer interaction and computer system knowledge will be important human factors considerations for UAV maintenance personnel.
- Maintenance personnel may need to update UAV autopilot system software, and then verify and clearly document the software versions being operated.
- UAV ground stations commonly record flight history such as engine performance. These data are useful for evaluating performance and identifying anomalous conditions. UAV maintenance personnel will require the ability to interpret such data.
- In cases where a UAV was delivered with maintenance documentation, maintenance personnel were sometimes dissatisfied with the quality of documentation.
- Aware that there is no human on board the aircraft, there is a potential for maintenance personnel to become complacent, particularly with regard to deviations from procedures.
- UAV maintenance personnel do not receive log book entries describing problems detected by an on-board pilot during flight. Although flight history may be recorded in the UAV ground control station and reports may be made by the ground-based UAV operator, these reports will not contain any information on a pilot’s direct sensory experience of the aircraft’s flight performance.

Williams, K. W. (2005). ***Unmanned Aircraft Pilot Medical and Certification Requirements****. FAA Civil Aerospace Medical Institute, Oklahoma City, OK, Unmanned Aerial Vehicles Human Factors, Program Review FY05, Office of the Chief Scientist for Human Factors, Federal Aviation Administration.*

(Noted in Section 2.1 as reference 54)

- There are, however, three areas that have been identified that distinguish manned from unmanned aircraft. These areas will be important during the development of training and test standards for these systems. The areas are 1) activities and information related to the data link, 2) activities and information related to the task of detecting, sensing, and avoiding aircraft, and 3) activities and information related to the handoff of control during the flight. (Page 3)
- There should be established procedures for detecting, sensing, and avoiding other aircraft during the flight. These procedures might begin before the flight, with the notification of other traffic that an unmanned aircraft will be flying in the airspace. The limitations of whatever method is in place for detecting other aircraft should be well understood. Also, the procedures for avoiding aircraft should be understood and practiced before they have to be used. (Page 3)

Tvaryanas, A. P., Thompson, W. T., and Constable, S. H. (2005). ***The U.S. Military Unmanned Aerial Vehicle (UAV) Experience: Evidence-Based Human Systems Integration Lessons Learned****, in Meeting Proceedings NATO RTO-MP-HFM-124, pp. 5-1 to 5-25. RTO (Paper 5) Neuilly-sur-Seine, France.*

(Noted in Section 2.1 as reference 42)

- A number of studies have demonstrated that poorly designed automation degrades system performance, especially in multi-task vigilance situations typical of the GCS environment. (Page 5-19)
- With regards to instrumentation/sensory feedback, the UAV operator often lacks peripheral visual, auditory, and haptic cueing and is thus relatively sensory deprived compared to the traditional pilot. (Page 5-19)
- NASA reported in a summary of their UAV flight test experience that incorporating a microphone in the UAV and providing a sound downlink to replicate cockpit environmental noise in the GCS ‘proved invaluable and potentially saved the UAVs in some instances.’ (Page 5-19)
- Additionally, they recommended ‘multifunction switches be limited or eliminated’ and the ‘status of critical parameters should be easily observable.’ (Page 5-19)
- After factor analysis, Navy/Marine UAV mishaps were found to be closely associated with workload and attention and risk management latent factors. The workload and attention factor included issues of ops tempo, formal training programs and procedures, workstation design, and UAV operator attentional focus and motivation. Interventions for this factor should focus on a thorough job task analysis of UAV operator crew positions with the goal of improving job and workstation design, assessing manpower requirements, and developing empirically-based training programs and formal procedures and guidance. (Page 5-19)
- Recommendations include acquiring a simulator with high-fidelity to vehicle handling characteristics to increase operator proficiency or automate the landing phase of flight to eliminate the need for proficiency in the landing skill set. (Page 5-21)
- In contrast to skill-based errors, there was no difference between the services in the frequency of mishaps involving judgment and decision-making errors. Also noteworthy is the fact this study found no difference between the services in the frequency of mishaps involving crew resource management. Together these findings contrast with the results from a Predator operator focus group summarized by Hall and Tirre where the justification for not utilizing enlisted personnel was the need to quickly and accurately make difficult decisions, effectively communicate those decisions to superiors and subordinates, and be responsible for implementing those decisions. This also challenges the assumption officers, particularly rated pilots, already possess these skills and additional training is not required in their case. Further empirical work is needed to optimize policies regarding future UAV operator selection and training. (Page 5-21)
- … HSI failures within the human factors domain, particularly organizational interfaces, were most frequent irrespective of service and would be prime targets for joint HSI issues coordination as proposed by Risser et al. Examples of organizational interfaces issues include job design, unit structure, and policies and regulations. Organizational interfaces failures contributed to both operator error and electromechanical malfunctions. (Page 5-21)

McCarley, J. S., and Wickens, C. D. (no date). ***Human Factors Concerns in UAV Flight.*** *Institute of Aviation, Aviation Human Factors Division, University of Illinois at Urbana-Champaign.*

(Noted in Section 2.1 as reference 28)

- Multimodal operator controls (e.g., speech commands) may also help to distribute workload across sensory and response channels (Draper, et al, 2003; Gunn, et al, 2002), and should be explored.
- Of further interest is the possibility of augmented reality and/or synthetic vision systems (SVS) to supplement sensor input (Draper, et al, 2004). Studies by Van Erp & Van Breda (1999) have found that such augmented reality displays can improve the accuracy and reduce the cognitive demands of target tracking with a payload sensor, and by extension improve UAV flight control.

Hopcroft, R., Burchat,E., and Vince, J. (2006). ***Unmanned Aerial Vehicles for Maritime Patrol: Human Factors Issues****, DSTO-GD-0463, Air Operations Division, Defence Science and Technology Organisation, Department of Defence, Australian Government.*

(Noted in Section 2.1 as reference 19)

- Two very high-risk segments of flight for both manned and unmanned aircraft are the take-off and landing phases (Williams, 2004). Automating these phases so that the pilot (or operator) prompts the system to begin the take-off or landing sequence and then monitors the progress of the system has significantly reduced the rate of accidents during these phases of flight. (Page 2)
- Increases in automation are usually accompanied by a decrease in system transparency. The lack of transparency can result in a reduction in operator SA as the operator may misinterpret or be unaware of the actions taken by the system and thus may develop an inaccurate or incomplete mental model of the flight environment or tactical situation. This reduction in SA is likely to reduce the operator's ability to detect system failures. The lack of system transparency can also affect the operator's trust in the system. The operator may lose trust and rely less on the automated functions, and thus not benefit from them to the same degree. Or the operator's trust may inflate when such an increase in trust is unfounded, causing a reduction in the level of monitoring and a decrease in the likelihood of detecting and responding to system failures. (Page 2)
- Automation of flight control has been found to free the attentional resources of pilots and allow the reallocation of these resources to higher-level operations and decisions. However, the degree to which this can be achieved depends on the design of the system and the requirements of the mission. There is evidence to suggest that automation can actually increase operator workload and reduce SA … (Page 3)
- High levels of automation can, however, prevent the operator from rapidly intervening to override automation when necessary. (Page 6)
- While it is clear that automated systems have the potential to provide a range of benefits, it is also clear that these benefits will only be realised if the integration of automation involves a thorough investigation of potential human factors issues. The investigation should determine the strengths and weaknesses of the human operators and the strengths and weaknesses of the automated system, and all attempts should be made to ensure that the two entities coordinate such that the benefits of each are maximised and the costs of each minimised. (Page 6)
- Mission planning and in flight re-tasking should be evaluated as they have been shown to be problematic with certain platforms (e.g., Global Hawk). (Page 7)
- Williams identified automation as being central to many of the human factors issues that are of concern in the case of the Global Hawk UAV. He suggested that Global Hawk operators find it difficult to monitor the automated system closely over extended periods. This can cause a reduction in SA and a decreased ability to deal with system faults and failures when they occur. (Page 8)
- It may be appropriate to provide access to hierarchies of information through which operators can navigate to find the information they require; however, it is important to ensure that this navigation process does not consume excessive time or mental effort, particularly when the operator is required to act under time pressure. (Page 9)
- It may be necessary to include software that is designed to check for hazardous contingency plans and other mistakes made during mission planning. Research aimed at improving the efficiency and effectiveness of this type of software may help to reduce aircraft attrition. (Page 9)

- The human factors issues that have been found to be of concern for Global Hawk are also likely to be of concern for the UAV selected. These include:
    - costs due to the length and complexity of mission planning,
    - human error during mission planning. (Page 10)
- During flight, Global Hawk operators are also faced with the challenge of
    - maintaining adequate SA of the flight environment,
    - flight climate, and
    - system performance over long periods, a task made more difficult by inadequate automation feedback. (Page 10)
- Mission control element (MCE) operators for the 2001 deployment of Global Hawk in Australia rated status displays and controls in the MCE as consistently unacceptable …. Several areas were identified as problematic including the physical arrangement of the displays (too far apart), the unnecessarily complicated retasking processes, and difficult-to-read displays (due to the fonts and colours that were used). Such problems suggest that some standard design guidelines have been overlooked. (Page 10)
- Alerts are another aspect of the HMI that should be carefully considered. Alerts – visual, auditory, or otherwise - should signal to operators that there is a situation that requires their attention, but with minimal disruption to work. It is important for alerts to be easily interpreted; … A criterion for how serious a situation becomes before an alert is displayed must be set. The level to which this is set should minimise the risk of failing to alert the operator to a serious condition, while ensuring that the alerts do not become an annoyance … (Page 12)
- The manual controls are the operators' means of interacting with the software interface, and have serious implications for the safety of the system. For example, due to the assignment of menu selections to function keys on the Predator aircraft, the sequence of key presses required to control the lights was almost identical to the sequence for cutting off the engine, and hence offered the possibility of confusion with catastrophic consequence. (Page 12)
- An examination of UAV literature reveals that one of the most prominent HMI issues is that of the sensory isolation of the operators (and other crew) due to their physical separation from the aircraft. Mission control element operators for the 2001 deployment of the Global Hawk rated their ability to detect and diagnose abnormal conditions on the UAV via the human-computer interface as poor. (Page 12)
- While the evidence provided by initial studies of multisensory interfaces suggests that they could be used to improve the performance of UAV operators, further investigation is required. (Page 15)
- Investigation of a number human factors issues relating to the use of augmented reality displays in UAV ground stations is still required. The appropriate level of augmentation for optimal interpretation of UAV imagery needs to be determined, and any risk of operators placing too much trust in the augmented imagery must be taken into account. The possibility of cognitive tunnelling (excessive focus on an element of synthetic vision symbology leading to neglect of the sensor images), and clutter must also be considered. (Page 16)
- Crew selection processes should be aimed at finding those that are best suited to maintaining vigilance over long periods, and training operators to use specific techniques for maintaining SA on long and potentially boring monitoring tasks is also of importance. Additionally, the maximum length of time that an operator can safely monitor the UAV status, and ideal rest periods need to be determined. (Page 17)
- Transfer of control is argued to be a critical and high-workload phase of UAV operation, as procedures for hand-over may be complex and require precision, placing additional demands on human operators. (Page 18)

- In terms of the hand-over of UAV control, two areas of future research are vital to ensuring the safe operation of large, highly automated UAVs (McCarley & Wickens, 2005). These are the development of formal procedures for hand-over of UAV control between teams of operators, and the further development of systems and displays to ensure that operators are adequately informed of system status. (Page 19)
- The introduction of and reliance on data link and digital voice for communication introduces additional problems for UAV operation and ATC. … digital voice communications also have important drawbacks, such as propagation delay, which in turn increases the numbers of step-ons. Step-ons represent instances in which a pilot or controller interferes with another's transmission causing the interference of both transmissions. Time lags in communication during time-critical operations such as ATC, which are unpredictable in terms of the controller's expectations, impact negatively on working methods, strategies, and performance of ATC. (Page 19)
- Co-ordination of crew activities through communication has been recognized as crucial to success in UAV operations such as location and identification of surface targets. In such scenarios, success is heavily dependent on efficient communication between team members. However, communication may be hampered by separation from the aircraft, the separation of crew-members in the GCE, and frame-of-reference differences between earth-referenced locations and sensor-referenced locations. (Page 19)
- Communication delays may affect changes in team dynamics, impacting the nature of command and control. (Page 19)

Tvaryanas, A. P. (2006). ***Human Systems Integration in Remotely Piloted Aircraft Operations****,*
pp. 1278-1282, Aviation, Space, and Environmental Medicine • Vol. 77, No. 12.

(Noted in Section 2.1 as reference 43)

- One of the biggest changes in large RPAs involves the personnel and training domains and current efforts to develop a new career field for USAF RPA operators. The proposed training pipeline will start with new officer accessions and involve significantly less manned flight training when compared with the current practice of using experienced military pilots and navigators. (Page 1279)
- Additionally, current selection and aeromedical accession and certification processes will need to be evaluated for their partial or total applicability to this new career field. (Page 1280)
- The RPA crew is unique compared with traditional aircrew since their task environment is the ground control station (GCS) rather than the cockpit. They often lack peripheral visual, auditory, and haptic cueing and are, therefore, relatively sensory deprived. They are nearly entirely dependent on focal vision in order to obtain information on vehicle state through either automation and displays or direct visual contact. (Page 1280)
- A review of RPA mishaps found human machine interface design and crewmember attentional factors were frequent causes of crew-related errors. Advances in automation are decreasing the need for RPA pilots to have traditional pilot skills and instead emphasize monitoring and collaborative decision-making skills. However, the role of passive monitor makes maintaining a constant level of alertness exceedingly difficult and predisposes to “hazardous states of awareness”. Although one of the best ways to overcome these effects is work breaks, there is concern for an acute decrement in crew situational awareness when control is transferred to another crew not currently involved in the mission. (Page 1281)
- Restated from an HSI perspective, RPA crewmember performance is at risk because of multiple, potentially synergistic domain shortfalls involving manpower (extended duty days and reduced crew size), habitability (fatigue), and environment, safety, and occupational health (reduced operator effectiveness). Additionally, the HFE domain can be added to this mix when the design of the human machine interface drives human error or inefficiency. (Page 1281)

Tobias Nisser, T. and Westin, C. (2006). ***Human Factors Challenges in Unmanned Aerial Vehicles (UAVs): A Literature Review****, Lund University School of Aviation.*

(Noted in Section 2.1 as reference 41)

- The human factors literature provides a number of lessons about the possible human performance impact of automation. Some of the main lessons for the development of UAVs include the following:
    - Tasks need to be automated in such a way that human retains interesting and challenging parts of the job;
    - Automation should offload the routine an mundane portions of the operator's task;
    - Systems must give clear indications of their underlying performance; and
    - Systems must facilitate human's monitoring of automated performance. (Page 8)

Tvaryanas, A. P. (2006). ***Human Factors Considerations in Migration of Unmanned Aircraft System (UAS) Operator Control****. Performance Enhancement Directorate Performance Enhancement Research Division, 311th Human Systems Wing, United States Air Force.*

(Noted in Section 2.1 as reference 44)

- While the ability to migrate operator control adds a new dimension of flexibility in operating UASs, it also comes at a cost in terms of increased complexity and has been a factor in several UAS mishaps. (Page iv)
- There are potential advantages to control migration to include the maintenance of operator performance by mitigating fatigue and vigilance decrements through optimum shift lengths (e.g., 6-10 hours) and the provision of work breaks, facilitating enhanced operator functional specialization, and allowing for the adjustment of workload during multi-aircraft and payload control tasks via control migration strategies. (Page iv)
- Possible significant disadvantages to control migration include transient degraded operator situational and systems awareness and more complex and potentially distributed teams of operators. (Page iv)

Mouloua, M., Gilson, R., and Kring, J., and Hancock, P. (2001). ***Workload, Situation Awareness, And Teaming Issues For UAV/UCAV Operations****. University of Central Florida, Orlando, Florida, Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting, pp.162 to 165.*

(Noted in Section 2.1 as reference 32)

- Although the negative effects of high workload have been well documented and makes intuitive sense, low workload can be equally as damaging to performance. For example, in highly automated systems, a large portion of the operator's task load is supervisory in nature, monitoring system parameters and maintaining alertness for malfunctions. Tasks may include visual scanning of status indicators, running computer-assisted diagnostics, or making subtle changes in the system's ultimate goal or purpose. These tasks, which require sustained attention from the operator, can become repetitious and dull over time and can lead to degraded performance and operational errors. (Page 163)
- Therefore, it is important to consider both ends of the spectrum, from high workload to low workload in developing effective interface and controls for UCAV operation. (Page 163)
- In the context of complex UCAV systems, a high level of situation awareness will be necessary for enhanced mission performance. (Page 163)
- Exemplar solutions to similar problems might include furnishing operators with the capability to visualize or conceptualize the system and environment at several levels. For instance, for awareness inside and outside the UCAV, window screens that indicate the underlying processes controlled by automation will allow operators to see and understand what the automation is doing and why. … Such a design will decrease automation surprises, and enable the operator to maintain a broader picture of the overall system. (Page 164)

Unmanned Aircraft Systems, Federal Actions Needed to Ensure Safety and Expand Their Potential Uses within the National Airspace System. United States Government Accountability Office, Report to Congressional Requesters. May 2008.

