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A10 – UAS Control Station Ergonomics Considerations: Tasks CS-6 through CS-8

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EXECUTIVE SUMMARY

The overall objective of the control station tasks within Project A-10 is to provide the Federal Aviation Administration (FAA) with information on an ergonomic design of unmanned aircraft system (UAS) control stations which will allow safe piloting of UASs. A large percentage, 69%, of unmanned aircraft accidents have been attributed to human factors issues including both physical workstation design and human-machine interaction (Waraich, Mazzuchi, Sarkani, Rico, 2013). The purpose of this document, a subpart of A-10, is to provide the FAA with the minimal physical control station design recommendations that will promote favorable operator comfort and performance and reduce musculoskeletal injury risks. A detailed review of UAS control station design specific literature was conducted. While there is literature relating to UAS control stations, very little is actually directed at the physical design of the workstation. Therefore, a review of existing workstation design literature was used to develop a preliminary set of minimum design recommendations for UAS control stations (Waraich et al., 2013). Additionally, subject matter experts were surveyed and interviewed to provide input into control station design features that were not addressed through the literature review. The focus of this report is on the physical design of the control station; information pertaining the content of the displays is outside the scope of this document. Much of the information included in this report was sourced from existing standards and regulations, and supplemented by recent (within the last 10 years) of peer reviewed literature. Seminal publications or data sets (e.g., anthropometry) were included if they remained the most relevant source of information. Section 7 of this document provides a consolidated listing of all recommendations identified through the completion of this task.

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Acronym	Definition
ACGIH	American Conference of Governmental Industrial Hygienists
AirSTAR	Airborne Subscale Transport Aircraft Research
ANSI	American National Standards Institute
CET	Corrected Effective Temperature
DoD	United States Department of Defense
ET	Effective Temperature
FIRRE	Family of Integrated Rapid Response Equipment
HVAC	Heating, ventilation and air conditioning
ISO	International Organization for Standardization
SI	International System of Units
TLV	Threshold Limit Value
UAS	Unmanned Aircraft Systems
VDT	Video Display Terminal
WBGT	Wet Bulb Globe Temperature Index

Keywords	Definition
Accessible	Design of the environment to accommodate individuals with disabilities.
Accessible Means of Egress	"A continuous and unobstructed way of egress travel from any accessible point in a building or facility to a public way." (IBC, 2015)
Anterior	Front plane of the body.
Biomechanical Stress	The study of the mechanics of a living body, especially of the forces exerted by muscles and gravity on the skeletal structure.
Body core temperature	Core body temperature is the temperature of the internal environment of the body including the organs such as the heart and liver, and the blood.
Cold injury	The injury caused due to extreme cold exposure such as frostbite, trench foot, chilblain, etc. Cold injury may lead to loss of limbs or even death.
Contrast ratio	Same as luminance ratio.
Corrected effective temperature	Corrected effective temperature is the modification of effective temperature when radiant heat is also considered with the effective temperature.
Cross slope	The cross slope is the slope that is measured in the direction perpendicular to the pedestrian travel.
Dark adaptation	Adjustment of eyes under reduced illumination condition in which the sensitivity to light is highly increased. Also called scotopic adaptation.
Deadband	An interval of a signal domain or band where no action occurs.
Deep body temperature	Deep body temperature is the core temperature of the body determined through conventional methods for rectal temperature measurements.

Downlights	Lamp or light bulbs which are set in a metal cylinder in a way that if they are mounted on or recessed into the ceiling, light beams fall directly towards downward direction.
Dry bulb temperature	It is simply the measure of temperature conducted by freely exposing the thermometer to air but the thermometer is shielded from moisture and radiation. It is also called air temperature.
Effective temperature	It is a comfort index which considers the dry bulb air temperature, wet bulb air temperature, air velocity, and clothing.
Footprint	A unique set of characteristics that leave a trace andserve as identification.
Glare	Very bright light or high luminance in the visual field that is much higher than the luminance to which eyes are adjusted.
Guardrail system	The rail system or strong fence which prevents people from falling off.
Handedness	The propensity to use one hand rather than the other.
Hysteresis	The lag in response exhibited by a body reacting to changes in the forces.
Luminance	The amount of light reflected from per unit area of a surface. It does not change with the distance of the observer from the surface. Measured in Candela.
Luminance ratio	Luminance ratio is the ratio of foreground luminance and background luminance. It indicates the brightness of a pure white output relative to a pure black output.
Parallax	Object appears to differ when viewed from different directions or positions.
Pile thickness	This is the thickness of a rug or carpet from its surface to its backing.
Posterior	Rear or caudal plane of the body.
Running slope	Running slope of walking surface is the slope measured in the direction of pedestrian travel.
Sedentary task	Any task done in sitting posture.
Sit-only workstation	A workstations that requires the user to sit to use the workstation.
Sit-to-Stand workstation	A workstation that allows the user to modify the height of the work surface of the workstation so that the user can use the desk while sitting or standing.
Specular Reflectance	A type of surface reflection in which light reflects from a smooth surface at a definite angle. A reflectometer is used to take measurements, and the units are referred to as gloss units (GU).
Spot cooling	Spot cooling is a portable air conditioning system used for cooling overheated areas.
Stand-only workstation	A workstation that requires the user to stand to use the workstation.
Threshold Limit Values	These are the limits up to which a worker can be exposed to a chemical substance without any adverse health effect. TLV term is reserved for ACGIH.

Wet bulb globe temperature index	The wet bulb globe temperature index is an indicator of heat stress which considers temperature, humidity, and radiant energy.

1. INTRODUCTION

This document provides a summary of publicly available peer-reviewed literature and standards pertaining to the design of control stations of unmanned aircraft systems (UASs). As gaps were identified in the literature for UAS specific design recommendations, relevant office and work environment literature was reviewed and used to fill these gaps. Ultimately, what is provided is a set of minimum recommendations based on the available literature for the physical design of the control station.

In general, it is expected that control of UASs will occur within a fixed location and facility. However, as UASs may also need to be controlled using mobile control stations, recommendations for two additional scenarios were developed: 1) control station located in a movable environment (e.g., trailer, van, ship, airplane) and 2) an operator(s) on foot. As such, environmental factors for all three levels (fixed control station, mobile control station, and mobile operator carried control station) were also considered and recommendations are provided.

This document is partitioned based on UAS control station location. The first section details workspace design literature for fixed locations and facilities. The second section explores elements of mobile workspace design, including mobile operator carried control station, dissimilar to fixed facilities. Each subpart was formed by examining standards and literature for physical workspace design guidelines or recommendations. All values were consolidated into tables, Appendix A, and the minimum dimensions accommodating the anthropometrics of the 5th to 95th percentile male and female were chosen. The chosen minimums are discussed in each subpart and represented in the Final Recommendation tables found at the end of each subpart. Finally, all Final Recommendation tables were combined for ease of reading in Table 22.

1.1 ASSUMPTIONS

This document is largely a compilation of dimensions presented in previously published ergonomic standards and guidelines. This document was written under the assumption that each document provided recommendations accommodating the anthropometrics of the 5th to 95th percentile male and female.

1.2 LIMITATIONS/DELIMITATIONS

The authors aimed at providing recommendations based on ergonomic standards and scholarly literature published within ten years prior to 2016. In the absence of pertinent information in the literature within this time frame, older documents were used. In some instances, ergonomic standards failed to address specific physical aspects of a workstation, so scholarly literature was used to provide dimensions.

2. METHODOLOGY

2.1 LITERATURE REVIEW

Using the Mississippi State University Libraries, a literature search was conducted via several databases and search terms to identify existing standards or other recommendations for the physical design of the control station (e.g., workstation height, chair design, location and orientation of displays). For peer reviewed journals and conference proceedings, searches were limited to the last 10 years and, using treeing from these documents' bibliographical sections, seminal references could be identified and obtained by the research team.

The search initially focused on UAS, control stations, and related terms to obtain any documents that could be used in the making of UAS specific recommendations. Table 1 provides a listing of search terms used. From the initial search, over 150 articles were identified. However, the review of these documents identified few details or recommendations for the physical design of the control station. A number of these articles (approximately 85%) were focused on display design, warning indicators, and other relevant aspects of the control station that are outside of the physical design focus of this document. Therefore, few documents were found that provided actual dimensional recommendations for the control station.

Given the gap in research literature regarding the physical design of UAS control stations, the search was then expanded to focus on general workstation and work environment literature, with an emphasis on computer workstation recommendations. A number of military and civilian references, along with publicly available peer reviewed journal articles and conference proceedings were identified to supplement the UAS literature.

Table 1: Literature Identification Search Terms (terms were used individually and in various combinations).

Terms Related to UAS	Terms Related to General Workstation Design	Terms Related to Control Station Design	Terms Related to Environment	Terms Related to Mobility
Unmanned Remote Autonomous Vehicle Aircraft Aerial Drone Pilot Control Station Ground Mobile Command Safety Center	Workstation Workspace Layout Sit Stand Sit-to-stand Chair Suspension Ergonomic Desk Computer Laptop Height Length Width Depth Walkway	Design Configuration Monitor Laptop Computer Display Control Touch Screen Stylus Trackball Voice Control Input Device Joystick Power Supply Mobile Power Source Keyboard Mouse	Occupancy Egress Exit Lighting Illuminance Temperature Heat Cool Air condition Humidity Danger Stress Vibration Minimum Maximum Values Exposure Noise Comfort	(Incorporated many similar words from previous columns) Mobile Trailer Vehicle Backpack Rucksack Load Carriage Durability Safety

		Durability	Outside Inside Ventilation	

2.2 SURVEY/INTERVIEW

Based on the literature review, several gaps were identified for UAS specific control station design (e.g., display configuration, number of operators, work surface dimensions, etc.). As such, general workstation recommendations were used to supplement the missing information. Additionally, little to no literature currently exists relating to mobile control station design. Therefore, experienced unmanned pilot SMEs were used to address these gaps by asking for their thoughts, experiences, and ideas on UAS control station design parameters. Both survey and interview methods were used to collect this data. All protocols were reviewed and approved by the Mississippi State University institutional review board (IRB) prior to any data collection.

2.2.1 Survey

A survey was developed to collect general information pertaining to current UAS control station designs. The survey contained a total of 43 questions and consisted of the following sections (see Appendix A for a copy of the survey and SME responses):

1. SME consent (Question 1) – Provides option for yes or no response to begin survey
2. Demographics (Questions 2-4)—Information gathered included gender, age, and ethnicity.
3. Pilot Experience (Questions 5-11)—Information gathered included flight certification, experience, and aircraft category.
4. Controls and Displays (Questions 12-19; 27&28)—Information gathered included type of controls, subjective rating of controls, and number and configuration of displays.
5. Operator Comfort (Questions 20-23; 29)—Information gathered included physical discomfort and time spent in the control station.
6. Number of Individuals in the Control Station (Questions 24-26)—Information gathered included the number and role of individuals in the control station.
7. Desired Physical Changes to Current Control Station (Questions 30-37)—Information gathered included desired changes to the physical design of the currently used control station.
8. Mobile Control Station (Questions 38-43)—Information gathered included environmental conditions and load carriage.

The questionnaire was developed using Survey Monkey; and a link for completing the survey was distributed to survey respondents who chose to provide contact information for a follow-up interview. Select SMEs with broad ranges in experience using different types of UAS validated that appropriate verbiage was used throughout the survey so that experienced UAS pilots would have adequate understanding of the questions and their intent. The survey remained open for 38 days.

Responses were initially analyzed using descriptive statistics (frequency counts). Given the different sizes of UASs and the focus of the CS tasks in A-10 on UASs greater than 25kgs/55lbs, responses were then categorized based on survey Question 11 using Table 2: “Based on the UAS categories described what type(s) of UAS do you currently or have you previously controlled (select all that apply)?" All responses for SMEs experienced with Group 1 and 2 were considered small UAS and analyzed together (UASs 25kgs/55lbs or less). Responses for Group 3, 4, and 5 were considered other than small UAS and analyzed together (UASs greater than 25kgs/55lbs). Descriptive statistics were recalculated based on UAS category and those for non-small UASs are described in detail below.

Table 2. Characteristics used to group UAS types.

UAS Group	Maximum weight (lb) (MGTOW)	Nominal operating altitude (ft)	Speed (kn)	Representative UAS
Group 1	0–20	< 1,200 AGL	100	RQ-11 Raven, WASP
Group 2	21–55	< 3,500 AGL	< 250	ScanEagle
Group 3	< 1,320	< FL 180		RQ-7B Shadow, RQ-21 Blackjack, NAVMAR RQ-23 Tigershark
Group 4	> 1,320		Any airspeed	MQ-8B Fire Scout, MQ-1A/B Predator, MQ-1C Gray Eagle
Group 5		> FL 180		MQ-9 Reaper, RQ-4 Global Hawk, MQ-4C Triton

2.2.2 Interviews

Questionnaire results provided insight into concerns or issues with current UAS control station designs or identified discrepancies/conflicts in responses. Interview questions were designed specifically to provide insight as to why the operators preferred certain physical design elements and why other designs were less preferred. A total of 31 questions were developed (see Appendix B), though interviews often included additional questions based on the answers provided in order to make the flow of the interview more conversational. All interviews were conducted over phone and averaged 60 minutes in length. The phone interviews were conducted by the project's co-principal investigator (Co-PI) with one to three research assistants present to capture all comments from the SMEs. In one instance, five SMEs participated in the same interview (upon request by the SMEs). All interviews were audio recorded and transcribed followed by a content analysis that was conducted on the transcriptions in order to identify themes in the responses.

2.2.3 Results

Of the 78 participants who began the survey, 39 completed the survey questions. Eleven SMEs reported piloting other than small UASs, and 32 reported piloting small UASs. Because SMEs were allowed to select multiple Groups (ex. Group 1 and Group 4), some SME data was included in both other than small and small UAS data. Other than small UASs are typically piloted from a fixed control station or a fixed-mobile control station such as a naval vessel, manned aircraft, ground vehicle, and trailer; therefore, the data from these groups are included in sections associated with fixed control stations. Small UASs are typically piloted from mobile control stations (ex. Radio Control or RC controllers, laptops, tablets, etc.), and the data from these groups are included in the sections associated with mobile control stations.

Three distinct control station groups were recognized during the interviews: fixed, fixed-mobile, and out-and-about mobile control stations. Fixed control stations are identified as permanent control stations positioned in a stationary structure such as a building. Fixed-mobile control stations are identified as control stations housed within trailers, tents, boats, aircraft, and ground-based vehicles which maintain their position for an extended duration. Out-and-about mobile control stations are categorized as control stations which are not housed in any one location for an extended period such as handheld RC controllers, tablets, laptops, or anything else that allows the remote pilot in charge (RPIC) to move freely as needed while not being restricted to a desk or other more permanent operating space. Due to analogous configurations in fixed and fixed-mobile control stations, interview data from both groups were combined. A total of twelve SMEs were interviewed. Nine SMEs identified as having experience flying from a fixed or fixed-mobile control station including control stations located in an airplane, military ship, trailer, and back of a vehicle. Nine SMEs identified as operating from an out-and-about mobile control station. Six SMEs identified with both control station categories.

3. WORKSTATION TYPES

A number of workstation types exist and these are well described in HF-STD-001B (2016). Many current UAS control stations are similar to traditional computer workstations; thus, the focus of the results will summarize these workstation types.

3.1 SIT-ONLY WORKSTATION

3.1.1 Desk Dimensions

Sit-only workstations are typically confined to tasks that require forces less than 4.5 kg (9.9 lb), an average hand above work surface distance less than 15.0 cm (5.0 in), and a task able to be completed within the confines of a seated workstation (Chengalur, Rodgers, & Bernard, 2003). Desktop objects should be maintained within a horizontal arc of grasp distance 35.0 - 45.0 cm (13.8 – 17.7 in) for primarily used objects that need to be in repetive reach and 55.0 – 65.0 cm for secondarily used objects that is reached for occasionally by the user is measured from the shoulder to the hand (Figure 1) (Kroemer & Grandjean, 1997). In this figure, the white area represents the “near zone” where primarily used objects should remain. The grey area represents the “far zone” where secondarily used objects should remain. (This figure represents distances in inches. The conversion factor for inches to centimeters is 2.54 cm in one inch.) These zones represent object handling zones only, viewing distances are addressed later for monitors or other objects.

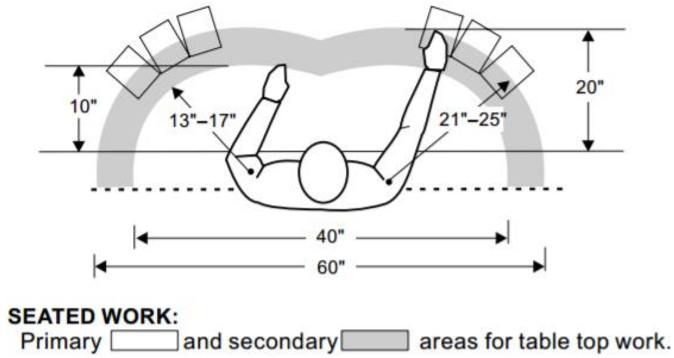


Figure 1. Recommended seated desktop object placement (This image was adapted from Fitting the Task to the Human, Volume 1, 1982 (Kroemer and Grandjean, 1982) by the 1997 National Institute of Occupational Safety and Health publication number 117 (NIOSH, 1997)).

3.1.2 Knee Clearance

In order to adhere to the 2010 Americans with Disabilities Act Standards, workstations that require sitting should provide a knee depth clearance under an element of at least 28.0 cm at 23.0 cm above the floor with a maximum of 63.5 cm (25.0 in), and at least 20.5 cm (8.1 in) of knee depth clearance should be provided when the element is at 68.5 cm (27.0 in) above the floor (ADA, 2010-306.3.3). For elements between 23.0 cm (9.1 in) and 68.5 cm (27.0 in) above the floor, the knee depth clearance should be permitted to reduce at a rate of 2.5 cm (1.0 in) for each 15.0 cm (5.9 in) in height (ADA, 2010-306.3.4). Depth at the knee for sit-only workstation should be at least 38.1 cm (15.0 in) (MIL-STD-1472G-Table XLVII) and should not increase about the allowable limits of the 2010 Americans with Disabilities Act Standards. Knee width clearance should provide at least 76.0 cm of clearance (ADA, 2010-306.3.5). At least 63.5 cm (27.0 in) of knee height clearance should be provided in sit-only workstations (MIL-STD-1472G-Figure 63).