(Noted in Section 2.1 as reference 50)

- Current regulations do not indicate how, in the absence of an on-board pilot, UASs should detect, sense, and avoid other aircraft to avoid collisions. (Page 1)
- A key technological challenge is providing the capability for UASs to meet the safety requirements of the national airspace system. (Page 3)
- No technology has been identified as a suitable substitute for a person on board the aircraft in seeing and avoiding other aircraft. (Page 3)
- UASs' communications and control links are vulnerable to unintentional or intentional radio interference that can lead to loss of control of an aircraft and an accident, and in the future, ground control stations—the UAS equivalent to a manned aircraft cockpit—may need physical security protection to guard against hostile takeover. (Page 3)
- Routine UAS access to the national airspace system poses a variety of technological, regulatory, workload, and coordination challenges. Technological challenges include developing a capability for UASs to detect, sense, and avoid other aircraft; addressing communications and physical security vulnerabilities; improving UAS reliability; and improving human factors considerations in UAS design. (Page 16)

Greenley, M., Scipione, A., Brooks, J., Salwaycott, A., Dyck, W., and Shaw, C. M. (2008). ***The Development and Validation of a Human Systems Integration (HSI) Program for the Canadian Department of National Defence.*** *Defence Research and Development Canada, Contract Report DRDC -CR-2008-005.*

(Noted in Section 2.1 as reference 16)

- It is a very small effort to transition a Human Factors Engineering trial plan into a HSI Trial plan. The additional effort requires the addition of measures related to health hazards, safety, training, and personnel impact into the evaluation set. The result of incorporating these additions is a significantly more comprehensive analysis of the "human component" in the system. (Page F32)
- Sharing lessons learned with all the stakeholders i.e. operations, ADM(HR) and Training, is one of the biggest HSI challenges in technology demonstration projects. The reason is that while all stakeholders are all interested in the lessons learned, they may not be in a position (timing wise) to exploit them. A central HSI repository that can be actively promoted to users and searched by users would substantially improve the usefulness and re-use of HSI data and analysis. (Page F32)

Waraich, Q, R., Mazzuchi, T. A., Sarkani, S., and Rico, D. F. (2013). ***Minimizing Human Factors Mishaps in Unmanned Aircraft Systems****. Ergonomics in Design: The Quarterly of Human Factors Applications Volume 21: 25-32.*

(Noted in Section 2.1 as reference 55)

- UASs are often put into service without complete assessment and mitigation of HF/E issues with the ground control stations (Air Line Pilots Association, 2007). (Page 27)
- The preliminary findings indicate that UAS GCSs are a derivative of general-purpose CWSs. Therefore, it might be possible to apply the ANSI/HFES 100-2007 standard to the design, development, and evaluation of UAS GCSs. (Page 30)

*Williams, K.W. (2006). **Human Factors Implications of Unmanned Aircraft Accidents: Flight Control Problems**. Washington, DC: U.S. Department of Transportation, Federal Aviation Administration, Office of Aerospace Medicine. Technical Report Publication No. DOT/FAA/AM-06/8.*

(Noted in Section 2.1 as reference 56)

- The problem of transfer of control centers around the fact that the receiver of control is not always fully aware of the status of the system. The problem can be solved by designing the displays in such a way that all critical system parameters are available to the pilot during the transfer. (Page 5)
- Another method for reducing problems related to transfer of control is a yoked interface between control stations performing a handoff. Basically, the idea consists of establishing a protocol between two control stations (or within stations if the goal is to transfer control from one side to the other) that ensures that all system parameters of the receiving station match those of the sending station." (Page 5)
- Automation problems occur because not all circumstances can be predicted. The inability to anticipate all possible contingencies leads to situations in which the system behaves as it was designed but not in a manner that was expected. (Page 5)

European Aviation Safety Agency. (2009). ***Airworthiness certification of Unmanned Aircraft Systems (UAS).*** *EASA Policy Statement E.Y013-01*

(Noted in Section 2.1 as reference 13)

- The Agency acknowledges that USAR (Unmanned Systems Airworthiness Requirements) developed by the French Military Authorities, and later updated by NATO FINAS group to STANAG 4671, has been developed using a methodology closely related to the one described in this policy. At an applicant's request, the Agency may accept USAR version 3, STANAG 4671, or later updates, as the reference airworthiness code used in setting the type-certification basis, provided that:
    - the applicable airworthiness code identified from application of the methodology in Appendix 1 of this policy does not indicate that safety standards in excess of CS23 (single engine) are required, and
    - the safety targets included in the system safety assessment reflect values resulting from the application of this policy.

APPENDIX C – Basic of Certification (HF Review Required)

BoC ID	USAR Paragraph	Sub-Paragraph	Human Factors - Basis of Certification (BoC) DTAES 6-7 Specialist Review Required STANAG 4671 - Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR)	Usability	Advisory, Caution, and Warning	Situation Awareness	Reach, Vision, Clearance	workload	Intended Function	Environmental Assessment
1	141	a	USAR.141 General (a) The UAV must meet the requirements of USAR.143 to USAR.253. When operated in the automatic control mode the UAV should be shown to have acceptable controllability, manoeuvrability and stability characteristics throughout the flight envelope protection (see USAR.334 and USAR.1329) maintained by the flight control system, without requiring exceptional skill or alertness from the UAV crew.					x		
2	280	d	USAR.U280 Launch performance (d) A manual abort function must be easily accessible to the UAV crew in order to cancel the UAV launch at any time before the irreversible catapult or rocket ignition phase.	x						
3	290	c	USAR.U290 UAV performance before parachute landing (c) It must be possible to abort the normal landing procedure at any point prior to the initiation of the final deployment sequence and it must be shown that a safe transition to a normal flight mode or go around conditions can be made.	x		x				
4	671	a	USAR.671 General See AMC.671 (a) Each control must operate easily, smoothly and positively enough to allow proper performance of its functions.	x						
5	677	d	USAR.677 Trim systems (d) It must be demonstrated that the UAV is safely controllable by the flight control system and that the UAV crew can perform all the manoeuvres and operations necessary to effect a safe landing following any probable powered trim system runaway that reasonably might be expected in service. The demonstration must be conducted at the critical UAV weights and centre of gravity positions.	x						
6	703	a	USAR.703 Take-off protection If the UAV is an unsafe take-off configuration, either (a) the UAV crew and ground staff (where applicable) must be notified; or		x					
7	729	c	729 USAR.729 Landing gear extension and retraction system (See AMC.729 (g)) (c) Emergency operation. For a UAV having retractable landing gear , there must be means to extend the landing gear in the event of either (1) Any reasonably probable failure in the normal landing gear operation system; or (2) Any reasonably probable failure in a power source that would prevent the operation of the normal landing gear operation system.	x						

BoC ID	USAR Paragraph	Sub-Paragraph	Human Factors - Basis of Certification (BoC) DTAES 6-7 Specialist Review Required STANAG 4671 - Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR)	Usability	Advisory, Caution, and Warning	Situation Awareness	Reach, Vision, Clearance	workload	Intended Function	Environmental Assessment
8	729	e	729 USAR.729 Landing gear extension and retraction system (See AMC.729 (g)) (e) If a retractable landing gear is used, there must be landing gear position sensor and switches to actuate the indicator in the UCS (see USAR.1793) to inform the UAV crew that each gear is secured in the extended (or retracted) position. If switches are used, they must be located and coupled to the landing gear mechanical system in a manner that prevents an erroneous indication of either “down and locked” if each gear is not in the fully extended position, or of “up and locked” if each landing gear is not in the fully retracted position.	x	x					
9	863	b4	USAR.863 Flammable fluid fire protection (See AMC.863) (b) Compliance with sub-paragraph (a) must be shown by analysis or tests and the following factors must be considered: (4) Means available for controlling or extinguishing a fire, such as stopping flow of fluids, shutting down equipment, fireproof containment, or use of extinguishing agents.	x						
10	903	d2	USAR.903 Engines and auxiliary power units See AMC.903(a) and AMC.903(f) (d) Starting and stopping (2) For safety purpose, there must be a means to prevent inadvertent engine starting on the ground.	x						
11	905	c	USAR.905 Propellers (See AMC.905 (d), AMC.905 (e) and AMC.905 (g)) (c) Each featherable propeller must have a means to unfeather it in flight.	x						
12	955	f3	955 USAR.955 Fuel flow (f) Turbine engine fuel systems. Each turbine engine fuel system must provide at least 100% of the fuel flow required by the engine under each intended operation condition and manoeuvre. The conditions may be simulated in a suitable mock-up. This flow must (3) For single engine UAV, require no UAV crew action after completion of the engine starting phase of operations unless means are provided that unmistakenly alert the UAV crew to take any needed action at least five minutes prior to the needed action; such UAV crew action must not cause any change in engine operation; and such UAV crew action must not distract UAV crew attention from essential flight duties during any phase of operations for which the UAV is approved.	x	x			x		
13	995	a	995 USAR.995 Fuel valves and controls (See AMC.995) (see also USAR.1743 Fuel controls) (a) There must be a means on board, commanded from the UCS, to allow UAV crew to rapidly shut off, in flight, the fuel to each engine individually.	x						
14	1001	i	USAR.1001 Fuel jettisoning system (i) Fuel jettisoning must be performed by the UAV crew. Nevertheless, in case of total loss of data link, automatic procedures of fuel jettisoning must be assessed according to safety objectives stated in USAR.1309.	x						

BoC ID	USAR Paragraph	Sub-Paragraph	Human Factors - Basis of Certification (BoC) DTAES 6-7 Specialist Review Required STANAG 4671 - Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR)	Usability	Advisory, Caution, and Warning	Situation Awareness	Reach, Vision, Clearance	workload	Intended Function	Environmental Assessment
15	1203	c	1203 USAR.1203 Fire detector system A fire detection system must be installed in each designated fire zone, as defined in USAR.1181, and comply with the following: (c) There must be means to allow the UAV crew to check, in flight, the functioning of each fire detector electric circuit.	x						
16	1203	e	1203 USAR.1203 Fire detector system A fire detection system must be installed in each designated fire zone, as defined in USAR.1181, and comply with the following: (e) The fire detection system must be designed to minimise false warnings or inappropriate warnings and if they occur shall not result in a hazardous or more serious event		x					
17	1301	a	USAR.1301 Function and installation Each item of installed equipment must (a) Be of a kind and design appropriate to its intended function;						x	
18	1301	b	USAR.1301 Function and installation Each item of installed equipment must (b) Be labelled as to its identification, function or operating limitations, or any applicable combination of these factors;	x						
19	1301	d	USAR.1301 Function and installation Each item of installed equipment must (d) Function properly when installed.	x						
20	1307	h	USAR.U1307 Environmental control system (ECS) (See AMC.1307) Cooling must be provided for flight critical equipment as required for it to meet its performance and reliability for the intended lifetime. h) Adequate controls and displays for the ECS shall be installed in the UCS or other appropriate locations to allow the ECS to function as intended. Sufficient cautions, warnings, and advisories are provided to alert the UAV crew to problems in time for corrective action to be taken from a safety of flight perspective.	x	x					
21	1307	j	U1307 USAR.U1307 Environmental control system (ECS) (See AMC.1307) Cooling must be provided for flight critical equipment as required for it to meet its performance and reliability for the intended lifetime. j) Bleed air or other compressed air duct system shall be monitored for leaks and structural integrity. Hot air leaking from damaged ducting shall not cause ignition of any flammable fluids or other materials or cause damage to safety-critical equipment. Shutdown capability, with a UCS advisory or warning, shall be provided when a potentially damaging or fire-producing leak occurs. The sensors for the leak detection system shall recover their required leak detection function following exposure to a leak.	x	x					

BoC ID	USAR Paragraph	Sub-Paragraph	Human Factors - Basis of Certification (BoC) DTAES 6-7 Specialist Review Required STANAG 4671 - Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR)	Usability	Advisory, Caution, and Warning	Situation Awareness	Reach, Vision, Clearance	workload	Intended Function	Environmental Assessment
22	1309	a2i	1309 USAR.1309 Equipment, systems and installations (See AMC.1309 (b)) (a) The UAV system must be designed to reduce the risk to people including UAV crew, maintainers and third parties to a level acceptable to the Certifying Authority. It must also be designed to reduce the risk of material loss or damage to a level acceptable to the Certifying Authority. (2) Each item of equipment, each system, and each installation: (i) When performing its intended function, may not adversely affect the response, operation, or accuracy of any: - Equipment essential to safe operation; or - Other equipment unless there is a means to inform the UAV crew of the effect.		x					
23	1309	b2 1	1309 USAR.1309 Equipment, systems and installations (See AMC.1309 (b)) (b) The design of each item of equipment, each system, and each installation must be examined separately and in relationship to other systems and installations to determine (2) if failure of a system would significantly reduce the capability of the UAV or the ability of the UAV crew to cope with adverse operating conditions. Each item of identified equipment, system and installations categorised by (1) or (2) must be designed to comply with the following additional requirements: (1) It must perform its intended function under any foreseeable operating condition.	x						
24	1309	b2 3	1309 USAR.1309 Equipment, systems and installations (See AMC.1309 (b)) (b) The design of each item of equipment, each system, and each installation must be examined separately and in relationship to other systems and installations to determine (2) if failure of a system would significantly reduce the capability of the UAV or the ability of the UAV crew to cope with adverse operating conditions. Each item of identified equipment, system and installations categorised by (1) or (2) must be designed to comply with the following additional requirements: (3) Warning information must be provided to alert the UAV crew to unsafe system operating conditions and to enable the UAV crew to take appropriate corrective action. Systems, controls, and associated monitoring and warning means must be designed to minimise UAV crew errors that could create additional hazards.	x	x			x		

BoC ID	USAR Paragraph	Sub-Paragraph	Human Factors - Basis of Certification (BoC) DTAES 6-7 Specialist Review Required STANAG 4671 - Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR)	Usability	Advisory, Caution, and Warning	Situation Awareness	Reach, Vision, Clearance	workload	Intended Function	Environmental Assessment
25	1329	a	USAR.1329 Flight control system (See AMC.1329 (e), AMC.1329 (i) and AMC.1329 (j)) The flight control system comprises sensors, actuators, computers and all those elements of the UAV System, necessary to control the attitude, speed and trajectory of the UAV. The flight control system must meet the following: (a) The modes of control of the UAV must be the following categories, which may be selected at any time in flight by the UAV crew: (1) automatic : in this mode the UAV attitude, speed and flight path are fully controlled by the flight control system. No input from the UCS is needed other than to load or modify the required flight plan. (2) semi-automatic : with this type of control the UAV crew commands outer loop parameters such as altitude, heading and air speed. The flight control system operates the UAV controls to achieve the commanded outer loop parameter value.	x						
26	1329	b	USAR.1329 Flight control system (See AMC.1329 (e), AMC.1329 (i) and AMC.1329 (j)) The flight control system comprises sensors, actuators, computers and all those elements of the UAV System, necessary to control the attitude, speed and trajectory of the UAV. The flight control system must meet the following: (b) The flight control system must be designed so that a UAV crew of average skill can operate the UAV System with acceptable workload,	x				x		
27	1329	d	USAR.1329 Flight control system (See AMC.1329 (e), AMC.1329 (i) and AMC.1329 (j)) The flight control system comprises sensors, actuators, computers and all those elements of the UAV System, necessary to control the attitude, speed and trajectory of the UAV. The flight control system must meet the following: (d) The UAV crews must have the opportunity to intervene at any time during the flight to manage safe control of the UAV, except : (1) during emergency situations such as total loss of data link, (2) during launch phase before achieving the minimum safe flight parameters, (3) during landing phase after reaching the decision point as defined in USAR.1490 and USAR.1492, (4) for UAV designed to be recovered by parachute, during the landing phase under parachute, (5) for rocket or catapult assisted take-off UAV, during the launch phase before reaching the limits specified in USAR.282.	x						

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28	1329	j	USAR.1329 Flight control system (See AMC.1329 (e), AMC.1329 (i) and AMC.1329 (j)) The flight control system comprises sensors, actuators, computers and all those elements of the UAV System, necessary to control the attitude, speed and trajectory of the UAV. The flight control system must meet the following: (j) The flight control system must have a comprehensive self-test available and operating during all phases of flight, including preflight.	x						
29	1331	c	USAR.1331 Measuring devices using a power source For each measuring device that is safety critical for continued safe operation that uses a power source, the following apply: (c) There must be at least two independent sources of power (not driven by the same engine on multi-engine UAV), and a manual or an automatic means to select each power source.	x						
30	1337	d	1337 USAR.1337 Powerplant installation measuring device (d) Oil quantity indicator. There must be a means to indicate the quantity of oil in each tank when the UAV is on the ground (see also USAR.1729 Fuel quantity and oil quantity data)	x						
31	1353	g2	1353 USAR.1353 Storage battery or emergency power supply design and installation (g) Battery installations must have (2) A battery temperature sensing and over temperature warning system with a means for automatically disconnecting the battery from its charging source in the event of an over temperature condition; or		x					
32	1353	g3	1353 USAR.1353 Storage battery or emergency power supply design and installation (g) Battery installations must have (3) A battery failure sensing and warning system with a means for disconnecting the battery from its charging source in the event of battery failure.		x					
33	1357	c1	USAR.1357 Circuit protective devices (See AMC.1357 (a)) (c) Where installed, each remote resettable circuit protective device ("trip free" device in which the tripping mechanism cannot be over-ridden by the operating control) must be designed so that (1) A remote operation to be done by the UAV crew is required to restore service after tripping; and	x						
34	1385	e	USAR.1385 Position light system installation (e) The position lights must be able to be switched on and off from the UCS and while the UAV is in flight.	x						

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35	1412	a	U1412 USAR.U1412 Emergency recovery capability (See USAR.1412 (a)(2) and AMC.1412 (e)) (a) The UAV System must integrate an emergency recovery capability that consists of : (1) a flight termination system, procedure or function that aims to immediately end normal flight, or, (2) an emergency recovery procedure that is implemented through UAV crew command or through autonomous design means in order to mitigate the effects of critical failures with the intent of minimising the risk to third parties, or, (3) any combination of USAR.1412 (a) (1) and USAR.1412 (a) (2).	x						
36	1412	c	U1412 USAR.U1412 Emergency recovery capability (See USAR.1412 (a)(2) and AMC.1412 (e)) (c) The emergency recovery capability must be safeguarded from interference leading to inadvertent operation.	x						
37	1413	a	USAR.U1413 Engine shut down procedure In the event of an engine failure that causes shutdown, the following requirements apply : (a) the UAV must be designed to retain sufficient control and manoeuvrability until it has reached a forced landing area.	x						
38	1485	e	USAR.U1485 Environmental Control System (ECS) (See AMC.1485) (e) Adequate controls and displays for the ECS must be installed in the UCS or other appropriate locations to allow the ECS to function as intended. Sufficient cautions, warnings, and advisories must be provided to alert the UAV crew to problems in time for corrective action to be taken from a safety-of-flight perspective.	x	x			x		
39	1490	a	USAR.U1490 General See AMC.1490 (f)(2) When a UAV System, designed for conventional take-off and landing on a runway is equipped with an automatic take-off system or an automatic landing system or both, it should meet the following requirements (a) Once the automatic take-off or landing mode has been engaged, the UAV crew monitors the whole process from the UCS, via the command and control data link, but is not required to perform any manual “piloting action”, except manual abort, where required, as per provisions of USAR.1492.			x				
40	1490	d	USAR.U1490 General See AMC.1490 (f)(2) When a UAV System, designed for conventional take-off and landing on a runway is equipped with an automatic take-off system or an automatic landing system or both, it should meet the following requirements (d) Automatic take-off system or automatic landing system data and status must be displayed in the UCS. All indications must be designed to minimise crew errors.	x						

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41	1492	a2	USAR.U1492 Manual abort function Where a UAV System is designed for conventional take-off and landing on a runway, it must include the following function : (a) The automatic system must incorporate a manual abort function. Its control shall be easily accessible to the UAV crew in order to (2) where it is safe to perform, initiate a go around during the landing phase at every height down to a Decision Point.	x			x			
42	1501	b	USAR.1501 General (b) The operating limitations and other information necessary for safe operation must be made available to the UAV crew as prescribed in USAR.1541 to USAR.1589.	x						
43	1541	b1	USAR.1541 General (b) Each marking and placard of the UAV System prescribed in sub-paragraph (a) (1) Must be displayed in a conspicuous place; and	x						
44	1541	d	USAR.1541 General (d) The units of measurement used on placards must the same as those furnished in the UAV System Flight Manual or displayed to the UAV crew.	x						
45	1607	b	U1607 USAR.U1607 Command and control data link performance and monitoring (b) For each command and control data link, the effective maximum range which may include a safety margin to be agreed by the Certifying Authority must be displayed in the UCS for a specific availability level for both uplink and downlink on request of the UAV crew. The corresponding availability level must be displayable on UAV crew request at the appropriate position on the UCS display.	x						
46	1607	d	U1607 USAR.U1607 Command and control data link performance and monitoring (See AMC.1607 (a)) (d) Maximum range cues must be provided in the UCS on UAV crew request or automatically in case of a likely breakdown of the command and control data link.	x						
47	1607	e	U1607 USAR.U1607 Command and control data link performance and monitoring (See AMC.1607 (a)) (e) Intervisibility information must be displayed in the UCS and warning cues provided to the UAV crew in order to prevent a total loss of command and control data link.	x	x					
48	1613	c	USAR.U1613 Command and control data link loss strategy (See AMC.1613 (a), AMC.1613 (b) and AMC.1613 (c)) (c) There must be an alert for the UAV crew, via a clear and distinct aural and visual signal, for any total loss of the command and control data link.		x					

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49	1615	c	USAR.U1615 Command and control data link antenna maskings (c) Warning cues shall be provided to the UAV crew in case of approaching masking attitudes in order to prevent a total loss of command and control data link.		x					
50	1701	b	USAR.U1701 General (See AMC.1701 and AMC.1701 (e)) (b) The design of a UCS must facilitate the command and control of the UAV by the UAV crew for safe operations as agreed by the Certifying Authority.	x	x			x		
51	1703	a	USAR.U1703 UAV crew work place (a) The UCS and its equipment must allow each UAV crew at work place to perform their duties without unreasonable concentration or fatigue.	x	x			x		
52	1703	b	USAR.U1703 UAV crew work place (b) The UAV crew work place conditions (temperature, humidity, vibration, noise, heat emissions, …) must not hamper safe execution of the flights.							x
53	1704	a	USAR.U1704 Minimum UAV crew The minimum UAV crew must be established so that it is sufficient for safe operation considering (a) The workload on individual UAV crew members taking into account at least the following tasks: (1) Operation and monitoring of all essential UAV System elements, (2) Navigation, (3) Flight path control, (4) Communications, (5) Compliance with airspace, air traffic, and air traffic control requirements, (6) Command decisions including Crew resource management,					x		
54	1704	b	USAR.U1704 Minimum UAV crew The minimum UAV crew must be established so that it is sufficient for safe operation considering (b) The accessibility and ease of operation of necessary controls.	x						
55	1705	a	USAR.U1705 UAV crew work place lights The UAV crew work place lights must (a) Make each indicator, data display, information, markings, placard and control easily readable and discernible;	x			x			
56	1705	b	USAR.U1705 UAV crew work place lights The UAV crew work place lights must (b) Be installed so that their direct rays, and rays reflected from any surface, are shielded from the UAV crew's eyes;	x						

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57	1707	a	USAR.U1707 Communication system (See AMC.1707 (a) and AMC.1707 (c)) (a) For those UAV Systems that require more than one UAV crew member in the UCS, or whose operation will require communication with more than one UAV crew member, the UCS must be evaluated to determine if the UAV crew, when at their work places, can converse without difficulty under the actual UCS environment. If the UCS design includes provisions for the use of communication headsets, the evaluation must also consider conditions where headsets are being used. If the evaluation shows conditions under which it will be difficult to converse, an intercommunication system must be provided.	x						
58	1707	b	USAR.U1707 Communication system (See AMC.1707 (a) and AMC.1707 (c)) (b) If the communication equipment that is installed incorporates transmit switches, these switches must be such that when released, they return from the “transmit” to the “off” position.	x						
59	1707	c	USAR.U1707 Communication system (See AMC.1707 (a) and AMC.1707 (c)) (c) If provisions for the use of communication headsets are provided, it must be demonstrated that the UAV crew will receive all aural warnings under the actual UCS noise conditions when any headset is being used.	x						
60	1709	d2	U1709 USAR.U1709 Voice recorders (See AMC.1709 and AMC.1709 (e)) (d) Each UCS voice recorder must be installed so that (2) There is an aural or visual means for pre-flight checking of the recorder for proper operation.	x	x					
61	1721	a	USAR.U1721 Arrangement and visibility (See AMC.1721) (a) Each flight, navigation, powerplant and UAV status data must be clearly arranged and visible to UAV crew as required or UAV crew selectable.	x						
62	1721	b	USAR.U1721 Arrangement and visibility (See AMC.1721) (b) For each multi-engined UAV, identical powerplant data must be available and located so as to prevent confusion as to which engine the data relates.	x						
63	1721	c	USAR.U1721 Arrangement and visibility (See AMC.1721) (c) Data required for safe operation of the system must be grouped appropriately and located within the normal scan pattern of the UAV crew.	x						
64	1721	d	USAR.U1721 Arrangement and visibility (See AMC.1721) (d) If a visual indicator is provided to indicate malfunction of an instrument, it must be effective under all lighting conditions.	x	x					
65	1721	e	USAR.U1721 Arrangement and visibility (See AMC.1721) (e) All displays, indications and warnings must be visible under all UCS lighting conditions.	x	x					

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66	1722	a	USAR.U1722 Part-time data display (Aee AMC.1722) Many UAV System parameters or status indications are required in subpart H and I to be displayed, yet they may be only necessary or required in certain phases of flight. (a) When parameters are not displayed full-time, flight safety must not be impaired.	x						
67	1722	b	USAR.U1722 Part-time data display (See AMC.1722) Many UAV System parameters or status indications are required in subpart H and I to be displayed, yet they may be only necessary or required in certain phases of flight. (b) Part-time displays of UAV System parameters or status indicators must be shown not to create an unsafe conditions.	x				x		
68	1723	a	U1723 USAR.U1723 Flight and navigation data (a) The following are the minimum required flight and navigational data that must be displayed at all times in the control station at an update rate consistent with safe operation: (1) indicated airspeed, (2) pressure altitude and related altimeter setting, (3) heading or track, (4) UAV position: the UAV position must be continuously displayed on a map at a scale selectable by the UAV crew at a level of detail to ensure safe flight. (5) where semi-automatic flight control modes as defined in USAR.1329 are activated, the commanded flight or navigation parameters sent to the UAV must be displayed in the UCS.	x						

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69	1723	b	U1723 USAR.U1723 Flight and navigation data (b) Considering USAR.1722, the following are the minimum required flight and navigational data that shall be selectable or available when queried by the UAV crew for display in the control station at an update rate consistent with safe operation : (1) airspeed limitations identified under USAR.1505 to USAR.1513, (2) sideslip angle, (3) free air temperature, (4) A speed warning device for (i) Turbine engine-powered UAV; and (ii) Other UAV for which VMO/MMO and VD/MD are established under USAR.335 (b) (2) and USAR.1505 (c) if VMO/MMO is greater than 0.8 VD/MD. The speed warning device must give effective aural warning (differing distinctively from aural warnings used for other purposes) to the UAV crew whenever the speed exceeds that agreed by the Certifying Authority. The upper limit of the production tolerance for the warning device may not exceed the prescribed warning speed. The lower limit must be set to minimise nuisance warnings. The need for or the exact setting of this speed warning device may nevertheless consider the existence of high speed protections maintained by the flight control system, when it may be shown that the UAV is prevented from reaching such speeds. (5) UAV position: (i) the UAV position relative to the LOS data link transmitter/receiver must be also displayed in terms of range and bearing ; (ii) the deviation between the planned ground track and the actual flightpath of the UAV. (6) UAV attitude in terms of roll and pitch, (7) vertical speed, (8) time (hours, minutes, seconds), (9) navigation systems status, (10) UAV identification in accordance with USAR.1883 (b), where multiple UAV are being operated. (11) Wind direction and speed at UAV level, if only track data is displayed to the UAV crew.	x						
70	1725	a	U1725 USAR.U1725 Powerplant data (a) The following are the minimum required powerplant data that must be displayed at all times in the control station at an update rate consistent with safe operation: (1) remaining fuel quantity, (2) an indicating means to indicate the good functioning of each engine.	x						