3.1.3 Toe Clearance

Toe clearance depth should extend at least 43.0 cm (16.9 in) under an element with a maximum distance of 63.5 cm (25.0 in) (ADA, 2010-306.2). A toe clearance width of at least 76.0 cm (29.9 in) and a toe depth of at least 43.0 cm (16.9 in) to a maximum of 63.5 cm (25.0 in) from the front surface of the desk surface should be provided (ADA, 2010-306.2). All work surfaces that require the user to sit or stand close to the front surface should incorporate a kick space at least 10.0 cm (3.9 in) in depth and 10.0 cm (3.9 in) in height (MIL-STD-1472G, 2012-5.10.2.3).

3.1.4 Elbow, Shoulder, Wrist Positioning

Seated workstations should allow users to maintain postures which allow the elbow angle to be between 70° and 135°, shoulder abduction angle less than 20°, Shoulder flexion angles less than 30°, wrist flexion angles less than 30°, wrist extension angles less than 30°, and a torso-to-thigh angle equal to or greater than 90° (ANSI/HFES 100-2007-8.2.1).

3.1.5 Work Surface

The work surface should be at least 73.5 cm (28.9 in) in height above the floor (MIL-STD-1472G, 2012-Figure 63), with the Americans with Disabilities Act Standards, 2010 requiring a minimum height of 71.0 cm (28.0 in) and a maximum height of 86.5 cm (34.1 in) to accommodate wheelchair users (ADA, 2010-902.3). The work surface should have a width of at least 61.0 cm and a depth of at least 61.0 cm (24.0 in) (MIL-STD-1472G-Table XLVII). The work surface should allow for at least 3.8 cm (1.5 in) of depth for wrist/palm and forearm support (ANSI/HFES 100-2007- 8.3.4.2). Workstation surfaces should have a matte finish with a specular reflectance of no more than 45 gloss units at an angle of 60° (ANSI/HFES 100-2007-8.3.5.1).

3.1.6 Lateral/Vertical Clearance

Minimum lateral work clearances should be provided with 58.5 cm (23.0 in) for the shoulders, 63.5 cm (25.0 in) for the elbows, and an ideal overall work clearance would allow for 100.0 cm (39.4 in) of lateral clearance (MIL-STD-1472G, 2012-Figure 63). A clearance of 81.0 cm (31.9 in) should be provided from the desk to the wall, 38.1 cm (15.0 in) from the chair to the wall (MIL-STD-1472G-Table XLVII), and 61.0 cm (24.0 in) from the armrest to the wall (MIL-STD-1472G-Figure 63). Finally, all objects placed overhead to be grasped by the user should be no higher above the seat surface than 116.8 cm (46.0 in) (MIL-STD-1472G-5.10.3.4.9).

3.1.7 Display/Input Devices

For seated workstations that incorporate a computer display, the display should be mounted at least 15.2 cm (6.0 in) above the seat level with 35.6 cm (14.0 in) being the preferred minimum height (MIL-STD-1472G, 2012-Figure 68). The maximum mount height for vision over the top should be 68.6 cm (27.0 in). If a keyboard is incorporated, it should be located 10.0 - 25.0 cm (3.9 – 9.8 in) from the work surface edge (Chengular et al., 2003). The input device work surface should adjustably tilt from -15° to +20° (ANSI/HFES 100-2007-8.3.2.4.1). When using a laptop the tilt angle of the laptop keyboard should be 20°, the keyboard-screen angle should be 119°, and the laptop should be positioned 41.0 cm (16.1 in) from the body (Nanthavanij et al., 2016). Touchscreens should be mounted within reach and operate all areas of the screen including corners of the display for 90% of the population (MIL-STD-1472G, 2012).

3.1.8 Desk-RPIC Input

Approximately 64% of RPICs suggested their desk was rectangular in shape, and 73% were unsure of whether their current work surface was the best design for their operations. More detailed interview re-sponses demonstrated the variability in desk design including multi-level table, a pullout work surface containing a trackball and keyboard, and knee boards. Multiple RPICs indicated there was not enough space on the work surface to perform writing tasks.

3.1.9 Chair Dimensions

The chair is essentially an extension of the desk which requires proper dimensions and adjustments to minimize discomfort and risk for injury or illness. A comfortable distance from the seat surface to the desk surface has been found to be around 27.0 – 30.0 cm (10.6 – 11.8 in) (Kroemer & Grandjean, 1997) or 39.0 – 51.0 cm (15.4 – 20.1 in) from backrest to keyboard home row (Nanthanvanij, 1996). Seat heights should be within the range of 38.0 - 56.0 cm (15.0 – 22.0 in) with at least 11.4 cm (4.5 in) of adjustability (ANSI/HFES, 100-2007-8.3.3.1).

For fixed height work surfaces, some individuals may require an adjustable footrest to allow resting of the feet (Chengular, 2003) to reduce pressure in the back of the knee (popliteal) area (Chaffin & Andersson, 1984), and prevent decreased blood flow to the lower limbs (Yamaguchi et al., 2014). Footrests should be provided when workers must sit for an extended duration in seats higher than 46.0 cm (18.1 in) or with work surfaces higher than 76.0 cm (29.9 in) (MIL-HDBK-759C-5.7.3.5, 1995) with a distance from center of the chair of 18.0 cm (7.1 in), a depth of 15.0 cm (5.9 in), length 25.5 cm (10.0 in) (MIL-HDBK-759C-Table 20), and height up to 22.0 cm (8.7 in) (ANSI/HFES, 100-2007-8.3.4.3).

Seminal literature suggests office chairs should have a well-padded seat pan with a waterfall anterior surface to reduce the pressure on the user's legs (Lueder, 1986). Chairs should incorporate cushioning when the operator must remain seated for more than an hour or more than 20% of the total work time (MIL-HDBK-759C-5.7.3.3). The cushioning should incorporate the following features: a) a flat, firm shape, but with enough softness to deform, b) have resilient material under the cushion to absorb shocks, c) support body weight, primarily around the two bony points of the pelvis, d) be shaped to follow the inward curve of the lower back, and provide adequate support for it, to relieve strain on the back muscles, e) avoid applying pressure under the thighs, f) use perforated or ventilated material, to prevent "hotness" or "sweatiness," and g) allow the operator to shift positions. Fabric covers which allow air circulation and reduce the risk for tearing and cracking should be implemented (DOE, 2001). However, more recent literature suggest chairs should include net-like material and a suspension (no hard platform under the material) design to provide increased comfort compared to cushioned chairs (Vlaović, Domljian, Župčić, & Grbac, 2016). Moreover, the suspension design has been found to reduce pressure between the buttock-thigh region and the seat compared to cushioned (foam) chairs (Makhsous et al, 2012; Yoo, 2015).

The seat pan should incorporate an adjustable range of 4° that includes a reclined position of 3° (ANSI/HFES 100-2007-8.3.3.4). Chairs should accommodate a torso-thigh angle of no less than 90° (ANSI, 100-2007-8.2.1) and a pan-backrest angle of 90°-100° (MIL-STD-1472G-Table XLVII). The seat depth should be at least 38.1 cm (15.0 in) with a maximum adjustable range of 43.2 cm (17.0 in) (MIL-STD-1472G-Table XLVII). The seat pan width should be at least 40.6 cm (16.0 in) (MIL-STD-1472G-Table XLVII). The inclusion of a lumbar support has been shown to reduce lumbar load and muscle activity (Makhsous, 2009) and is recommended to be located between 15.0 (5.9 in) and 25.0 cm (9.8 in) above the compressed seat height with user adjustability between 15.0 (5.9 in) and 25.0 cm (9.8 in) (ANSI/HFES, 100-2007-8.3.3.6). Chairs should incorporate a backrest with an adjustable recline of 15° or more within the range of 90°-120° relative to the horizon (ANSI/HFES 100-2007-8.3.3.5) and a headrest if the recline angle is greater than 120° (ANSI/HFES 100-2007- 8.3.3.5). Backrests should incorporate a width of 36.0 cm (14.2 in) (ANSI/HFES 100-2007-8.3.3.6) and a height of at least 38.0 cm (15.0 in) that is adjustable in increments of no larger than 2.5 cm (1.0 in) (MIL-STD-1472G-Table XLVII). The vertical space between the seat pan and backrest should not exceed 15.2 cm (6.0 in), but it is preferred that no vertical space exists between these two pieces (MIL-STD-1472G, 2012-Table XLVII).

Armrests should be incorporated in the chair design to increase comfort and decrease static load in the upper extremities (Odell et al., 2007). Armrests should have an adjustable height 17.0 (6.7 in) to 27.0 cm (10.6 in) above the compressed seat pan, a non-abrasive or non-irritating covering, and at least 46.0 cm (18.1 in) of clearance between the armrests (ANSI/HFES, 100-2007-8.3.4.1). Moreover, armrests should have a length of 25.4 cm (10.0 in) and a width of 5.0 cm (2.0 in) (MIL-STD-1472G, 2012-Table XLVII).