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71	1725	b	U1725 USAR.U1725 Powerplant data (b) For the following data, they are only required to be displayed full time if the system is not capable of providing a warning to the UAV crew if a safe range is exceeded. (1) For reciprocating engine-powered UAV. In addition to the powerplant data required by sub- paragraph (a), the following powerplant data are required: (i) RPM for each engine. (ii) manifold pressure for each altitude engine and for each engine with a controllable propeller. (2) For turbine engine-powered UAV. In addition to the powerplant data required by sub-paragraph (a) , the following powerplant data are required: (i) gas temperature for each engine. (ii) speed of the rotors with established limiting speeds for each engine. (3) For turbojet/turbofan engine-powered UAV. In addition to the powerplant data required by sub- paragraphs (a) and (b)(2), the following powerplant data are required: (i) For each engine, thrust or a parameter that can be related to thrust, including free air temperature if needed for this purpose. (ii) For each engine with a thrust reverser, an indication to the UAV crew of the thrust reverser position. (4) For turbopropeller-powered UAV In addition to the powerplant data required by sub-paragraphs (a) and (b)(2), the following powerplant data is required: torque for each engine.	x						

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72	1725	c	U1725 USAR.U1725 Powerplant data (c) Considering USAR.1722, the following are the minimum required powerplant data that shall be selectable or available when queried by the UAV crew for display in the control station at an update rate consistent with safe operation: (1) For all UAV: (i) oil pressure for each engine, except for engines where the design does not include a separate lubrication device; (ii) oil temperature for each engine, except for engines where the design does not include a separate lubrication device; (iii) oil quantity for each oil tank which meets the requirements of USAR.1337(d), except for engines where the design does not include a separate lubrication device. (2) For reciprocating engine-powered UAV. In addition to the powerplant data required by sub- paragraph (a), (b)(1) and (c)(1), the following powerplant data are required: (i) induction system air temperature for each engine equipped with a preheater and having induction air temperature limitations that can be exceeded with preheat. (ii) cylinder head temperature for each air-cooled engine with cowl flaps; (iii) fuel pressure for pump fed engines. (iv) For each turbocharger installation: - If limitations are established for either carburettor (or manifold) air inlet temperature or exhaust gas or turbocharger turbine inlet temperature, data must be furnished for each temperature for which the limitation is established unless it is shown that the limitation will not be exceeded in all intended operations. - If its oil system is separate from the engine oil system, oil pressure and oil temperature must be provided. (v) coolant temperature for each liquid-cooled engine. (3) For turbine engine-powered UAV. In addition to the powerplant data required by sub-paragraph (a), (b)(2) and (c)(1) , the following powerplant data are required: (i) fuel flow for each engine. (ii) fuel low pressure warning means for each engine. (iii) fuel low level warning means for any fuel tank that should not be depleted of fuel in normal operations. (iv) oil low pressure warning means for each engine. (v) An indicating means to indicate the functioning of the powerplant ice protection system for each engine. (vi) For each engine, a means to indicate the contamination of the fuel strainer or filter (required by USAR 997) before it reaches the capacity established in accordance with USAR.997(d). (vii) For each engine, a means to indicate the contamination of the oil strainer or filter (required by USAR.1019), if it has no bypass, before it reaches the established capacity. (viii) An indicating means to indicate the functioning of any heater used to prevent ice clogging of fuel system components. (4) For turbopropeller-powered UAV In addition to the powerplant data required by sub-paragraphs (a), (b)(2), (b)(4), (c)(1) and (c)(3), the following powerplant data is required: a position indicating means to indicate to the UAV crew when the propeller blade angle is belowthe flight low pitch position, for each propeller, unless it can be shown that such occurrence is highly improbable.	x						

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73	1726		USAR.U1726 Data display of equipment required by Operations regulation The data and status of equipment required by Operation regulation must be capable of display in the UCS as agreed by the Certifying Authority.	x						
74	1727	a	USAR.U1727 Electronic data display (See AMC.1727 and AMC.1727 (b)) (a) Electronic data display systems must (1) Meet the arrangement and visibility requirements of USAR.1721; (2) Be easily legible under all the lighting conditions encountered by the workstation considering the expected electronic display brightness level at the end of an electronic display indicator's useful life. Specific limitations on display system useful life must be addressed in the instructions for continued airworthiness requirements of USAR.1529; (3) Incorporate sensory cues for the UAV crew that are easily comprehensible, and (4) Incorporate visual displays of indicators or data display markings, required by USAR.1831 to USAR.1843, or visual displays that alert the UAV crew to abnormal operational values or approaches to established limitation values, for each parameter required to be displayed in USAR.	x	x					
75	1727	b	USAR.U1727 Electronic data display (See AMC.1727 and AMC.1727 (b)) (b) The electronic display systems, including their subsystems and installations, and considering other UAV systems, must be designed so that one display of information essential for continued safe flight and landing will remain available to the UAV crew after any single failure or probable combination of failures.	x						
76	1728		USAR.U1728 Data link data display, warnings and indicators Data link data display, warnings and indicators must meet the requirements of USAR.1607.		x					
77	1729	a	U1729 USAR.U1729 Fuel quantity and oil quantity data (a) Fuel quantity and consumption data. There must be means to indicate to the UAV crew the rate of fuel consumption and the quantity of usable fuel in each tank during flight. A calibrated scale in appropriate units and clearly marked to indicate those units, must be used. In addition (1) Tanks with interconnected outlets and airspaces may be considered as one tank and need not display separate data; and (2) No fuel quantity data is required for an auxiliary tank that is used only to transfer fuel to other tanks if the relative size of the tank, the rate of fuel transfer and operating instructions are adequate to (i) Prevent overflow; and (ii) Give to the UAV crew a prompt warning if a transfer malfunction occurs.	x	x					
78	1729	b	U1729 USAR.U1729 Fuel quantity and oil quantity data (b) Oil quantity data. There must be a means to indicate in the UCS the quantity of oil in each tank in flight, if there is an oil transfer system or a reserve oil supply system.	x						

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79	1730	a	USAR.U1730 Automatic take-off system or automatic landing system data For UAV equipped with an automatic take-off system or an automatic landing system or both, the following data must be continuously displayed to the UAV crew during the respective flight phases in compliance with USAR.1490 (d) (a) the UAV flightpath,	x						
80	1730	b	USAR.U1730 Automatic take-off system or automatic landing system data For UAV equipped with an automatic take-off system or an automatic landing system or both, the following data must be continuously displayed to the UAV crew during the respective flight phases in compliance with USAR.1490 (d) (b) the deviation between the UAV flightpath and the planned flightpath.	x						
81	1731	a	USAR.U1731 General (See AMC.1731) (a) Each control in the UCS must be located and (except where its function is obvious) identified to provide convenient operation and to prevent confusion and inadvertent operation.	x			x	x		
82	1731	b	USAR.U1731 General (See AMC.1731) (b) The controls must be located and arranged so that the UAV crew, when at their workstation have full and unrestricted movement of each control without interference from either their clothing or the UCS structure.	x			x			
83	1731	c	USAR.U1731 General (See AMC.1731) (c) The control system must be designed so that the controls needed for continued safe flight and landing remain available to the UAV crew in normal, abnormal and emergency conditions.	x						
84	1732	a	USAR.U1732 Safety critical controls (a) The design, location and accessibility of safety critical controls (i.e. requiring immediate action of the UAV crew) must be compatible with a rapid and precise reaction of the UAV crew during emergency operation.	x			x			
85	1732	b	USAR.U1732 Safety critical controls (b) Where the interface with UAV crew is based on a "pull down menus" architecture, (1) the controls that necessitate a prompt reaction of the UAV crew must be accessible at the first level of the pull down menus, (2) otherwise, safety critical controls in the UCS must have dedicated knobs or levers.	x						
86	1732	c	USAR.U1732 Safety critical controls (c) Safety critical controls must be designed to prevent the possibility of confusion and subsequent inadvertent operation.	x			x			

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87	1733	a	U1733 USAR.U1733 Conventional controls and indicators (a) Where conventional flying controls and indicators are employed, the form, the location and layout must ensure safe operation.	x			x			
88	1733	b	U1733 USAR.U1733 Conventional controls and indicators (b) For each conventional indicators in the UCS (1) When markings are on the cover glass of the indicator, there must be means to maintain the correct alignment of the glass cover with the face of the dial, (2) Each arc and line must be wide enough and located to be clearly visible to the UAV crew, (3) All related indicators must be calibrated in compatible units.	x						
89	1733	c	U1733 USAR.U1733 Conventional controls and indicators (c) If conventional flap and landing gear control knobs are used by the UAV crew, they must conform to the general shapes (but not necessarily the exact sizes or specific proportions) in the following figure: (Figure omitted)	x			x			
90	1733	d	U1733 USAR.U1733 Conventional controls and indicators (d) If conventional powerplant control knobs are used by the UAV crew, they must conform to the general shapes (but not necessarily the exact sizes of specific proportions) in the following figures (Figures omitted)	x			x			
91	1735		USAR.U1735 Motion and representation of controls UCS controls must be designed so that they, or their representations, operate intuitively for the UAV crew. The representation of these controls must be similar to conventional flight controls that exist in manned aircraft.	x			x			
92	1741	b	USAR.U1741 UCS flight controls (b) The design of UCS flight controls must allow the UAV crew to rapidly and easily change the following flight parameters of the UAV (1) heading or track, (2) altitude, and, (3) airspeed.	x						
93	1742	b	USAR.U1742 Flight termination system control When the UAV is equipped with a flight termination system, (b) Its controls must be arranged and identified such that they are readily available and accessible. The use of these controls must be intuitive and minimise the possibility of confusion and subsequent inadvertent operation	x			x			
94	1742	c	USAR.U1742 Flight termination system control When the UAV is equipped with a flight termination system, (c) Two distinct actions of the UAV crew are required to initiate the flight termination command.	x						

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95	1743	a	USAR.U1743 Fuel controls (a) There must be a means readily available to allow the UAV crew to rapidly shut off, in flight, the fuel to each engine individually.	x						
96	1743	b	USAR.U1743 Fuel controls (b) In addition, there must be means to (1) Prevent inadvertent operation of each shut-off valve; and (2) Allow appropriate UAV crew to reopen each valve rapidly after it has been closed.	x			x			
97	1745	b	USAR.U1745 Fuel jettisonning control (b) There must be an indication compliant with USAR.1831, adjacent to the jettison control to warn the UAV crew against jettisoning fuel while any means (including flaps, slots and slats) of changing the airflow across or around the wings is in use, unless it is shown that using such means does not adversely affect fuel jettisoning.	x						
98	1745	c	USAR.U1745 Fuel jettisonning control (c) Fuel jettisoning control must be designed to prevent inadvertent operation	x			x			
99	1747		USAR.U1747 Air induction control Each automatic alternate air induction door must have an override means accessible to the UAV crew.	x			x			
100	1751		USAR.U1751 Engine and APU controls The controls necessary to perform all functions in normal, abnormal and emergency modes must be provided to the UAV crew taking into account the level of automation substantiated by the flight control system.	x			x			
101	1753	b	USAR.U1753 Ignition switches (See AMC.1753 (b)) (b) There must be means readily available to the UAV crew to quickly shut off all ignition circuits on multi- engine UAV.	x			x			
102	1753	c	USAR.U1753 Ignition switches(See AMC.1753 (b)) (c) Ignition switches must have safeguards to prevent inadvertent operation.	x			x			
103	1755	a	USAR.U1755 Mixture controls When mixture control is provided, there shall be a separate control for each engine. Each mixture control must be designed to prevent confusion and inadvertent operation. (a) The controls must be grouped and arranged to allow (1) Separate control of each engine; and (2) Simultaneous control of all engines.	x			x			

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104	1755	b	USAR.U1755 Mixture controls When mixture control is provided, there shall be a separate control for each engine. Each mixture control must be designed to prevent confusion and inadvertent operation. (b) The control must require a separate and distinct operation to move the control towards lean or shut-off position.	x			x			
105	1757	a	USAR.U1757 Propeller speed and pitch controls (a) Where propeller speed or pitch controls exist, they must be grouped and arranged to allow (1) Separate control of each propeller; and (2) Simultaneous control of all propellers.	x			x			
106	1757	b	USAR.U1757 Propeller speed and pitch controls (b) The controls must allow ready synchronisation of all propellers on multi-engine UAV.	x			x			
107	1759		USAR.U1759 Propeller feathering controls Where propeller feathering controls exist, it must be possible to feather each propeller separately. Each control must have means to prevent inadvertent operation.	x			x			
108	1761		USAR.U1761 Turbine engine reverse thrust and propeller pitch settings below the flight regime For turbine engine installations, each control for reverse thrust and for propeller pitch settings, where existing, below the flight regime must have means to prevent its inadvertent operation. The means must have a positive lock or stop at the flight idle position and must require a separate and distinct operation by the UAV crew to displace the control from the flight regime (forward thrust regime for turbojet powered UAV).	x			x			
109	1763		USAR.U1763 Carburettor air temperature controls Where existing, there must be a separate carburettor air temperature control for each engine.	x			x			
110	1765	a	USAR.U1765 Shut-off controls (a) For each UAV function that can be shut-off from the UCS, there must be a means to prevent inadvertent operation of the shut-off control. In addition, there must be a means to restore the function after it has been shut-off.	x			x			
111	1769		USAR.U1769 “Abort” control for automatic take-off system or automatic landing system (See AMC.1769) Where a UAV System is equipped with an automatic take-off system or an automatic landing system there must be a means readily available to the UAV crew to rapidly abort the take-off phase or the landing phase in compliance with USAR.1492	x			x			

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112	1785		USAR.U1785 Warning, caution and advisory information colour code The warning, caution or advisory information installed in the UCS, must, unless otherwise approved by the Certifying Authority, be (a) Red, for warning information (information indicating a hazard which may require immediate corrective action); (b) Amber, for caution information (information indicating the possible need for future corrective action); (c) Green, for safe operation information; and (d) Any other colour, including white, for information not described in sub-paragraphs (a) to (c), provided the colour differs sufficiently from the colours prescribed in sub-paragraphs (a) to (c) to avoid possible confusion. (e) Effective under all probable UCS lighting conditions.	x	x					
113	1787	a	USAR.U1787 UAV automatic diagnostic and monitoring (See AMC.1787 (a)) (a) The UCS must include an automatic diagnostic and monitoring capability for the status of the UAV System and provide to the UAV crew appropriate warning indication.	x	x					
114	1787	b	USAR.U1787 UAV automatic diagnostic and monitoring (See AMC.1787 (a)) (b) Guidance for corrective actions shall be provided either automatically or in the UAV System Flight Manual.	x	x					
115	1788		USAR.U1788 Degraded modes of operation warning The UCS must be configured to ensure that the UAV crew is informed of any abnormal or emergency mode, including cases in which there is an automatic switching to an alternate mode of operation.	x	x					
116	1789	a	U1789 USAR.U1789 Low speed warning (a) There must be a clear and distinctive low speed warning in the UCS, with the flaps and landing gear in any normal position in straight and turning flight, in accordance with the following (1) It should not be possible to command from the UCS speed values lower than the minimum steady flight speed (except take-off and landing) allowed by the flight envelope protection maintained by the flight control system. (2) Adequate low speed cues and warning should be provided in the UCS when approaching the stalling speed or Vmin DEMO if the stalling is not to be demonstrated. (3) During the tests required by USAR.201 the low speed warning must begin at a speed exceeding the stalling spped or Vmin DEMO (if the stalling is not to be demonstrated) by a margin of not less than 5 knots and must continue as long as the condition is true. (4) When following the procedures of USAR.1585, the low speed warning must not occur during a take-off with all engines operating, a take-off continued with one engine inoperative or during an approach to landing.	x	x					
117	1789	b	U1789 USAR.U1789 Low speed warning (b) The low speed warning must be furnished by a device that will give clearly distinguishable indication. A visual low speed warning device that requires the attention of the UAV crew within the UCS is not acceptable by itself.	x	x					

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118	1790		USAR.U1790 UAV mode of control indicator There must be a means in the UCS to indicate to the UAV crew the active mode of control of the flight control system. If semi-automatic mode is engaged, a specific indicator must be activated in clear view of the UAV crew.	x						
119	1791		USAR.U1791 Wing flaps position indicator Where a UAV is equipped with wing flaps, there must be a wing flap position indicator in the UCS	x						
120	1793	a	USAR.U1793 Landing gear position indicator and warning (See AMC.1793 (b)) (a) Position indicator. If a retractable landing gear is used, there must be a landing gear position indicator in the UCS to inform the UAV crew that each gear is secured in the extended (or retracted) position.	x						
121	1793	b	USAR.U1793 Landing gear position indicator and warning (See AMC.1793 (b)) (b) Landing gear warning. If a retractable landing gear is used, an aural or equally effective landing gear warning devices must be provided to inform the crew of an imminent landing without the gear fully extended and locked	x	x					
122	1795		USAR.U1795 Pressurised compartment indicator (See AMC.1795) Where a UAV is equipped with a pressurised compartment, there must be a warning to indicate when the safe pressure differential is exceeded.	x	x					
123	1797		USAR.U1797 Fuel pumps warning Where a UAV is equipped with fuel pumps, if both the main pump and emergency pump operate continuously, there must be a means to indicate to the UAV crew a malfunction of either pump.	x	x					
124	1799		USAR.U1799 Air induction indicator Where a UAV is equipped with an air induction door, each alternate air induction door must have a means to indicate to the UAV crew when it is not closed.	x	x					
125	1801		USAR.U1801 Battery discharge warning (See AMC.1801) There must be means to warn the UAV crew if malfunctioning of any part of the electrical system is causing the continuous discharge of any battery which is relevant for safe flight.	x	x					
126	1803	i	USAR.U1803 Indicators for power-assisted valves in the powerplant (See AMC.1803) For power-assisted valves in the powerplant, there must be a means in the UCS to indicate to the UAV crew when the valve (i) is in the fully open or fully closed position	x	x					

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127	1803	ii	USAR.U1803 Indicators for power-assisted valves in the powerplant (See AMC.1803) For power-assisted valves in the powerplant, there must be a means in the UCS to indicate to the UAV crew when the valve (ii) is moving between the fully open and fully closed position.	x	x					
128	1805		USAR.U1805 Shut off valves indicator Where a UAV is equipped with power operated shut off valves they must have means to indicate to the UAV crew when the valve has reached the selected position	x	x					
129	1809	a	USAR.U1809 UAV electrical systems warning and indicator (See AMC.1809) (a) There must be a means to give immediate warning to the UAV crew of a failure of any UAV electrical power generating device.		x					
130	1809	b	USAR.U1809 UAV electrical systems warning and indicator (See AMC.1809) (b) A means must exist in the UCS to indicate to the UAV crew the electric power system quantities essential for safe operation	x	x					
131	1809	c	USAR.U1809 UAV electrical systems warning and indicator (See AMC.1809) (c) A warning which is unambiguous and clearly distinguishable to the UAV crew shall be immediately provided for any UCS power supply failure which could result in an unsafe condition in any phase of UAV flight, including landing and take off.		x					
132	1811		USAR.U1811 De-icer boot system indicator If certification with ice protection provisions is desired and a de-icer boot system is installed there must be means to indicate to the UAV crew that the de-icer boot system is functioning normally.	x	x					
133	1813		USAR.U1813 Hydraulic systems indicator There must be a means to indicate to the UAV crew the pressure in each hydraulic system which supplies two or more primary functions.	x	x					
134	1817		USAR.U1817 Fire protection warning If action by the UAV crew is required to prevent or extinguish fire (e.g. equipment shut-down or actuation of a fire extinguisher) in the UAV, quick acting means must be provided to immediately alert the UAV crew in the UCS.	x	x					
135	1819		USAR.U1819 Pitot heat indicator If a pitot heating system is installed to meet the requirements specified in USAR.1323 (b), an indication system must be provided to indicate to the UAV crew when that pitot heating system is not operating.	x	x					
136	1821		USAR.U1821 UCS Power distribution indicator (See AMC.1821) Each UCS power distribution circuit must have an indicator in the UCS to indicate when power is below safe minimum.	x	x					

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137	1825		USAR.U1825 Flight control system lock warning If there is a device on the UAV to lock the flight controls as mentioned in USAR.679, the UAV crew must be warned when the device is engaged.	x	x					
138	1827		USAR.U1827 Flightpath deviation warning Where automatic flight control modes as defined in USAR.1329 are activated, a warning must be displayed when excessive deviation from the pre-programmed flightpath occurs. The acceptable deviation shall be agreed with the Certifying Authority.	x	x					
139	1829		USAR.U1829 UAV safety status indication An indication must be provided in the UCS which shows the safety status of the UAV so approaching ground staff can be notified if the UAV is in an unsafe state (e.g. radiation hazard present, laser energized, etc.).	x	x					
140	1831	a	USAR.U1831 General Each information, markings and placard displayed in the UCS prescribed in USAR.1541 (a) must be (a) continuously displayed in a conspicuous place relative to the object, indicator or data it is assumed to be associated with;	x						
141	1831	b	USAR.U1831 General Each information, markings and placard displayed in the UCS prescribed in USAR.1541 (a) must be (b) easily interpreted unambiguously by the UAV crew.	x						
142	1835	a	USAR.U1835 Airspeed data (a) If required to maintain safe flight, each airspeed data must be marked as specified in sub-paragraph (b), with the marks located at the corresponding indicated airspeeds.	x						
143	1835	b	USAR.U1835 Airspeed data (b) The following markings must be made: (1) For the never-exceed speed VNE, a red line. (2) For the caution range, a yellow band extending from the red line specified in sub-paragraph (1) to the upper limit of the green band specified in sub-paragraph (3) . (3) For the normal operating range, a green band with the lower limit at VS1 with maximum weight and with landing gear and wing flaps retracted, and the upper limit at the maximum structural cruising speed VNO established under USAR.1505 (b). (4) For the flap operating range, a white band with the lower limit at VS0 at the maximum weight and the upper limit at the flaps-extended speed VFE established under USAR.1511. (5) For multi-engine powered UAV, for the speed at which compliance has been shown with USAR.69 (b) relating to rate of climb, at maximum weight and at sea-level, a blue line. (6) For multi-engine powered UAV, for the maximum value of minimum control speed (one or more engine inoperative) determined under USAR.149 (b), VMC, a red line.	x						

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144	1835	c	USAR.U1835 Airspeed data (c) If VNE or VNO vary with altitude, there must be means to indicate to the UAV crew the appropriate limitations throughout the operating altitude range.	x	x					
145	1835	d	USAR.U1835 Airspeed data (d) Sub-paragraphs (b) (1) to (b) (3) and sub-paragraph (c) do not apply to UAV for which a maximum operating speed VMO/MMO is established under USAR.1505 (c). For those UAV System there must either be a maximum allowable airspeed indication showing the variation of VMO/MMO with altitude or compressibility limitations (as appropriate), or a red line marking for VMO/MMO must be made at lowest value of VMO/MMO established for any altitude up to the maximum operating altitude for the UAV.	x						
146	1835	e	USAR.U1835 Airspeed data (e) There must be an airspeed indication in clear view of the UAV crew and as close as practicable to the airspeed indicator. This indication must list (1) The operating manoeuvring speed, Vo; (2) The maximum landing gear operating speed VLO; and (3) For multi-engine-powered UAV, the maximum value of the minimum control speed (one or more engine inoperative) determined under USAR.149 (b), VMC.	x						
147	1839	a	USAR.U1839 Powerplant and auxiliary power unit data For each required powerplant and auxiliary power unit, data shall be available in the UCS, as appropriate to the type of powerplant. (a) Each maximum and if applicable, minimum safe operating limit must be marked with a red radial or a red line;	x						
148	1839	b	USAR.U1839 Powerplant and auxiliary power unit data For each required powerplant and auxiliary power unit, data shall be available in the UCS, as appropriate to the type of powerplant. (b) Each normal operating range must be marked with a green arc or green line not extending beyond the maximum and minimum safe limits;	x						
149	1839	c	USAR.U1839 Powerplant and auxiliary power unit data For each required powerplant and auxiliary power unit, data shall be available in the UCS, as appropriate to the type of powerplant. (c) Each take-off and precautionary range must be marked with a yellow arc or a yellow line; and	x						
150	1839	d	USAR.U1839 Powerplant and auxiliary power unit data For each required powerplant and auxiliary power unit, data shall be available in the UCS, as appropriate to the type of powerplant. (d) Each engine, auxiliary power unit or propeller range that is restricted because of excessive vibration stresses must be marked with red arcs or red lines.	x						

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151	1841		USAR.U1841 Oil quantity data Each oil quantity data displayed in the UCS must be marked in sufficient increments to indicate readily and accurately the quantity of oil.	x						
152	1843		USAR.U1843 Fuel quantity data A red line must be marked on each data displayed in the UCS at the calibrated zero reading, as specified in USAR.1337 (b)(1).	x						
153	1845	a	U1845 USAR.U1845 Control markings (See AMC.1845 (e)(2)) (a) Every control, switch, knob or lever in the UCS must be plainly marked as to its function and method of operation.	x						
154	1845	b	U1845 USAR.U1845 Control markings (See AMC.1845 (e)(2)) (b) Each remote control, as defined in USAR.1741, must be suitably marked.	x						
155	1845	c	U1845 USAR.U1845 Control markings (See AMC.1845 (e)(2)) (c) For powerplant fuel controls (1) Each fuel tank selector control must be marked to indicate the position corresponding to each tank and to each existing cross feed position; (2) If safe operation requires the use of any tanks in a specific sequence, that sequence must be marked on or near the selector for those tanks; (3) The conditions under which the full amount of usable fuel in any restricted usage fuel tank can safely be used must be stated adjacent to the selector valve for that tank; and (4) Each valve control for any engine of a multi-engine UAV must be marked to indicate the position corresponding to each engine controlled. (5) For fuel jettisonning control, see USAR.1745 (b).	x						
156	1845	d	U1845 USAR.U1845 Control markings (See AMC.1845 (e)(2)) (d) Usable fuel capacity must be marked as follows: (1) For fuel systems having no selector controls, the usable fuel capacity of the system must be indicated near the fuel quantity data displayed in the UCS (2) For fuel systems having selector controls, the usable fuel capacity available at each selector control position must be indicated near the selector control.	x						

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157	1845	e	U1845 USAR.U1845 Control markings (See AMC.1845 (e)(2)) (e) For accessory, auxiliary and emergency controls (1) If retractable landing gear is used, the indicator required by USAR.1793 must be marked so that the UAV crew can, at any time, ascertain that the wheels are secured in the extreme positions; and (2) Each emergency control must be red and must be marked as to method of operation. (3) No control other than an emergency control shall be this colour.	x			x			
158	1849	a	USAR.U1849 Operating limitations indications (a) There must be an indication in clear view of the UAV crew stating in the UCS that the UAV must be operated in accordance with the UAV System Flight Manual;	x						
159	1849	b	USAR.U1849 Operating limitations indications (b) There must be an indication in clear view of the UAV crew that specifies the kind of operations to which the operation of the UAV is limited or from which it is prohibited under USAR.1525.	x						
160	1881	a	USAR.U1881 UAV hand over between two UCS (See AMC.1881 (b), AMC.1881 (c) and AMC.1881 (d)) Where the UAV System is designed for UAV hand over between two UCS: (a) The in-control UCS must be clearly identified to all UAV crew members.	x						
161	1881	b	USAR.U1881 UAV hand over between two UCS (See AMC.1881 (b), AMC.1881 (c) and AMC.1881 (d)) Where the UAV System is designed for UAV hand over between two UCS: (b) Positive control must be maintained during handover.	x				x		
162	1881	c	USAR.U1881 UAV hand over between two UCS (See AMC.1881 (b), AMC.1881 (c) and AMC.1881 (d)) Where the UAV System is designed for UAV hand over between two UCS: (c) The command and control functions that are transferred during handover must be approved by the Certifying Authority and defined in the UAV System Flight Manual.	x				x		
163	1881	d	USAR.U1881 UAV hand over between two UCS (See AMC.1881 (b), AMC.1881 (c) and AMC.1881 (d)) Where the UAV System is designed for UAV hand over between two UCS: (d) Handover between two UCS must not lead to unsafe conditions.	x				x		
164	1881	e	USAR.U1881 UAV hand over between two UCS (See AMC.1881 (b), AMC.1881 (c) and AMC.1881 (d)) Where the UAV System is designed for UAV hand over between two UCS: (e) The in-control UCS must have the required functionality to accommodate emergency situations.	x				x		

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165	1883	a	USAR.U1883 Command and control of multiple UAV Where a UCS is designed to command and control multiple UAV, the following requirements apply: (a) The minimum UAV crew must be established so that it is sufficient for safe operation of each vehicle in compliance with USAR.1704 and emergency conditions.	x				x		
166	1883	b	USAR.U1883 Command and control of multiple UAV Where a UCS is designed to command and control multiple UAV, the following requirements apply: (b) The UAV data shall be displayed in the UCS in a manner that prevents confusion and inadvertent operation.	x				x		
167	1883	c	USAR.U1883 Command and control of multiple UAV Where a UCS is designed to command and control multiple UAV, the following requirements apply: (c) The UAV controls must be available to the UAV crew for each UAV of which it has command and control in a manner that prevents confusion and inadvertent operation.	x				x		
168	1883	d	USAR.U1883 Command and control of multiple UAV Where a UCS is designed to command and control multiple UAV, the following requirements apply: (d) All indicators and warnings must be available to the UAV crew for each UAV in a manner that prevents confusion and inadvertent operation.	x	x			x		
169	1885	a	U1885 USAR.U1885 UAV handover within the same UAV control station (See AMC.1885 (b) and AMC.1885 (d)) Where the UCS has more than one workstation designed for controlling the UAV: (a) The in-control workstation must be clearly identified to all UAV crew members.	x						
170	1885	b	U1885 USAR.U1885 UAV handover within the same UAV control station (See AMC.1885 (b) and AMC.1885 (d)) Where the UCS has more than one workstation designed for controlling the UAV: (b) Positive control must be maintained during handover.	x						
171	1885	d	U1885 USAR.U1885 UAV handover within the same UAV control station (See AMC.1885 (b) and AMC.1885 (d)) Where the UCS has more than one workstation designed for controlling the UAV: (d) Handover within the same UAV control station must not lead to unsafe conditions.	x						

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172	1885	e	U1885 USAR.U1885 UAV handover within the same UAV control station (See AMC.1885 (b) and AMC.1885 (d)) Where the UCS has more than one workstation designed for controlling the UAV: (e) The in-control workstation must have the required functionality to accommodate emergency situations.	x				x		
173	1887		USAR.U1887 Multiple UAV monitoring Where the UCS is designed to monitor multiple UAV, there must be a means to clearly indicate to the UAV crew the UAV over which it has command and control.	x						