3.1.10 Chair-RPIC Input

RPICs reported the use of a variety of chairs including an office-like chair, an automotive-like chair, and a fixed position aircraft seat. The fixed position aircraft seat allowed for recline of the entire seat but not the pan or backrest separately. Moreover, the aircraft seat allowed for tilt in the frontal plane so that the operator could maintain level seating while the aircraft was in a nose-up attitude. The automotive-like chair was cushioned with adjustable seat height, backrest recline, foldable armrests, and it was fixed to the floor. The office-like chair incorporated cushioning, no rollers, and a fixed reclined seat angle that allowed for more recline with the application of body weight to the chair due to a flexible design. It was noted that RPICs tend to fall asleep during long duration flights if the backrest is too reclined.

3.2 STAND-ONLY WORKSTATION

Stand-only workstations are typically confined to tasks that require forces greater than 4.5 kg (9.9 lb); high, low, or extended reaches; downward forces; frequent movement between workstations (Chengular et al., 2003); or when there is insufficient room for a seated workstation. The surface height should be near the height of the elbows (Kroemer & Grandjean, 1997), or should have adjustability over the range of 78.0 - 118.0 cm (30.7 – 46.5 in) with tilt adjustability from +20° to -45° (ANSI/HFES 100-2007-8.3.2.4.2). Based on the type of standing work, there are proposed slight deviations in workstation surface heights (Kroemer & Grandjean, 1997). Precision work requires a height of 5.0 – 10.0 cm (2.0 in – 3.9 in) above the elbows to reduce torso flexion, while light manual work benefits from a height of 10.0 – 15.0 cm (3.9 – 5.9 in) below elbow height. Finally, heavy manual work necessitates a surface height of 15.0 - 40.0 cm (5.9 – 15.7 in) below elbow height. Standing workstations should require a maximum overhead reach of 68.5 cm (27.0 in) and a maximum depth of reach of 58.5 cm (23.0 in) (MIL-STD-1472G-Figure 62). Foot clearance should accommodate at least 10.0 cm (3.9 in) height and 10.0 cm (3.9 in) depth (MIL-STD-1472G-5.10.2.3). Standing workstations should provide a passing body depth of 33.0 cm (13.0 in), passing body width of 51.0 cm (20.1 in), standing space of 76.0 cm (29.9 in), walking space width of 30.5 cm (12.0 in), and overhead clearance of 185.5 cm (73.0 in) (MIL-STD-1472G-Figure 62).

3.2.1 Stand-Only Workstation-RPIC Input

RPICs reported no use of stand-only workstations. Responses indicated RPICs are not comfortable ma-nipulating controls while standing and believed that standing while piloting could be a safety hazard. Moreover, the controls and displays were positioned at the height that made them easily usable while sitting. The controls were not adjustable in height and therefore could not be easily manipulated while standing.

3.3 SIT-TO-STAND WORKSTATION

Sit-to-stand workstations allow operators the ability to manipulate the work surface height to obtain the benefits of both sitting and standing workstations. Workstations that allow both sitting and standing while performing work are recommended when tasks are of an extended duration (e.g., two hours of continuous works) (Chengular et al., 2003) as in such tasks workers have been found to remain seated for extended durations (Jans, Proper, & Hildebrandt, 2007). Sedentary tasks have been associated with elevated risk of type 2 diabetes (Hu et al., 2001), cardiovascular disease, and mortality (Katzmarzyk, Church, Craig, & Bouchard, 2009), and other cardiometabolic and musculoskeletal disorders. Extended sitting likely deconditions the lumbopelvic postural muscles (O'Sullivan et al., 2002) augmenting the load on the lumbar discs (Goel et al., 1993) and increasing the chance for strain, instability, and injury (Cholewicki & McGill, 1996). Like sitting, occupational standing for extended durations leads to musculoskeletal injury risks, such as back and leg discomfort (Dieen, 1998), increased muscle activity, and reduced balance performance (Madeleine, Voigt, & Arendt-Nielsen, 1997).

In an attempt to reduce musculoskeletal risks associated with both sitting and standing, sit-to-stand workstations have been introduced. Sit-to-stand workstations have been shown to reduce seated time (Straker et al., 2013; Alkhajah et al., 2012) while reducing upper back and neck pain (Pronk, Katz, Lowry, & Payfer, 2011). Additionally, breaks in sedentary time have been shown to be beneficially associated with metabolic risk variables (Healy et al., 2008) and standing, in lieu of sitting, may benefit cardio-metabolic health (Healy et al., 2015). However, the introduction of sit-to-stand workstations has not always been successful as users have demonstrated the unwillingness to utilize the adjustable function of the desks (Wilks, Mortimer, & Nylen, 2006). This suggests improvements in design or increased awareness may be necessary along with behavior modification programs to encourage the use of the sit-to-stand adjustability of these workstations. Given the adverse health conditions associated with prolonged sitting and/or standing, sit-to-stand workstations are recommended for any task that can be accomplished in either posture.

When standing, the work surface should have adjustability over the range of 78.0 - 118.0 cm (30.7 – 46.5 in) with tilt adjustability from +20° to -45° (ANSI/HFES 100-2007-8.3.2.4.2). It is recommended that sit-to-stand workstations include work surfaces with adjustable tilt within the range of +20° and -45°, including 0° to -15°(ANSI/HFES 100-2007-8.3.2.4.2). For standing workstations that incorporate a display, the display should be mounted at least 104.0 cm (40.9 in) above the ground, with 139.7 cm (55.0 in) being the preferred minimum height (MIL-STD-1472G, 2012-Figure 61). For information concerning multiple displays, please see section 5.2 Multiple Display Configuration. The maximum mount height for vision over the top should be 150.1 cm (59.1 in). Sit-to-stand workstation clearances should comply with seated workstation clearance requirements when used in the seated position (ANSI/HFES 100-2007-8.3.2.4.3). Researchers have suggested sitting to standing ratios of both 1:3 and 3:1 (Paul, 1995; Paul & Helander, 1995); however, both ratios are criticized for either allowing too much standing or sitting. A recent recommendation of a 1:1 sit to stand ratio (Callaghan et al., 2015) appears to be a viable solution as it increases total standing time of the 3:1 sit to stand ratio, while complying with the 4 hour standing limit set by the Occupational Health and Safety Council of Ontario (OHSCO, 2008). Sit to stand ratio research is still very limited and therefore, it is recommended that operators select ratios that best fit their needs. An additional approach for sitting vs standing is to adjust position based on task (e.g., sit while making phone calls, stand while emailing).

Currently, there are three main sit-to-stand workstation types. Some desks are fitted with an adjustable surface that can be raised either manually or by a power source (Figure 2(1)). Another design incorporates an adjustable surface (typically manual) that sits on top of a stationary desk (Figure 2 (2). This workstation type provides some surface space for manual work when standing. Finally, a desktop mount is available that allows the user to raise (typically manual) the monitor and keyboard to a standing height (Figure 2 (3)). (NOTE: for multiple display configurations, please see section 5.2.) Some designs provide a small standing working surface while others do not.

		
Adjustable surface incorporated in the desk (1)	Adjustable surface sitting on a stationary desk (2)	Adjustable monitor/keyboard desk mount (3)

Figure 2. Sit-to-stand workstation types (images from ergotron.com).

3.3.1 Sit-to-Stand Workstation-RPIC Input

RPICs indicated that sit-to-stand workstations were not used.

3.3.2 Sitting Versus Standing-RPIC Input

Approximately 73% of RPICs reported sitting at least sometimes while piloting from a control station. Many RPICs suggested the only time they might stand would be to stretch or to take a bathroom break. Additionally, assisting staff may stand if they were not directly controlling the aircraft.

3.4 RECOMMENDATIONS FOR WORKSTATION DIMENSIONS

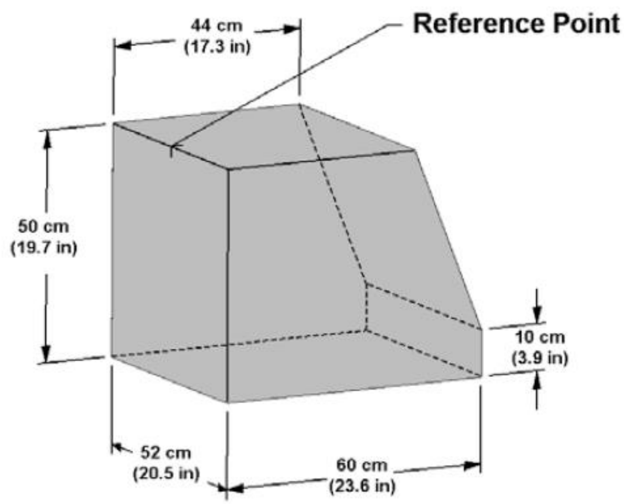
The following tables provide the consolidated recommendations reported in the literature for workstations and the chair. The first column of each table provides the source from which each recommendation was discovered. The second column lists the design element for which the recommendation is provided. The third column houses a minimum dimension in centimeters and inches. Finally, the fourth column lists adjustable ranges, if applicable, for the element. Adjustable ranges are not available in the literature for all design elements; however, authors included adjustable ranges as a reference for adjustable furniture. The minimum dimensions accommodating the anthropometrics of the 5^{th} to 95^{th} percentile male and females were chosen. The chosen minimums are discussed in each subpart and represented in the Final Recommendation tables found at the end of each subpart. Finally, all Final Recommendation tables were combined in Table 22.

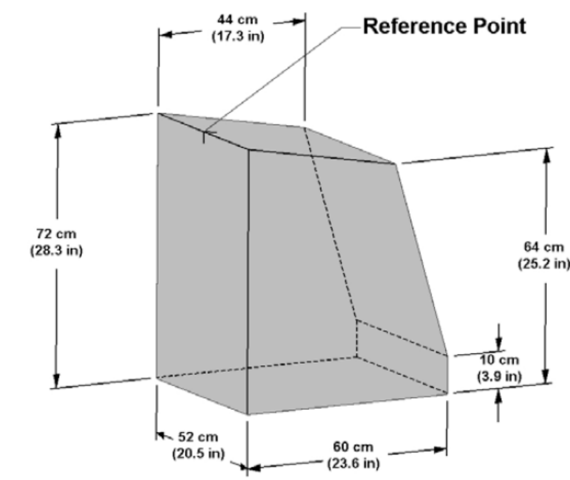
Table 3. Seated Workstation Dimension Recommendations

Workspace			
Source	**Dimensions**	**Minimum**	**Adjustment (unless otherwise specified)**
		cm (in)	**cm (in)**
(MIL-STD-1472G-Table XLVII)	Kneehole depth (at knee height)	38.1 (15.0)	
(ADA, 2010-306.3.5)	Knee clearance width	76.0 (29.9)	
(MIL-STD-1472G-Figure 63)	Kneehole height (standard office)	63.5 (25.0)	
(MIL-STD-1472G-Table XLVII)	Desk to wall	81.3 (32.0)	
(MIL-STD-1472G-Table XLVII)	Chair to wall	38.1 (15.0)	
(MIL-STD-1472G-Figure 63)	Armrest to wall	61.0 (24.0)	
(MIL-STD-1472G-Figure 63)	Lateral Work Clearance		
(MIL-STD-1472G-Figure 63)	Shoulders	58.5 (23.0)	
(MIL-STD-1472G-Figure 63)	Elbows	63.5 (25.0)	
(MIL-STD-1472G-Figure 63)	Best Overall	100.0 (39.4)	
(MIL-STD-1472G-Figure 63)	Height of work surface	73.5 (28.9)	76.0 (29.9) (preferred)
(ADA AG, 2002-4.32.3)	Surface height		71.0-86.5 (28.0 – 34.1)
(Chengalur et al., 2003)	Keyboard distance from front of desk surface		10.0-25.0 (3.9 – 9.8) (range)
(ANSI/HFES 100-2007-8.3.2.4.1)	Input device work surface tilt		Adjustable from -15° to +20°
(ANSI/HFES 100-2007- 8.3.4.2)	Wrist/Palm, Forearm support depth	3.8 (1.5)	
(MIL-STD-1472G-Table XLVII)	Work surface width	61.0 (24.0)	
(MIL-STD-1472G-Table XLVII)	Work surface depth	61.0 (24.0)	76.2 (30) (preference)
(MIL-STD-1472G-5.10.3.4.9)	Maximum overhead reach for gripping reach (above seated surface)		116.8 (46.0) (maximum)
	Kick space		
(MIL-STD-1472G-5.10.2.3)	Height	10.0 (3.9)	
(MIL-STD-1472G-5.10.2.3)	Depth	10.0 (3.9)	
	Toe clearance		
(ADA, 2010-306.2)	Depth (distance from front surface of the element)	43.0 (16.9)	63.5 (25.0) (maximum)
(ADA, 2010-306.2)	Width	76.0 (29.9)	
	Display mounting heights		

Source	Dimensions	Minimum cm (in)	Adjustment (unless otherwise specified) cm (in)
(MIL-STD-1472G-Figure 68)	Height (seated)	15.2 (6.0) / (35.6 (14.0)preferred) from seat height	111.8 (44.0) / (90.0 (35.4) preferred)
(MIL-STD-1472G-Figure 68)	Maximum height for vision over top (seated)		68.6 (27.0) (maximum)
	Laptop Specific Dimensions		
(Nanthavanij et al., 2016)	Tilt angle of laptop keyboard		20° (preferred)
(Nanthavanij et al., 2016)	Laptop keyboard-screen angle		119° (preferred)
(Nanthavanij et al., 2016)	Distance from body to laptop		41.0 (16.1) (preferred)
*Refer to Upright, Reclined, and Declined Seated Clearances (ANSI/HFES 100-2007-Figure 8.3b)			

Upright, Reclined, and Declined Seated Clearances





The three-dimensional images above represent the clearance spaces under a work surface. The image on the left demonstrates clearance when the height of work surface and the height of knee clearance are at the low end of the adjustable ranges detailed in the table above, while the image on the right represents the high end of the adjustable ranges.

(ANSI/HFES 100-2007-Figure 8.3b)

Table 4. Sit-to-Stand Workstation Dimension Recommendations

Source	Dimensions	Minimum	Adjustment (unless otherwise specified)
		cm (in)	cm (in)
(ANSI/HFES 100-2007- 8.3.2.1)	Clearances	Comply with seated standards in Section 8.3.2.1	
	Work surface		
(ANSI/HFES 100-2007- 8.3.2.4.3)	Height (height adjustable only)		56.0 – 118.0 (22.0 – 46.5) from floor to front edge of support
(ANSI/HFES 100-2007- 8.3.2.4.3)	Height (height and tilt adjustable)		Some portion of range 56.0 – 72.0 (22.0 – 28.3) from floor to front edge of support/ additional height (greater than 72.0 (28.3)) for standing when combined with tilt
(ANSI/HFES 100-2007- 8.3.2.4.3)	Tilt (height and tilt adjustable)		+20° to -40°, to include 0°

Table 5. Chair Dimension Recommendations

Source	Dimensions	Fixed/Minimum	Adjustment (unless otherwise specified)
		cm (in)	cm (in)
	Armrest		
(MIL-STD-1472G-Table XLVII)	Length	25.4 (10.0)	
(MIL-STD-1472G-Table XLVII)	Width	5.0 (2.0)	
(ANSI/HFES 100-2007- 8.3.4.1)	Height (adjustable)		17.0 – 27.0 (6.7 – 10.6) above compressed seat height
(ANSI/HFES 100-2007- 8.3.4.1)	Clearance between armrests	46.0 (18.1)	
	Seat pan		
(MIL-STD-1472G-Table XLVII)	Width	40.6 (16.0)	
(ANSI/HFES 100-2007- 8.3.3.1)	Height		38.0 – 56.0 (15.0 – 22.0) and adjustable over a minimum range of 11.4 (4.5)

(MIL-STD-1472G-Table XLVII)		Depth	38.1 (15.0)	Up to 43.2
(ANSI/HFES 100-2007- 8.3.3.4)		Angle		Range of 4° that includes a re-clined position of 3°
Source	**Dimensions**		**Fixed/Minimum**	**Adjustment (unless otherwise specified)**
			cm	**cm**
(MIL-STD-1472G-Table XLVII)		Pan-backrest angle		90° - 100°
(Leuder, 1986)		Front edge	waterfall	
(Kroemer & Grandjean, 1997)		Distance to desk surface		27.0-30.0 (10.6- 11.8) (pre-ferred)
	Backrest			
(ANSI/HFES 100-2007- 8.3.3.5)		Angle		Adjustment range of 15° or more within the range of 90° - 120° relative to horizontal
(ANSI/HFES 100-2007- 8.3.3.5)		Recline angle		If greater than 120° should provide a headrest
(MIL-STD-1472G-Table XLVII)		Vertical space between seat pan and backrest	15.2 (6.0)	It is preferred there is no space between seat pan and bottom of backrest.
(MIL-STD-1472G-Table XLVII)		Height	38.0 (15.0)	Height should be adjustable unless it is solid from seat pan to minimum height. Adjust-ments should be in incre-ments no larger than 2.5 cm (1.0)
(ANSI/HFES 100-2007- 8.3.3.6)		Width	36.0 (14.2)	
(ANSI/HFES 100-2007- 8.3.3.6)		Lumbar support height		15.0 – 25.0 (5.9 – 9.8) above compressed seat height
(Nanthanvanij, 1996)		Distance to keyboard home row		39.0-50.0 (15.4 – 19.7) (pre-ferred)
(MIL-HDBK-759C-5.7.3.5)	Footrests		Should be provided when user is seated in seats of height 46.0 or higher for extended durations or with work surfaces higher than 76.0.	
(MIL-HDBK-759C-Table 20)		From center	18.0 (7.1)	
(MIL-HDBK-759C-Table 20)		Depth	15.0 (5.9)	

(ANSI/HFES 100-2007- 8.3.4.3)		Depth	20.0 (7.9)	
(MIL-HDBK-759C-Table 20)		Width	25.5 (10.0)	
(ANSI/HFES 100-2007- 8.3.4.3)		Width	51.0 (20.1)	
(ANSI/HFES 100-2007- 8.3.4.3)		Height		Up to 22.0 (8.7)
	Chair Design			
(Vlaović et al., 2016)		Contact Surface Material	Net-like material and suspension design	

4. COMPUTER WORKSTATIONS

4.1 WORKSTATION CONTROLS

4.1.1 Keyboard

Keyboards should be located in the center of the operator's usual work space. This may be in front of a single display or centered between two displays, as determined by the task analysis, information allocation, etc. (ISO, 2013).