APPENDIX D – Basis of Certification (HF Review not required)

ID	USAR Paragraph	Sub-Paragraph	Requirements with Human Factors Implication DTAES 6-7 Specialist Review Not Required STANAG 4671 - Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR)
1	55	d2	USAR.55 Accelerate-stop Distance or Critical Field Length (See AMC.55) (d) The following shall be included in the ground roll calculation (2) System and UAV crew reaction time to sense a failure and make the appropriate response to the failure.
2	253	b	USAR.253 High Speed Characteristics If a maximum operating speed VM0/MM0 is established under USAR.1505 (c), the following speed increase and recovery characteristics must be met (b) Allowing for UAV crew or flight control system reaction time after occurrence of effective inherent or artificial speed warning specified in USAR.1723, it must be shown that the UAV can be recovered to a normal attitude and its speed reduced to VMO/MMO without (1) Exceeding VD/MD, the maximum speed shown under USAR.251, or the structural limitations; or (2) Buffeting that would impair the UAV ability for recovery.
3	290	d	USAR.U290 UAV performance before parachute landing (d) The normal and emergency parachute landing sequence must be precisely defined in the UAV System Flight Manual including for normal landing the approach phase and the go around procedure.
4	599	c	U599 USAR.U599 Installation of the parachute in the airframe Consideration shall be given to the following aspects of the parachute installation: (c) Adequate means should be provided to permit the close examination of the parachute and other system components to ensure proper functioning, alignment, lubrication, and adjustment during the required inspection of the system.
5	611		USAR.611 Accessibility provisions (See AMC.611) For each part that requires maintenance, inspection, or other servicing, appropriate means must be incorporated into the UAV design to allow such servicing to be accomplished. The inspection means for each item must be appropriate to the inspection interval for the item.
6	679	b1	USAR.679 Primary or secondary flight controls lock If there is a device to lock the flight controls (b) There must be a means to (1) Warn the ground staff when the device is engaged;
7	685	d	USAR.685 Control system details (d) Each element of the flight control system must have design features, or must be distinctively and permanently marked, to minimise the possibility of incorrect assembly that could result in malfunctioning of the control system.
8	697	b	USAR.697 Wing flap controls (b) The rate of movement of the flaps in response to the operation of the UAV crew’s control or flight control system must give satisfactory flight and performance characteristics under steady or changing conditions of airspeed, engine power or thrust and attitude.
9	773	b	USAR.733 Tyres (b) If specially constructed tyres are used, the wheels must be plainly and conspicuously marked to that effect. The markings must include the make, size, number of plies and identification marking of the proper tyre.

ID	USAR Paragraph	Sub-Paragraph	Requirements with Human Factors Implication DTAES 6-7 Specialist Review Not Required STANAG 4671 - Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR)
10	783	e1	783 USAR.783 Doors, covers and hatches (e) Each external door and hatch must comply with the following requirements: (1) There must be a means to lock and safeguard each external door and hatch, including payload and service type doors, against inadvertent opening in flight, as a result of mechanical failure or failure of a single structural element, either during or after closure.
11	783	e2	783 USAR.783 Doors, covers and hatches (e) Each external door and hatch must comply with the following requirements: (2) There must be a provision for direct visual inspection of the locking mechanism to determine if the external door or hatch, for which the initial opening movement is not inward, is fully closed and locked. The provisions must be discernible, under operating lighting conditions, by inspection and maintenance staff using a flashlight or an equivalent lighting source.
12	881	e4	USAR.U881 Parachute design (See AMC.881 (a)) Where a UAV is designed to be recovered by parachute, (e) Information concerning parachute assemblies and components must be furnished in the UAV System documentation, including : (4) instruction for packing method and inspection at approved intervals
13	901	b2	USAR.901 Installation (See AMC.901) (b) Each powerplant installation must be constructed and arranged to (2) Be accessible for necessary inspections and maintenance,
14	901	c	USAR.901 Installation (See AMC.901) (c) Engine covers, cowls and nacelles must be easily removable or openable by the inspection and maintenance staff to provide adequate access to and exposure of the engine compartment for the required pre- flight checks.
15	903	d1	USAR.903 Engines and auxiliary power units See AMC.903(a) and AMC.903(f) (d) Starting and stopping (1) Any techniques and associated limitations for engine starting and stopping must be established and included in the UAV System Flight Manual and in the UAV Maintenance Manual.
16	905	f	USAR.905 Propellers (See AMC.905 (d), AMC.905 (e) and AMC.905 (g)) (f) Each pusher propeller must be marked so that the disc is conspicuous under normal daylight ground conditions.
17	953	b3	USAR.953 Fuel system independence (b) If a single fuel tank (or series of fuel tanks interconnected to function as a single fuel tank) is used on a multi-engine UAV, the following must be provided: (3) Filler caps designed to minimize the probability of incorrect installation or inflight loss.
18	955	f2ii	955 USAR.955 Fuel flow (f) Turbine engine fuel systems. Each turbine engine fuel system must provide at least 100% of the fuel flow required by the engine under each intended operation condition and manoeuvre. The conditions may be simulated in a suitable mock-up. This flow must (2) For multi-engine UAV, notwithstanding the lower flow rate allowed by sub-paragraph (d), be automatically uninterrupted with respect to any engine until all the fuel scheduled for use by that engine has been consumed. In addition, (ii) The fuel system design must clearly indicate the engine for which fuel in any tank is scheduled.

ID	USAR Paragraph	Sub-Paragraph	Requirements with Human Factors Implication DTAES 6-7 Specialist Review Not Required STANAG 4671 - Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR)
19	963	c	USAR.963 Fuel tanks: general (c) Each integral fuel tank must have adequate facilities for interior inspection and repair.
20	971	c	USAR.971 Fuel tank sump (c) Where required by the Certifying Authority, each reciprocating engine fuel system must have a sediment bowl or chamber that is accessible for drainage; has a capacity of 30 cm3 (1 fl oz) for every 75.7 litres (16.7 Imperial gallon/20 US-gallon) of fuel tank capacity; and each fuel tank outlet is located so that, in the normal flight attitude, water will drain from all parts of the tank except the sump to the sediment bowl or chamber.
21	973	a	USAR.973 Fuel tank filler connection (See AMC.973) (a) Each fuel tank filler connection must be marked as prescribed in USAR.1557 (c).
22	977	d	USAR.977 Fuel tank outlet (d) Each strainer must be accessible for inspection and cleaning.
23	979	b	USAR.979 Pressure fuelling systems For pressure fuelling systems, the following applies: (b) An automatic shut-off means must be provided to prevent the quantity of fuel in each tank from exceeding the maximum quantity approved for that tank. This means must allow checking for proper shut-off operation before each fuelling of the tank;
24	995	e	995 USAR.995 Fuel valves and controls (See AMC.995) (see also USAR.1743 Fuel controls) (e) Each fuel valve handle and its connections to the valve mechanism must have design features that minimise the possibility of incorrect installation.
25	995	f	995 USAR.995 Fuel valves and controls (See AMC.995) (see also USAR.1743 Fuel controls) (f) Each valve must be constructed, or otherwise incorporate provisions, to preclude incorrect assembly or connection of the valve.
26	995	g1	995 USAR.995 Fuel valves and controls (See AMC.995) (see also USAR.1743 Fuel controls) (g) If fuel tanks valves are installed on the UAV for ground procedures purpose, these fuel tank selector valves must (1) Require a separate and distinct action to place the selector in the “OFF” position;
27	995	g2	995 USAR.995 Fuel valves and controls (See AMC.995) (see also USAR.1743 Fuel controls) (g) If fuel tanks valves are installed on the UAV for ground procedures purpose, these fuel tank selector valves must (2) Have the tank selector positions located in such a manner that it is impossible for the selector to pass through the “OFF” position when changing from one tank to another.
28	997	a	USAR.997 Fuel strainer or filter (See AMC.997) There must be a fuel strainer or filter between the fuel tank outlet and the inlet of either the fuel metering device or an engine driven positive displacement pump, whichever is nearer the fuel tank outlet. This fuel strainer or filter must (a) Be accessible for draining and cleaning and must incorporate a screen or element which is easily removable;
29	997	b	USAR.997 Fuel strainer or filter (See AMC.997) There must be a fuel strainer or filter between the fuel tank outlet and the inlet of either the fuel metering device or an engine driven positive displacement pump, whichever is nearer the fuel tank outlet. This fuel strainer or filter must (b) Have a sediment trap and drain except that it need not have a drain if the strainer or filter is easily removable for drain purposes;

ID	USAR Paragraph	Sub-Paragraph	Requirements with Human Factors Implication DTAES 6-7 Specialist Review Not Required STANAG 4671 - Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR)
30	999	b2i	999 USAR.999 Fuel system drains (See AMC.999) (b) Each drain required by sub-paragraph (a) and USAR.971 must (2) Have a drain valve (i) That has manual or automatic means for positive locking in the closed position;
31	999	b2ii	999 USAR.999 Fuel system drains (See AMC.999) (b) Each drain required by sub-paragraph (a) and USAR.971 must (2) Have a drain valve (ii) That is readily accessible;
32	999	2iii	999 USAR.999 Fuel system drains (See AMC.999) (b) Each drain required by sub-paragraph (a) and USAR.971 must (2) Have a drain valve (iii) That can be easily opened and closed;
33	999	2iv	999 USAR.999 Fuel system drains (See AMC.999) (b) Each drain required by sub-paragraph (a) and USAR.971 must (2) Have a drain valve (iv) That allows the fuel to be caught for examination;
34	999	b2v	999 USAR.999 Fuel system drains (See AMC.999) (b) Each drain required by sub-paragraph (a) and USAR.971 must (2) Have a drain valve (v) That can be observed for proper closing; and
35	1019	a3	USAR.1019 Oil strainer or filter (a) Each turbine engine installation must incorporate an oil strainer or filter through which all of the engine oil flows and which meets the following requirements: (3) The oil strainer or filter, unless it is installed at an oil tank outlet, must incorporate a means to indicate contamination before it reaches the capacity established in accordance with sub-paragraph (2)
36	1021	a	USAR.1021 Oil system drains A drain or drains must be provided to allow safe drainage of the oil system. Each drain must (a) Be accessible;
37	1021	b	USAR.1021 Oil system drains A drain or drains must be provided to allow safe drainage of the oil system. Each drain must (b) Have drain valves, or other closures, employing manual or automatic shut-off means for positive locking in the closed position;

ID	USAR Paragraph	Sub-Paragraph	Requirements with Human Factors Implication DTAES 6-7 Specialist Review Not Required STANAG 4671 - Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR)
38	1021	c	USAR.1021 Oil system drains A drain or drains must be provided to allow safe drainage of the oil system. Each drain must (c) Be located or protected to prevent inadvertent operation.
39	1061	f3	1061 USAR.1061 Installation (f) Drains. There must be an accessible drain that (3) Has means to positively lock it closed.
40	1101	b	USAR.1101 Induction air preheater design Each exhaust-heated, induction air preheater must be designed and constructed to (b) Allow inspection of the exhaust manifold parts that it surrounds; and
41	1101	c	USAR.1101 Induction air preheater design Each exhaust-heated, induction air preheater must be designed and constructed to (c) Allow inspection of critical parts of the preheater itself.
42	1125	2	USAR.1125 Exhaust heat exchangers For reciprocating engine-powered UAV, each exhaust heat exchanger must be constructed and installed to withstand the vibration, inertia and other loads that it may be subjected to in normal operation. In addition (2) There must be means for inspection of critical parts of each exchanger.
43	1189	a1	USAR.1189 Shut-off means (See AMC.1189 (a) (5)) (a) For each multi-engined UAV the following apply: (1) Each engine installation must have means to shut off or otherwise prevent hazardous quantities of fuel, oil, de-icing fluid and other flammable liquids from flowing into, within, or through any engine compartment, except in lines, fittings and components forming an integral part of an engine.
44	1193	b	USAR.1193 Cowling and nacelle (See AMC.1193) (b) There must be means for rapid and complete drainage of each part of the cowling in the normal ground and flight attitudes. No drain may discharge where it will cause a fire hazard.
45	1307	g	USAR.U1307 Environmental control system (ECS) (See AMC.1307) Cooling must be provided for flight critical equipment as required for it to meet its performance and reliability for the intended lifetime. g) ECS normal and emergency procedures shall be included in the UAV System flight manual.
46	1329	e	USAR.1329 Flight control system (See AMC.1329 (e), AMC.1329 (i) and AMC.1329 (j)) The flight control system comprises sensors, actuators, computers and all those elements of the UAV System, necessary to control the attitude, speed and trajectory of the UAV. The flight control system must meet the following: (e) The flight control system must be designed and adjusted so that, within the range of adjustment (if any) available to UAV crew, it cannot produce an unsafe condition.

ID	USAR Paragraph	Sub-Paragraph	Requirements with Human Factors Implication DTAES 6-7 Specialist Review Not Required STANAG 4671 - Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR)
47	1337	c	1337 USAR.1337 Powerplant installation measuring device (c) Fuel flowmeter system. If a fuel flowmeter system is installed, each metering component must have a means to by-pass the fuel supply if malfunctioning of that component severely restricts fuel flow.
48	1351	c3	1351 USAR.1351 General (See AMC.1351 (a)(2)) (c) UAV Generating system. There must be at least one electrical power generating device if the electrical system supplies power to load circuits essential for safe operation. In addition (3) Automatic means must be provided to prevent either damage to any electrical power generating device, or adverse effects on the UAV electrical system, due to reverse current. A means must also be provided to disconnect each electrical power generating device from the battery and the other electrical power generating device(s).
49	1351	f	1351 USAR.1351 General (See AMC.1351 (a)(2)) (f) External power. If provisions are made for connecting external power to the UAV and that external power can be electrically connected to equipment other than that used for engine starting, means must be provided to ensure that no incompatible external power supply e.g. a reverse polarity, or a reverse phase sequence, can supply power to the UAV's electrical system. The external power connection must be located so that its use will not result in a hazard to the UAV or ground crew. The location should be such that there is no detrimental effect to the UAV structure.
50	1353	h	1353 USAR.1353 Storage battery or emergency power supply design and installation (h) In the event of a complete loss of the primary electrical power generating system, any battery or emergency power supply must be capable of providing enough electrical power to those loads that are essential to perform emergency procedures as defined in USAR.1413 during the associated time duration. This time duration includes the time needed for the UAV crew to recognise the loss of generated power and to take appropriate action.
51	1361	a	USAR.1361 Master switch arrangement (See AMC.1361) (a) There must be a master switch arrangement on the UAV to allow ready disconnection by ground staff of each electric power source from the power distribution systems when the UAV is on the ground and except as provided in sub-paragraph (b).
52	1365	c	USAR.1367 Electric cables and equipment (c) Means of identification must be provided for electrical cables, connectors and terminals.
53	1367	c	USAR.1367 Switches Each switch must be (c) Accessible to appropriate maintenance staff ; and
54	1367	d	USAR.1367 Switches Each switch must be (d) Labelled as to operation and the circuit controlled.
55	1383	a	1383 USAR.1383 Taxi and landing lights If needed, each taxi and landing light must be designed and installed so that (a) If a sensor is required for taxi, take-off or landing phase then there should be no dangerous glare from taxi and landing lights that would affect UAV operational safety.
56	1383	c	1383 USAR.1383 Taxi and landing lights If needed, each taxi and landing light must be designed and installed so that (c) It provides enough light for all intended operations;

ID	USAR Paragraph	Sub-Paragraph	Requirements with Human Factors Implication DTAES 6-7 Specialist Review Not Required STANAG 4671 - Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR)
57	1401	a	USAR.1401 Anti-collision light system (a) General. The UAV must have an anti-collision light system that (1) Consist of one or more approved anti-collision lights located so that their light will not detract from the conspicuity of the position lights;
58	1413	b	USAR.U1413 Engine shut down procedure In the event of an engine failure that causes shutdown, the following requirements apply : (b) therefore, the emergency electrical power must be designed in such a way that its reliability and duration are compatible with USAR.1413 (a). The time period needed to perform a glide from maximum certificated altitude to sea level and reach a forced landing area includes the time needed for the UAV crew to recognise the failure and to take appropriate action, if required.
59	1459	a4	USAR.1459 UAV onboard flight recorders (See AMC.1459) (a) If required, each flight recorder must be installed so that: (4) There is an aural or visual means for pre-flight checking of the recorder for proper recording of data in the storage medium.
60	1543	a	USAR.1543 Instrument markings: general (see also USAR.1733 Conventional controls and indicators) For each instrument installed on the UAV, (a) When markings are on the cover glass of the instrument, there must be means to maintain the correct alignment of the glass cover with the face of the dial; and
61	1543	b	USAR.1543 Instrument markings: general (see also USAR.1733 Conventional controls and indicators) For each instrument installed on the UAV, (b) Each arc and line must be wide enough and located to be clearly visible to the ground staff.
62	1551		USAR.1551 Oil quantity indicator (see also USAR.1841 Oil quantity data) Where an oil quantity indicator is installed on the UAV for use by the ground staff, it must be marked in sufficient increments to indicate readily and accurately the quantity of oil.
63	1553		USAR.1553 Fuel quantity indicator (see also USAR.1843 Fuel quantity data) Where a fuel quantity indicator is installed on the UAV for use by the ground staff, a red radial line must be marked on each indicator at the calibrated zero reading.
64	1555	a	USAR.1553 Control markings on the UAV (see also USAR.1845 Control markings in the UCS) If installed on the UAV, (a) Each control (switch, button, selector, …) on the UAV must be plainly marked as to its function and method of operation.
65	1555	c1	USAR.1553 Control markings on the UAV (see also USAR.1845 Control markings in the UCS) If installed on the UAV, (c) For powerplant fuel controls (1) Each fuel tank selector control on the UAV must be marked to indicate the position corresponding to each tank and to each existing cross feed position.

ID	USAR Paragraph	Sub-Paragraph	Requirements with Human Factors Implication DTAES 6-7 Specialist Review Not Required STANAG 4671 - Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR)
66	1555	c3	USAR.1553 Control markings on the UAV (see also USAR.1845 Control markings in the UCS) If installed on the UAV, (c) For powerplant fuel controls (3) The conditions under which the full amount of usable fuel in any restricted usage fuel tank can safely be used must be stated on a placard adjacent to the selector valve for that tank.
67	1555	e2	USAR.1553 Control markings on the UAV (see also USAR.1845 Control markings in the UCS) If installed on the UAV, (e) For accessory, auxiliary and emergency controls (2) Each emergency control must be red and must be marked as to method of operation. No control other than an emergency control shall be this colour.
68	1557	a	1557 USAR.1557 Miscellaneous information markings and placards (a) Payload compartments and ballast location. Each payload compartment, and each ballast location, must have a placard stating any limitations on contents, including weight, that are necessary under the loading requirements.
69	1557	c	1557 USAR.1557 Miscellaneous information markings and placards (c) Fuel filler openings must be marked at or near the filler cover with : (1) the type of the fluid, and, (2) the permissible product designation, as indicated in the maintenance and operational handbook.
70	1557	e	1557 USAR.1557 Miscellaneous information markings and placards (e) The system voltage of each direct current installation must be clearly marked adjacent to its external power connection.
71	1557	f	1557 USAR.1557 Miscellaneous information markings and placards (f) Emergency access placards. Each placard and operating control for each emergency access panel must be red. A placard must be near each emergency access panel control and must clearly indicate the location of that access panel control and its method of operation.
72	1743	c	USAR.U1743 Fuel controls (c) Where fitted, fuel tank selector must (1) Require a separate and distinct action to place the selector in the “OFF” position; and (2) Have the tank selector designed to operate so that it is impossible for the selector to pass through the “OFF” position when changing from one tank to another.
73	1745	a	USAR.U1745 Fuel jettisonning control (a) Where existing, the fuel jettisoning valve must be designed to allow UAV crew to close the valve during any part of the jettisoning operation.
74	1885	c	U1885 USAR.U1885 UAV handover within the same UAV control station (See AMC.1885 (b) and AMC.1885 (d)) Where the UCS has more than one workstation designed for controlling the UAV: (c) The command and control functions that are transferred during handover must be approved by the Certifying Authority and defined in the UAV System Flight Manual.

APPENDIX E – Technical Standard Order (Human Factors Requirements)

Tailor as required:

Technical Standards Orders (TSO) that may apply to UAS GCS					
Technical Standard Order		Minimum Operational Performance Specification		Requirements with Human Factors Implications	
Number	Name	Number	Name	Evaluation	No Evaluation
TSO C2d	Airspeed Instruments	AS 8019 A	Airspeed Instruments	3.2.1, 3.2.2, 3.7	3.2.5
TSO-C3e	Turn and Slip Instrument	AS 8004	Turn and Slip Instrument	3.2, 3.3	3.7
TSO-C4c	Bank and Pitch Instruments	AS 8001	Bank and pitch instruments	3.3, 3.4, 3.8	
TSO-C5f	Direction Instrument; Non-Magnetic (gyroscopically stabilized)	AS 8021	Direction instrument; non-magnetic (gyroscopically stablilized)	3.1, 3.2, 3.6	3.10.2
TSO-C6e	Direction Instruments(Magnetic)	AS 8013a	Minimum Performance Standard for Direction Instrument - Magnetic (Gyro Stabilzed)	3.1, 3.2, 3.6(c)	3.10.2
TSO-C8e	Vertical Velocity Instruments (Rate-of-Climb)	AS 8016 A	VERTICAL VELOCITY INSTRUMENT	3.2.3, 3.5	3.2.4
TSO C10b	Altimeter; Pressure Actuated; Sensitive Type	AS 8009 B	Pressure Altimeter Systems	3.2, 4.1	3.7
TSO C112e	Air Traffic Control Radar Beacon System/Mode Select (ATCRBS / Mode S) Airborne Equipment	DO-181E	Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment	2.1.5, 2.1.6, 3.1.1, 3.1.3	
TSO-C113a	Airborne Multipurpose Electronic Displays	AS 8034B	Minimum Performance Standard for Airborne Multipurpose Electronic Displays	3.11.4, 3.11.5, 3.11.6, 4.2.10, 4.2.2, 4.2.5, 4.2.6, 4.2.7, 4.2.8, 4.2.8.2, 4.3.1, 4.3.2, 4.3.2.3, 4.3.2.4, 4.3.3.a, 4.3.3.b, 4.3.3.c, 4.3.3.d, 4.3.4, 4.3.4.1, 4.5.1, 4.5.2, 4.5.3, 4.5.4, 4.5.5, 4.5.8, 5.1.2, 5.1.3, 5.1.4, 5.1.6	4.2.1
TSO-C34e	ILS Glide Slope Receiving Equipment Operating Within The Radio Frequency Range Of 328.6-335.4 Megahertz (MHz)	DO-192	Airborne ILS Glide Slope Receiving Equipment Operating within the Radio Frequency Range of 328.6-335.4 Megahertz.	2.1.2, 2.1.5, 2.1.6, 3.1.3	2.2.4(d)
TSO-C35d	Airborne Radio Marker Receiving	DO-143	AIRBORNE RADIO MARKER RECEIVER EQUIPMENT OPERATING ON 75 MHz	1.1, 1.2	
TSO-C36e	Airborne ILS Localizer Receiving Equipment Operating Within The Radio Frequency Range Of 108-112 Megahertz (MHz)	DO-195	Airborne ILS Localizer Receiving Equipment Operating within the Radio Frequency Range of 108- 112 Megahertz	2.1.2, 2.1.5, 2.1.6, 3.1.3	2.2.3.d
TSO-C40c	VOR Receiving Equipment Operating Within The Radio Frequency Range Of 108-117.95 Megahertz (MHz)	DO-196	Airborne VOR Receiving Equipment Operating within the Radio Frequency Range of 108- 117.95 Megahertz	2.1.2, 2.1.5, 2.1.6, 2.2.10 , 3.1.3	2.2.3(c)
TSO-C41d	Airborne Automatic Direction Finding (ADF) Equipment	DO-179	FOR AUTOMATIC DIRECTION FINDING (ADF) EQUIPMENT	2.1.2, 2.1.5, 2.1.6, 3.2.2	
TSO-C43c	Temperature Instruments	AS 8005 A	TEMPERATURE INSTRUMENTS	3.7	
TSO-C44c	Fuel Flowmeters	AS 407 C	Fuel Flowmeters	4.2.2	4.2.5
TSO-C47a	Fuel; Oil; and Hydraulic Pressure Instruments	AS 408 C	Pressure Instruments - Fuel; Oil and Hydraulic	4.1.2, 4.1.3	
TSO-C55a	Fuel and Oil Quantity Instruments	AS 405D	Fuel and Oil Quantity Instruments	section: "Numerals", "Graduations"	
TSO-C63d	Weather Radar	DO-173	Airborne Weather and Ground Mapping Pulsed Radars	2.1.2, 2.1.4, 3.2.1, 3.2.2	
TSO-C66c	Distance Measuring Equipment (DME) Operating Within The Radio Frequency Range Of 960-1215 Megahertz (MHz)	DO-189	Airborne Distance Measuring Equipment (DME)	2.1.2, 2.1.5, 2.2.10, 2.2.10.4, 2.3, 2.3.12.4, 3.1.1	

Technical Standards Orders (TSO) that may apply to UAS GCS					
Technical Standard Order		Minimum Operational Performance Specification		Requirements with Human Factors Implications	
Number	Name	Number	Name	Evaluation	No Evaluation
TSO-C87a	Low-Range Radio Altimeter	ED-30		2.1	
TSO-C113a	Airborne Multipurpose Electronic Displays	AS 8034B	Minimum Performance Standard for Airborne Multipurpose Electronic Displays	3.11.4, 3.11.5, 3.11.6, 4.2.10, 4.2.2, 4.2.5, 4.2.6, 4.2.7, 4.2.8, 4.2.8.2, 4.3.1, 4.3.2, 4.3.2.3, 4.3.2.4, 4.3.3.a, 4.3.3.b, 4.3.3.c, 4.3.3.d, 4.3.4, 4.3.4.1, 4.5.1, 4.5.2, 4.5.3, 4.5.4, 4.5.5, 4.5.8, 5.1.2, 5.1.3, 5.1.4, 5.1.6	4.2.1
TSO-C115c	Flight Management System	DO-283A	Required Navigation Performance for Area Navigation	2.1, 1.4.4, 2.1.2, 2.1.4, 2.1.5, 2.1.7.1, 2.1.7.2, 2.2.2.12.1, 3.1.2	
TSO-C119d	Traffic Alert And Collision Avoidance System (TCAS) Airborne Equipment, TCAS II With Hybrid Surveillance	DO-185B_V1	Traffic Alert and Collision Avoidance System II (TCAS II) Version 7.1	2.1.7.1, 2.1.2, 2.1.7.2, 2.2.6.1.2.7.2.4, 2.2.6.1.2.7.4.1.2, 2.2.6.2.2.1.1, 2.2.6.2.2.1.2, 2.2.6.2.3.1.2, 2.2.6.2.3.4, 2.2.6.2.4.1, 2.2.6.3.1.1, 2.2.6.5.3.1, 2.2.6.5.3.2, 3.2.1, 3.2.2	2.1.7, 2.2.6.4.2
TSO-C146c	Technical Standard Order	DO-229D	Global Positioning System/Satellite-Based Augmentation System Airborne Equipment	2.2.1.1.4.2, 2.2.1.1.4.1, 2.1.1.1.2, 2.2.1.1, 2.2.1.1.1.2, 2.2.1.1.2, 2.2.1.1.4.1, 2.2.1.1.4.2, 2.2.1.1.4.4, 2.2.1.1.4.5, 2.2.1.1.5, 2.2.1.1.5.1, 2.2.1.1.5.2, 2.2.1.4.2	2.1.4, 2.2.1.1.3, 2.2.1.1.4.3, 2.2.1.6.1, 2.2.1.6.2
TSO-C147	Traffic Advisory System (TAS) Airborne Equipment	DO-197A	Active Traffic Alert and Collision Avoidance System I (Active TCAS I)	2.1.4.1, 2.1.4.2, 2.1.4.2.3.f, 2.2.12.3.f, 3.2.2	
TSO-C151c	Terrain Awareness and Warning System	DO-161A	Airborne Ground Proximity Warning Equipment	1.2, 1.3, 1.6.2	
TSO-C165	Electronic Map Display Equipment for Graphical Depiction of Aircraft Position	DO-257A	Depiction of Navigational Information on Electronic Maps	2.1.5.1(1), 3.1.1.3, 3.2.2.1, 2.1.2, 2.1.5, 2.1.5.1(3), 2.1.5.1(4), 2.1.5.2, 2.2.2.7, 2.2.3.1, 2.2.3.4, 2.3.1.1.1, 2.3.1.1.3.1, 2.4.4.2, 2.4.5, 3.1.1.2, 3.1.1.6, 3.1.3.1, 3.1.3.2, 3.1.3.3, 3.2.1, 3.2.2.2	2.2.3.3

Derived Human Factors Evaluation Requirements from Technical Standards Orders (TSO) Requirements

Tailor as required:

Appliance Level Requirements Requiring Human Factors Evaluation						
Human Factors Consideration	Evaluation ID	Human Factors Evaluation	Purpose	Technical Standard Order (TSO) and associated Minimum Operational Performance Specification Requirements informing the Human Factors Evaluation		
				TSO	Document	Requirement(s)
Usability	1	Operation of Controls	Confirm that controls intended for use during flight can be operated in any combination or sequence without causing any detriment in reliability or performance.	TSO-C4c	AS 8001	3.3
				TSO-C3e	AS 8004	3.2
				TSO-C6e	AS 8013a	3.1
				TSO-C5f	AS 8021	3.1
				TSO-C35d	DO-143	1.1
				TSO-C151c	DO-161A	1.2
				TSO-C63d	DO-173	2.1.4
				TSO-C41d	DO-179	2.1.5
				TSO C112e	DO-181E	2.1.5
				TSO-C119d	DO-185B_V1	2.1.7.1
				TSO-C66c	DO-189	2.1.5
				TSO-C34e	DO-192	2.1.5
				TSO-C36e	DO-195	2.1.5
				TSO-C40c	DO-196	2.1.5
				TSO-C147	DO-197A	2.1.4.1
				TSO-C115c	DO-283A	2.1
				TSO-C165	DO-257A	2.1.5.1(1), 3.1.1.3, 3.2.2.1
			Confirm all controls can be operated with one hand.	TSO-C115c	DO-283A	2.1.7.1
			Confirm that controls used through their entire range will not block the view of other controls or displays.	TSO-C165	DO-257A	3.1.1.6, 3.2.2.2
			Confirm that controls used through their entire range will not block the movement of other controls.	TSO-C165	DO-257A	3.1.1.6, 3.2.2.2
			Confirm that controls are not prone to inadvertent activation.	TSO-C165	DO-257A	2.1.5.1(3), 2.1.5.1(4)
			Confirm all mechanical devices function in a clear and unambiguous manner	TSO-C113a	AS 8034B	5.1.6
			Confirm that all controls provide appropriate feedback to the operator; tactile and visual cues are acceptable forms of feedback.	TSO-C115c	DO-283A	2.1.4
	2	Control Display Arrangement	Confirm that displays and controls are arranged to facilitate equipment usage (e.g., in accordance with Human Factors design principles: functional grouping, sequence of use, criticality, etc.).	TSO-C115c	DO-283A	2.1.7.2
	3	Readability	Confirm that each crew member has an unobstructed view of their displays (or shared displays) from their normal seated position within the within the defined viewing envelope.	TSO C112e	DO-181E	3.1.1, 3.1.3
				TSO-C119d	DO-185B_V1	3.2.1, 2.2.6.2.3.4, 2.2.6.1.2.7.4.1.2
				TSO-C66c	DO-189	3.1.1
				TSO-C34e	DO-192	3.1.3
				TSO-C36e	DO-195	3.1.3
				TSO-C40c	DO-196	3.1.3
				TSO-C115c	DO-283A	3.1.2, 2.1.7.2
				TSO-C113a	AS 8034B	4.5.1, 3.11.6, 4.3.1
				TSO-C151c	DO-161A	1.6.2
				TSO-C63d	DO-173	3.2.2
				TSO-C41d	DO-179	3.2.2
				TSO-C147	DO-197A	2.1.4.2.3.f, 2.2.12.3.f, 3.2.2
				TSO-C146c	DO-229D	2.2.1.1.4.2, 2.2.1.1.5

<table>
<tr><th colspan="7">Appliance Level Requirements Requiring Human Factors Evaluation</th></tr>
<tr><th rowspan="2">Human Factors Consideration</th><th rowspan="2">Evaluation ID</th><th rowspan="2">Human Factors Evaluation</th><th rowspan="2">Purpose</th><th colspan="3">Technical Standard Order (TSO) and associated Minimum Operational Performance Specification Requirements informing the Human Factors Evaluation</th></tr>
<tr><th>TSO</th><th>Document</th><th>Requirement(s)</th></tr>
<tr><td rowspan="38"></td><td rowspan="19"></td><td rowspan="19"></td><td></td><td>TSO-C165</td><td>DO-257A</td><td>2.2.3.1, 2.2.2.7, 3.1.3.1, 3.1.3.3, 3.2.1</td></tr>
<tr><td rowspan="13">Confirm that all controls, displays, and display symbology are readable under all expected cockpit lighting conditions, against all possible backgrounds, from the normal seated position. Note readability evaluations should consider luminance, contrast, colour difference, line uniformity, etc.</td><td>TSO-C115c</td><td>DO-283A</td><td>2.1.7.2</td></tr>
<tr><td>TSO-C113a</td><td>AS 8034B</td><td>3.11.6, 4.2.5, 4.3.1, 4.3.2, 4.3.3.a, 4.3.3.b, 4.3.3.c, 4.5.1, 4.5.2, 4.5.3, 5.1.2</td></tr>
<tr><td>TSO-C4c</td><td>AS 8001</td><td>3.8</td></tr>
<tr><td>TSO-C119d</td><td>DO-185B_V1</td><td>3.2.2, 2.2.6.2.3.4, 2.2.6.1.2.7.4.1.2</td></tr>
<tr><td>TSO C112e</td><td>DO-181E</td><td>3.1.3</td></tr>
<tr><td>TSO-C151c</td><td>DO-161A</td><td>1.6.2</td></tr>
<tr><td>TSO-C63d</td><td>DO-173</td><td>3.2.2</td></tr>
<tr><td>TSO-C34e</td><td>DO-192</td><td>3.1.3</td></tr>
<tr><td>TSO-C36e</td><td>DO-195</td><td>3.1.3</td></tr>
<tr><td>TSO-C40c</td><td>DO-196</td><td>3.1.3</td></tr>
<tr><td>TSO-C147</td><td>DO-197A</td><td>2.1.4.2.3.f, 2.2.12.3.f, 3.2.2</td></tr>
<tr><td>TSO-C146c</td><td>DO-229D</td><td>2.2.1.1.1.2, 2.2.1.1.4.2, 2.2.1.1.4.5, 2.2.1.1.5, 2.2.1.1.5.1</td></tr>
<tr><td>TSO-C165</td><td>DO-257A</td><td>2.2.2.7, 2.2.3.1, 3.1.3.1, 3.1.3.3, 3.2.1</td></tr>
<tr><td rowspan="5">Confirm that all colours are discernable under all expected cockpit lighting conditions.</td><td>TSO-C115c</td><td>DO-283A</td><td>2.1.7.2</td></tr>
<tr><td>TSO-C113a</td><td>AS 8034B</td><td>4.3.3.d</td></tr>
<tr><td>TSO-C165</td><td>DO-257A</td><td>2.2.3.4</td></tr>
<tr><td>TSO-C146c</td><td>DO-229D</td><td>2.2.1.1.4.2</td></tr>
<tr><td>TSO-C119d</td><td>DO-185B_V1</td><td>2.2.6.2.2.1.1, 2.2.6.2.2.1.2, 2.2.6.3.1.1, 2.2.6.2.3.1.2</td></tr>
<tr><td rowspan="10">4</td><td rowspan="10">Identification of Controls and Displays</td><td rowspan="3">Confirm that each crew member can readily identify each control, control mode, and any associated control label, from their normal seated position.</td><td>TSO-C165</td><td>DO-257A</td><td>2.2.2.7, 2.4.5, 3.1.1.2</td></tr>
<tr><td>TSO-C115c</td><td>DO-283A</td><td>3.1.2</td></tr>
<tr><td>TSO-C146c</td><td>DO-229D</td><td>2.2.1.1.1.2, 2.2.1.1.4.2</td></tr>
<tr><td>Confirm that aviation colour conventions have been observed.</td><td>TSO-C146c</td><td>DO-229D</td><td>2.2.1.1.4.2, 2.2.1.1.5</td></tr>
<tr><td rowspan="5">Confirm that all controls, displays, information, and display symbology are presented in a manner that precludes confusion or ambiguity to its information content under all expected cockpit lighting conditions, against all possible backgrounds. Note readability evaluations should consider luminance contrast, colour difference, etc.</td><td>TSO-C113a</td><td>AS 8034B</td><td>3.11.5, 4.2.2, 4.2.5, 4.2.8, 4.3.3.d, 4.3.4, 4.3.4.1, 4.5.4, 4.5.5, 5.1.3, 5.1.4</td></tr>
<tr><td>TSO-C115c</td><td>DO-283A</td><td>2.1.7.2, 2.2.2.12.1</td></tr>
<tr><td>TSO-C146c</td><td>DO-229D</td><td>2.2.1.1.1.2, 2.2.1.1.4.1, 2.2.1.1.4.4, 2.2.1.1.4.5, 2.2.1.4.2,</td></tr>
<tr><td>TSO-C119d</td><td>DO-185B_V1</td><td>2.2.6.2.4.1, 2.2.6.1.2.7.2.4</td></tr>
<tr><td>TSO-C165</td><td>DO-257A</td><td>2.4.5, 2.3.1.1.1, 2.3.1.1.3.1, 2.4.4.2</td></tr>
<tr><td rowspan="9">5</td><td rowspan="9">Instrument Markings</td><td rowspan="2">Confirm that all indicators are readily interpretable throughout their operating range.</td><td>TSO-C4c</td><td>AS 8001</td><td>3.8</td></tr>
<tr><td>TSO-C119d</td><td>DO-185B_V1</td><td>2.2.6.1.2.7.4.1.2</td></tr>
<tr><td>Should an indicator be "pegged" at its maximum or minimum rate, confirm that the direction of indication is clear and unambiguous.</td><td>TSO-C8e</td><td>AS 8016A</td><td>3.2.3</td></tr>
<tr><td rowspan="6">Confirm that the scale range, numerations, and graduation markings are appropriate for their required accuracy and dynamic range.</td><td>TSO-C113a</td><td>AS 8034B</td><td>3.11.4, 4.2.5</td></tr>
<tr><td>TSO-C55a</td><td>AS 405D</td><td>"Numerals", "Graduations" [missing paragraph numbers]</td></tr>
<tr><td>TSO-C44c</td><td>AS 407C</td><td>4.2.2</td></tr>
<tr><td>TSO-C47a</td><td>AS 408C</td><td>4.1.3, 4.1.2</td></tr>
<tr><td>TSO-C8e</td><td>AS 8016A</td><td>3.2.3</td></tr>
<tr><td>TSO C2d</td><td>AS 8019A</td><td>3.2.1, 3.2.2</td></tr>
</table>

Appliance Level Requirements Requiring Human Factors Evaluation						
Human Factors Consideration	Evaluation ID	Human Factors Evaluation	Purpose	Technical Standard Order (TSO) and associated Minimum Operational Performance Specification Requirements informing the Human Factors Evaluation		
				TSO	Document	Requirement(s)
				TSO-C147	DO-197A	2.2.12.3.h
				TSO-C119d	DO-185B_V1	2.2.6.1.2.7.4.1.2
	6	Luminance Uniformity and Contrast	When used throughout its operating range, confirm the display luminance is visually consistent, does not present distracting conditions (e.g., glare, display "hot spots"), and does not occlude any displayed information under all expected cockpit lighting conditions, against all possible backgrounds.	TSO-C113a	AS 8034B	4.3.2.3, 4.3.2.4
				TSO-C165	DO-257	3.1.3.2
	7	Display Artefacts	Confirm that there is no unacceptable level of display flicker under all expected cockpit lighting conditions.	TSO-C113a	AS 8034B	4.2.7
			Confirm that there is no unacceptable level of display jitter, jerkiness, or ratcheting under all expected cockpit lighting conditions.	TSO-C113a	AS 8034B	4.2.6, 4.2.8.2
			Confirm that there is no unacceptable level of display afterimages, under all expected cockpit lighting conditions, that would cause an erroneous interpretation of the display content.	TSO-C113a	AS 8034B	4.2.10, 4.2.8.2
			Confirm that there is no unacceptable level of display tunnelling (e.g., dimming) or smearing, under all expected cockpit lighting conditions, that would cause an erroneous interpretation of the display content.	TSO-C113a	AS 8034B	4.5.8, 4.2.8.2
Annunciations	8	Advisories, Cautions, and Warnings	Confirm all alerts are distinctive and readily discernable from other indications.	TSO-C146c	DO-229D	2.2.1.1.4.1
				TSO-C151c	DO-161A	1.6.2
			Confirm that visual annunciations are design with the appropriate criticality scheme influencing salience of the annunciation.	TSO-C146c	DO-229D	2.2.1.1.5
				TSO C10b	AS 8009B	4.1
				TSO-C5f	AS 8021	3.6
			Confirm that new annunciations are adequately identified to the appropriate crew member.	TSO-C146c	DO-229D	2.2.1.1.5.2
			Confirm that all failure or malfunction indications are unambiguous and not open to misinterpretation.	TSO-C6e	AS 8013a	3.6(c)
	9	Aural Messaging	Confirm that all aural annunciations are clear and unambiguous.	TSO-C66c	DO-189	2.2.10, 2.2.10.4, 2.3, 2.3.12.4
				TSO-C40c	DO-196	2.2.10
Situation Awareness	10	Situation Awareness	Confirm the crew is aware of the operational state of each control, (operational state, mode, or failure condition).	TSO C112e	DO-181E	2.1.5
				TSO-C119d	DO-185B_V1	2.2.6.5.3.1, 2.2.6.5.3.2
Reach, Vision, and Clearance	11	Accessibility of Controls	Confirm that controls that are not intended for use in flight are not readily accessible.	TSO-C4c	AS 8001	3.4
				TSO-C3e	AS 8004	3.3
				TSO-C87a	EUROCAE ED-30	2.1
				TSO-C43c	AS 8005A	3.7
				TSO C10b	AS 8009B	3.2
				TSO-C6e	AS 8013A	3.2
				TSO-C8e	AS 8016A	3.5
				TSO C2d	AS 8019A	3.7
				TSO-C5f	AS 8021	3.2
				TSO-C35d	DO-143	1.2
				TSO-C151c	DO-161A	1.3
				TSO-C41d	DO-179	2.1.6
				TSO C112e	DO-181E	2.1.6
				TSO-C119d	DO-185B_V1	2.1.7.2
				TSO-C66c	DO-189	2.1.5

Appliance Level Requirements Requiring Human Factors Evaluation						
Human Factors Consideration	Evaluation ID	Human Factors Evaluation	Purpose	Technical Standard Order (TSO) and associated Minimum Operational Performance Specification Requirements informing the Human Factors Evaluation		
				TSO	Document	Requirement(s)
				TSO-C34e	DO-192	2.1.6
				TSO-C36e	DO-195	2.1.6
				TSO-C40c	DO-196	2.1.6
				TSO-C147	DO-197A	2.1.4.2
				TSO-C115c	DO-283A	2.1.5
			Confirm that controls intended for use in flight are readily accessible from the normal seated position.	TSO-C63d	DO-173	3.2.1
				TSO C112e	DO-181E	3.1.1
				TSO-C119d	DO-185B_V1	3.2.1
				TSO-C66c	DO-189	3.1.1
				TSO-C34e	DO-192	2.1.6
				TSO-C36e	DO-195	2.1.6
				TSO-C40c	DO-196	2.1.6
				TSO-C147	DO-197A	3.2.1
				TSO-C165	DO-257A	2.1.5.2
Workload	12	Workload	Confirm that all controls and displays have been designed to maximize operational suitability, minimize human error, and minimize pilot workload.	TSO-C115c	DO-283A	1.4.4
				TSO C112e	DO-181E	2.1.5
				TSO-C146c	DO-229D	2.2.1.1
				TSO-C165	DO-257A	2.1.5
			Confirm that operations that occur with high frequency, criticality, or during high workload phases of flight can be accomplished with a minimum number of control operations.	TSO-C146c	DO-229D	2.2.1.1
				TSO-C165	DO-257A	2.1.5
			Confirm the system/ system functions have been designed to be error tolerant and error recoverable; ensure operating errors are detectable, and the reversal of errors is intuitive and can be accomplished with a minimum number of control operations.	TSO-C146c	DO-229	2.2.1.1.2
Intended Function	13	Intended Function	For items not covered by TSOs, confirm the equipment and functionality meet their intended function as defined by the manufacturer and agreed upon by the certification authority.	TSO-C63d	DO-173	2.1.2
				TSO-C41d	DO-179	2.1.2
				TSO-C119d	DO-185B_V1	2.1.2
				TSO-C66c	DO-189	2.1.2
				TSO-C34e	DO-192	2.1.2
				TSO-C36e	DO-195	2.1.2
				TSO-C40c	DO-196	2.1.2
				TSO-C115c	DO-283A	2.1.2
				TSO-C146c	DO-229D	2.1.1.1.2
				TSO-C165	DO-257A	2.1.2