Keyboards vary greatly in the arrangement of keys. Most designs include alphanumeric, dedicated formatting, modifier, navigation, fixed-function, and special purpose keys. The numeric keypad has the numbers 1 through 9 arranged in a three by three array with "0" centered below. The standard "QWERTY" arrangement for keyboards is used for alphabetic and numeric information. Cursor control keys on the keyboard are arranged in a two-dimensional array and reflect the direction of actual cursor movement (DOD-HFDG-ATCCS, 1992).

The surface horizontal width for a key on a typing keyboard should be 1.2 – 1.5 cm (0.47 - 0.59 in) wide for alphanumeric keys and .64 cm^2 (0.1 in^2) for other keys, such as Esc, Print Screen, and Scroll Lock (ANSI, 1988; NUREG 0700, 2002). The ISO and ANSI recommend a distance of 1.9cm $\pm$ 0.1 cm in the vertical and horizontal direction between adjacent key centers for alphanumeric and numeric keys (ANSI, 2007; ISO, 2008). ISO requirements for force needed to press the keys range from 0.5N to 0.8N (ISO, 2008). Pereira et al. (2014) found that females with small fingers and males with large fingers worked well using keys vertically spaced between 1.6 cm (0.63 in) and 1.8 cm (0.71 in) and horizontally spaced between 1.7 cm (0.67 in) and 1.9 cm (0.75 in). The participants in the study used between 0.65N (0.146 lbf) and 0.76N (0.171 lbf) of force, which is within ISO standards (Pereira, Hsieh, Laroche, & Rempel, 2014).

US guidelines for computer workstation layouts state the keyboard slope (anterior/posterior) should be between 0 and 25°, but a reduction in the slope to -15° (negative slope keyboard) has been shown to allow for reduced wrist extension, placing the hand/wrist in a more neutral position (ANSI/HFS, 1988; Simoneau & Marklin, 2001). Additional keyboard modifications, such as splitting the keyboard in half, angling the keyboard medially to laterally, and increasing the opening angle (horizontally rotated) from center of the keyboard to the front edge, have been implemented. Although research does not provide conclusive evidence that alternative keyboards reduce discomfort and injury, it is generally recommended to adjust chair height and/or keyboard feet or use alternative keyboards that allow for neutral wrist/hand postures. (OSHA eTool, 2003).

4.1.2 Mouse

The mouse is used on a flat surface or mouse pad to control and match cursor movements in the x and y direction displayed on the screen. In the workplace, the mouse is the most commonly used device with computers (Atkinson, Woods, Haslam, & Buckle, 2004). A mouse is used for pointing, cursor selection, coarse drawing, and dragging (MIL-STD-1472G, 2012).

The mouse should be placed near the keyboard for easy access and to avoid working in an uncomfortable position (OSHA eTool, 2003). Dennerlein and Johnson (2006) found that positioning the mouse closer to the centerline of the body helps with posture and reduction of strain on the upper extremities (Dennerlein & Johnson, 2006). The computer mouse should be gripped so that the hand/wrist remains in a neutral position, which may be aided by slanting the superior surface of the mouse to reduce the risk for injury (Barr, Ozkaya, Nordin, & Lee, 1996; OSHA, 1997). The mouse should be easy to move, with either the left or right hand, in any direction without changing hand placement. The mouse design should not have any sharp edges. Standard dimensions for the mouse are: 4.0 – 7.0 cm (1.6 – 2.8 in) in width, 7.0 – 12.0 cm (2.8 – 4.7 in) in length, and 2.5 – 4.0 cm (0.98 – 1.57 in) in height. Button characteristics include resistance of 0.5 N (0.112 lbf) – 1.5 N (0.337 lbf) and displacement of 0.5 – 0.6 cm (0.2 – 0.24 in) (MIL-STD-1472G, 2012).

4.1.3 Trackball

Trackballs are an alternative non-keyboard input device that can be used to select data on a display. Trackballs range in diameter from 5.0 – 15.0 cm (2.0 – 5.9 in) with 100.0 – 140.0 degrees of exposure. Arm and wrist support should be provided depending on the task. Trackball buttons and buttons near the trackball should be placed to prevent accidental actuation during trackball use (i.e., user hand placement while manipulating the trackball shall not accidentally actuate buttons). If the trackball is designed for finger control (i.e., roller manipulated using fingers), the primary actuation button shall be placed near the thumb position and permit thumb actuation (MIL-STD-1472G, 2012). Smaller diameter trackballs can be utilized where space availability is very limited and when there is no need for precision (MIL-STD-1472G, 2012).

4.1.4 Joystick

Joysticks can be used in control stations for tasks requiring precise or continuous control in two or more related dimensions. There are two types of joysticks, displacement and isometric, that can be operated by hand, finger, or thumbtip/fingertip. The Department of Defense (DoD) standards for hand operated joystick include that the hand grip length shall be 11.0 - 18.0 cm (4.3 – 7.1 in) and the hand grip diameter shall not exceed 5.0 cm (2.0 in). Clearance of at least 10.0 cm (3.9 in) to the side and 5.0 cm (2.0 in) to the rear allow for full range in motion (MIL-STD-1472G, 2012).

Displacement joysticks are designed to move smoothly in the direction pushed by the user and for position accuracy in addition to display functions. The spring-loaded design of displacement joysticks allow for the joystick to move within 45° and return to center once the operator's hand is removed. Displacement joysticks should not be used for automatic sequencing of a cursor if it has a deadband near the center or hysteresis (MIL-STD-1472G, 2012). Hysteresis is exhibited when a body's response, while reacting to changes, lags behind the forces affecting it (HF-STD-001B, 2016).

Isometric joysticks are used for position, speed, and display functions. This joystick type responds to applied pressure but does not move. Isometric joysticks should not be used for applications that require a constant force to be maintained for long periods of time, nor should these joysticks be used if no feedback is given when maximum control inputs have been surpassed (MIL-STD-1472G, 2012).

4.1.5 Touch-pad

Touchpads are input devices typically built into laptops as an alternative to a mouse. The touchpad can be operated with the left or right hand. Research supports that touchpads force the user to have static posture while operating a laptop, restricting hand movement. Conte's (2014) results suggest that a mouse be used with a laptop to allow for a wider range of arm movement and reduction of biomechanical stress (Conte, et al., 2014).

4.1.6 Stylus

Stylus can be used in the workstation for data pickoff, the entry of points onto a visual indicator, the generation of free-drawn graphics, and similar control applications. Movement of the stylus by the user is very smooth on the surface. Discrete placement of the stylus at any point on the display will be mirrored by the user and will remain in position if the stylus is not moved. The contact surface of a selector button that is mounted on a stylus or light pen shall have a diameter of no less than 0.005 cm (0.2 inch). The force required to actuate a button mounted on a stylus or light pen shall be 0.3 to 0.8 N (1.0 to 2.9 ounces of force) (MIL-STD-1472G, 2012).

4.1.7 Touchscreen

A touchscreen is an input device that permits users to interact with the system by using their fingertips to point to objects on the display. Touchscreens are appropriate for interactions involving the selection of devices or targets on position displays (e.g., radars), arrangement diagrams, piping diagrams, discrete-function controls, or opening/closing valves (MIL-STD-1472G, 2012).

Touchscreens are not ideal for entering large amounts of data. Touchscreens have been found to be very fast input devices in comparison to trackballs but less accurate while in a motion environment, e.g., a control room on a ship (Yau, Chao, & Hwang, 2008). Other input devices should be available if system movement or vibration degrades user performance below the level required to accomplish task (MIL-STD-1472G, 2012). Display of user command or action feedback for touch panels should appear immediate to the user. Touch-interactive devices should be mounted to minimize parallax problems and specular glare. Touchscreens should be mounted to ensure the central 90% of the anticipated user population can reach and operate all areas of the screen including corners of the display (MIL-STD-1472G, 2012).

4.1.8 Voice Control

Voice control is an input method that requires a user's vocal command to perform a task. Voice controls can include voice recognition and speech recognition. Voice recognition technologies identify the unique characteristics of an individual's voice to determine the words being spoken, whereas speech recognition only identifies the words being spoken and does not consider an individual's unique voice characteristics. In this document, voice control is associated with speech recognition technologies.This is desirable in situations where the user's visual and manual performances are constrained tasks (MIL-STD-1472G, 2012). Testing should be performed to determine which sounds, words, or phrases can be distinguished reliably under realistic conditions. Spoken command entries are not to be chosen arbitrarily. Tradeoffs between phonetic distinctiveness and familiarity of terminology need to be evaluated. Feedback and simple error correction procedures should be provided for speech input. If the computer has not correctly recognized a spoken entry, the user can easily cancel the entry and try again. Alternative input devices shall be available in the event that the system cannot recognize a voice entry after repeated attempts, or the device fails, another type of input entry can be substitutede. In noisy environments, active noise reduction should be used to cancel low frequency noise becauase low frequency noise is most responsible for masking audible speech. Voice controls should recognize and respond to speech between 200 and 6,300 Hz, with a minimum bandwith of 25 to 4,000 Hz. Further the control should allow variations in volume of at least 50 dB, and a noise cancelling microphone should be used (MIL-STD-1472G, 2012).

4.1.9 Advantages and Disadvantages of Non-keyboard Input Devices

The control workstation design should be designed for left or right handed placement of one-handed devices such as a mouse or trackball. The use of shared devices, i.e. one keyboard, mouse, etc. for multiple display devices, is preferred over dedicated keyboards for each display device. Shared input devices for one space should have their own dedicated spot on the work surface that doesn't interfere with other items such as telephones, operating manuals and log books (ISO, 2013). The ISO suggest that input devices be free to move around the workstation unless there is a need to be built in for to special reasons (vibrations, earthquake).The characteristics of these devices need to be considered in the selection of the appropriate controls for a given task. Table 6 summarizes the pros and cons of the non-keyboard input devices mentioned in the previous sections. Placement of these input devices should be at or below elbow height (ISO, 2013).

Table 6. Advantages and Disadvantages of some non-keyboard input devices (HF-STD-001B, 2016).

	Advantages	Disadvantages
Mouse	• Easy to learn and familiar to many users • Has fast pointing speed and low error rate • Used for pointing, cursor selection, coarse drawing and "dragging"	• Needs large footprint • Can cause wrist to be held at non-neutral positions • May need two devices to accommodate handedness • Can fall off or be knocked off the work surface
Trackball	• Small footprint required • Easy for user to locate without looking • Can be spun quickly to move the cursor over a long distance, such as a large display	• Difficulty with concurrent button pressing while using • Not good for drawing tasks • Not as fast or accurate as other devices • Can cause the wrist to be held in non-neutral position
Joystick	• Can provide automatic return to origin • Small footprint required • Finger-operated displacement joysticks can be fast for scrolling long distances	• Less accurate than other interaction devices • Cannot control speed independent of direction • Difficult to use for free-hand graphic input
Touchpad	• Small footprint • Can be used by both left and right hand	• Slower and less accurate than mouse • Friction between finger and pad may become uncomfortable to user
Touchscreen	• No separate input device needed • Fast • Direct mapping of input • Intuitive and easy to learn	• Hand may obstruct view • Fingerprints on screen • Not good for precise drawing tasks • User must be close to screen • Parallax can be a problem (e.g. user touching above or to the side of target).
Voice Input	• Does not require hands. • Does not require user to shift gaze. • Useable in dark or low light conditions. • Natural form of interaction	• Entry can be slow. • Difficult to correct errors. • Background noise may interfere with recognition. • May require headset. • Voice changes (e.g. become stressed) can hamper recognition. • Speaker-dependent systems require training. • Not appropriate for environments where voice is used extensively for other tasks.

The consoloidated recommendations for input devices is provided in Table 7. It was assumed that the keyboard and mouse would be the primary input controls for UAS control stations due to the fact that they are the most common input devices used in fielded control stations today (Waraich et al., 2013).

Table 7. Input Controls Recommendations

Source	Control		Minimum cm (in)	Maximum cm (in)
(ANSI, 1988, 2007; NUREG 0700, 2002; Pereira, Hsieh, Laroche, & Rempel, 2014; ISO, 2008; Simoneau & Marklin, 2001)	Keyboard			
		Key Width	1.2 (0.47)	1.5 (0.59)
		Vertical Spacing between keys	1.6 (0.63)	2.0 (0.79)
		Horizontal Spacing between keys	1.7 (0.67)	2.0 (0.79)
		Slope	0°	20°
(HF-STD-001B – Exhibit 5.7.3.2.4)	Mouse			
		Width	4.0 (1.6)	7.0 (2.8)
		Length	7.0 (2.8)	12.0 (4.7)
		Thickness	2.5 (1.0)	4.0 (1.6)
(MIL-STD-1472G, 2012)	Joystick			
		Handgrip length	11.0 (4.33)	18.0 (7.08)
		Handgrip diameter		5.0 (2.0)
		Side Clearance	10.0 (4.0)	
		Rear Clearance	5.0 (2.0)	

4.1.10 Controls-RPIC Input

RPICs reported the use of the keyboards, mice, and joysticks as the most common control types. Further evaluation during the interviews revealed former manned RPICs and military unmanned RPICs preferred keyboard and mouse control for autonomous flight and the option to manually fly the aircraft with a joystick similar to what might be found in a manned aircraft. These RPICs were adamant that game controllers, or any controls not commonly found in a manned aircraft, should not be used for UAS control because they seemed to make the RPIC feel more as if they were playing a video game versus flying an aircraft. Further, the buttons on game controllers are not standard between controls and the buttons' functions can change between users potentially increasing the risk for operator malfunction. However, RPICs without any manned aircraft experience, or who were familiar training RPICs who had no manned aircraft experience, preferred, or at least considered, game controllers as a viable option because many non-manned RPICs have been found to have more experience with these types of controls due to their prevalence in gaming and the significant number of hours the RPICs spent operating a video game console such as a Microsoft Xbox or Sony PlayStation (Figure 3).

Figure 3. Example game controllers; Microsoft Xbox (left) and the Sony PlayStation (right) controller (Game Controller).

Other controls were reported as being utilized to pilot UASs; however, their use appears to be less broad. Trackballs (Figure 4) were reported as being fairly common in lieu of a mouse; however, the trackball was susceptible to jamming due to dust and debris. Touchscreens (Figure 5) were thought to be useful for RPICs to tap on functions on the screen, but RPICs were adamant that manual control of an aircraft through a touch screen was unwanted. Finally, foot controls were reportedly used for intercom systems as well as rudder and break controls. However, foot controls are reportedly no longer widely used and are not preferred by RPICs since there is other software available that can control these tasks.

Figure 4. Example of Trackball (Trackball).

Figure 5. Example of touchscreen on a tablet (Touchscreen).

5. WORKPLACE ENVIRONMENT

5.1 WORKSTATION ILLUMINATION

Designing a workstation environment requires proper lighting so employees can safely and efficiently work. Open or closed offices require an interior illumination level of approximately 500 lux, while conference rooms require 300 lux (GSA, 2003), where Lux is the SI unit of illumination. Visual task performance is optimal between 322.92-1076.39 lux depending on text size and contrast, while varying monitor display tasks benefit from illumination between 215.3 and 785.8 lux (ANSI/IESNA, 2004; OSHA eTool, 2003). Some tasks may require dark adaptation: the process by which the eyes become more sensitive in dim light. In these tasks, the preferred forward field of view ambient lighting level should be 0.001 lux with 0.0001 lux ambient level for maintaining dark adaptation (MIL-STD-1472G). For interior lighting, fluorescent lights should be used (GSA, 2003). Compact fluorescent lights should be used as downlights (GSA, 2003). Table 8 shows the minimum and preferred illumination requirements based on work area and task types.

Table 8. Illumination requirements based on work area and specific tasks (MIL-STD-1472G).

Work area or type of task	**Illumination level[1]**	
	Minimum lux (fc)	**Preferred Lux (fc)**
Control rooms general lighting	325 (30)	540 (50)
Computer work	300 (28)	300 (28)
Computer workstation[2]	300 (28)	540 (50)
Consoles (front)	325 (30)	540 (50)
Consoles (rear)	110 (10)	325 (30)
Offices (general)	540 (50)	755 (70)
Ordinary visual tasks	325 (30)	540 (50)
Reading (large print)	110 (10)	325 (30)
Reading (news print)	325 (30)	540 (50)
Reading (small type reading)	540 (50)	755 (70)
Reading (prolonged reading)	540 (50)	755 (70)
Radio room	540 (50)	540 (50)
Stairs and ladders	110 (10)	215 (20)
Passageways (walkways, hallways)	150 (14)	215 (20)
Elevators	215 (20)	325 (30)
Emergency lighting	30 (3)	55 (5)

[1] Illumination level when measured on the task object or 76 cm (30 in) above from floor.
[2] This information also complies with OSHA (OSHA "Working safely with video display terminals", 1997)

Workstation illumination must adjust for when visual displays are present. High illumination levels may wash out the images on the screen of the visual display unit. Preferred illumination levels for any workstation having Video Display Terminals (VDT) is 300 - 540 lux (MIL-STD-1472G, 2012; OSHA "Working safely with video display terminals", 1997). Maintaining this level can be achieved particularly by ambient lighting, task lighting, or by the combination of both ambient and task lighting. When dimming is required, the lighting level should not be lower than 200 lux (ISO 11064-6,2005). Adequate illumination should be provided to support visual tasks or tasks associated with handling paper documents, such as reading. An illumination level of 500 lux is necessary for paperwork-based control stations.To fulfill this need, adjustable fixture systems can be utilized to allow users to change the direction of light to their preference (ANSI/HFES 100-2007).

Most monitors provide users with the option of adjusting the display luminance. Literature states that the range of luminance shall not be less than the ratio of 50:1 (MIL-STD-1472G). In the case of tasks requiring detection of faint (low level) signals, ambient luminance level should not be more than 2.7 lux and displays should be hooded, shielded, or recessed (MIL-STD-1472G). Additionally, where dark adaptation is needed for task completion, all displays should have an upper one-third hood with rounded corners. All displays should be oriented away from windows to minimize glare (MIL-STD-1472G, 2012). The contrast ratios between the lightest and darkest areas, or between the task area and the surroundings, should not be less than the listed values in Table 9 (ANSI/IESNA RP-1-1993; MIL-STD-1472G).

Table 9. Contrast ratios (MIL-STD-1472G).

Assessments	**Environmental classification**		
	A	**B**	**C**
Between lighter surfaces and darker surfaces within the task	5:1	5:1	5:1
Between tasks and adjacent surroundings	3:1	3:1	5:1
Between tasks and more remote surfaces	10:1	20:1	d
Between luminaries and adjacent surfaces	20:1	d	d
Between the immediate work area and the rest of the environment	40:1	d	d

Notes:

A = Interior areas where reflection off the entire space can be controlled for optimum visual conditions.

B = Areas where reflection off the immediate work area can be controlled, but there is only limited control over remote surroundings.

C = Areas (indoor and outdoor) where it is impractical to control reflection and difficult to alter environmental conditions.

d = Contrast ratio control not practical.

Glare is a serious illumination problem that reduces the visibility of objects seen by human operators. Parabolic shaped louvers in the luminaire, indirect lighting facing the ceiling from a distance of 30-46 cm (11.8 – 18.1 in), and avoiding natural light from windows are desirable solutions to minimize glare and direct light rays to the eyes (Anshel, 2005; Wiegand, 2013). Incorporating non-reflective desk surface material, window blinds or drapes, and computer glare filters (built in or external) may reduce glare as well (OSHA eTool, 2003; Wiegand, 2013). Figure 6 illustrates various light sources and recommendations to reduce glare. In the case of electric lighting the glare index should be 19 or less for every work position (ISO 11064-6,2005).

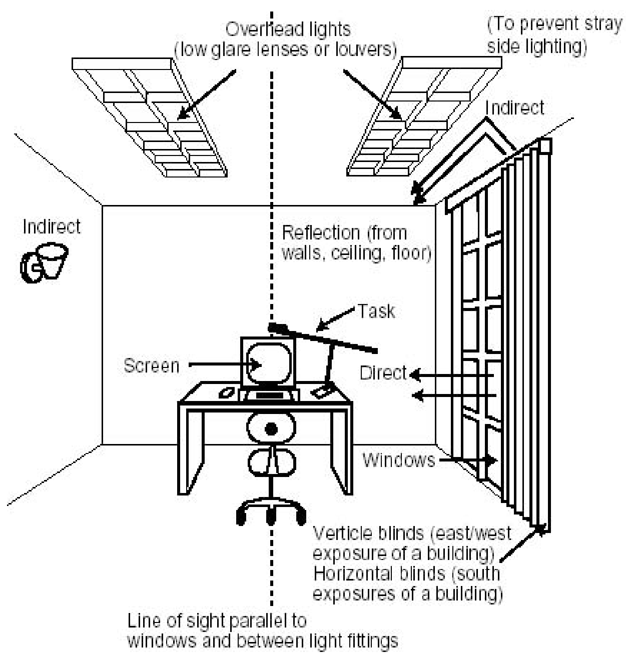


Figure 6. Position of light source relative to the computer monitor (OSHA "Working safely with video display terminals", 1997).

Flickers should be avoided as it can cause eye strain and seizures. High frequency control gears can be used to avoid flicker. If self- illuminated equipment is in use, the contrast ratio of the illuminated equipment to the immediate surroundings and peripheral surroundings should be a maximum 3:1 and 10:1 respectively (ISO 11064-6,2005).

5.2 MULTIPLE DISPLAY CONFIGURATION

Piloting an unmanned aircraft typically requires the use of one or more displays to provide the pilot with instrumentation outputs and live video of the flight from the prospective of the aircraft (Arnold, 2016). Previous literature proposes control room operators (not specific to UAS) tend to focus on a single complex task at any given time (Moray & Rotenberg, 1989), and utilizing a moderate number of displays while dealing with multiple systems increases response time (Murray & Caldwell, 1996). When multiple displays are used in combination for one task, the adjacent screens should be placed close together to reduce the required space and to minimize the distance between points of focus (ISO-11064-4-A-3-2). Moreover, the viewing distance should be equal for displays which are frequently viewed, and the displays should swivel if multiple operators are working at a common workstation. If displays are vertically stacked, the displays should be positioned as low as possible (ISO-11064-4-A-3-2-1). The vertically stacked displays should have similar viewing distances or the upper displays should not require viewing for long durations. Finally, physically larger displays should be used as they have been shown to improve performance on spatial tasks (Tan, Gergle, Scupelli, & Pausch, 2006).

Multiple display configurations have been used in UAS control stations. For example, the Family of Integrated Rapid Response Equipment (FIRRE) Command and Control Station (C2) ground control station is housed inside a vehicular shelter (Laird et al., 2006). The operator space includes a fixed desktop that supports two operator stations. Each operator station includes a keyboard, trackball, joystick, headphones, microphone, audio mixer, five-61 cm (24.0 in) computer monitors, and an adjustable chair. This example operator station layout can be seen in Figure 7.

Figure 7. Family of Integrated Rapid Response Equipment (FIRRE) operator console (Laird et al., 2006).

Another example is the control station used by the Airborne Subscale Transport Aircraft Research (AirSTAR) projects which utilized a similar RPIC console at their ground station and in the mobile operations station (Bailey et al., 2005). The RPIC console setup is devised of manual pilot controls, seven displays, and a tablet shown in Figure 8. These setups may not be acceptable from an ergonomic standpoint, but are some available setups available for the control of UASs.

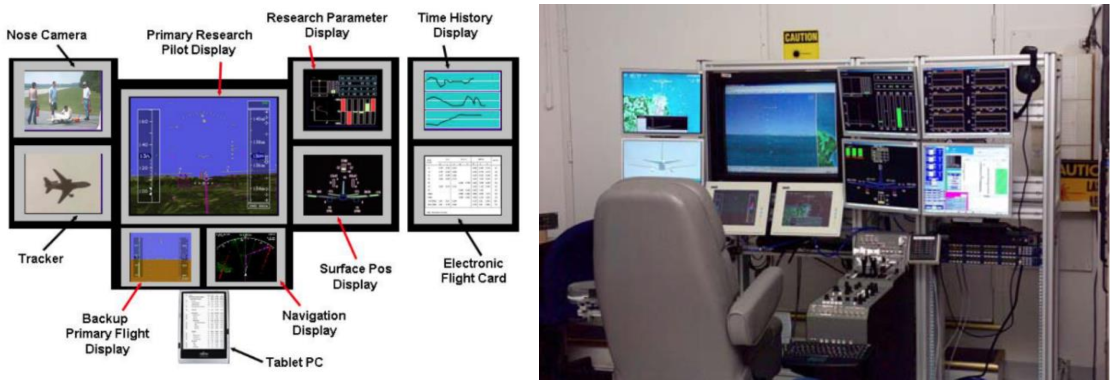


Figure 8. Airborne Subscale Transport Aircraft Research (AirSTAR) RPIC console (Bailey et al., 2005).

5.2.1 Display: RPIC Input

RPICs indicated they have used up to eight displays with about 73% suggesting they were comfortable using four or less displays and 27% indicating they were comfortable using up to six displays (Figure 9). Further, all RPICs reported the need for a minimum of three displays to pilot a UAS which was support-ed by the claim that having only one display would become oversaturated. Approximately 64% of RPICs used a combination of vertical (stacked) and horizontal (side by side) display configurations in-cluding a pyramid configuration with two displays configured horizontally with a third display centered below (Figure 10). One operator with experience in both fixed and mobile stations, such as the back of ground-based vehicles, preferred a vertical configuration because it allowed him to move his gaze hori-zontally to look away from the displays. This RPIC explained that looking away from the displays al-lowed him to keep a sense of awareness of his surroundings; whereas, a horizontal configuration made it more difficult to look away from the screen and therefore, decreased his awareness of the surroundings. Nonetheless, a display should not be located too high above the operators as displays positioned in this way tend to be ignored due to a large gaze displacement. Other RPICs preferred one large screen that could be subdivided via software and application windows. Finally, no matter the configuration, RPICs reported the scan area should be minimized by keeping displays close together.

Figure 9. RPIC using a six display configuration. (Displays in Control Station).

Figure 10. Example of pyramid display set up. Inverted pyramid setups are also used (Pyramid Display).

5.3 HEATING, VENTILATION AND AIR CONDITIONING (HVAC)

Comfortable workplace temperatures have been defined as 20 - 24°C (68 - 75.2°F) with optimal worker performance in temperatures of 21 - 22°C (69.8 – 71.6°F) (Fairfax, 2003; Seppanen, Fisk, & Lei, 2006). Within permanent and semi-permanent facilities, a minimum effective temperature (ET) or corrected effective temperature (CET) of at least 18°C (65°F) should be maintained, barring there are no other provisions; such as climate appropriate clothing (MIL-STD-1472 G). Heating systems should be provided to maintain this level. The ET and CET can be determined by using Figure 11 (MIL-STD-1472 G). The maximum ET or CET for enclosures where detailed work is done for prolonged periods is 29.5°C (85°F), while the preferred maximum level is 25.5°C (80°F) (MIL-STD-1472 G). The minimum interior dry bulb temperature level for the same type of work should be at least 10°C (50°F). In facilities where heating is provided, heated air flow should not be directed towards any personnel (MIL-STD-1472 G). In addition to using air-conditioning or heating to regulate indoor temperature, venetian blinds can be used on windows. By adjusting the level of openness of the blinds, they can influence the amount of heat entering through the windows (Carletti et al., 2016).

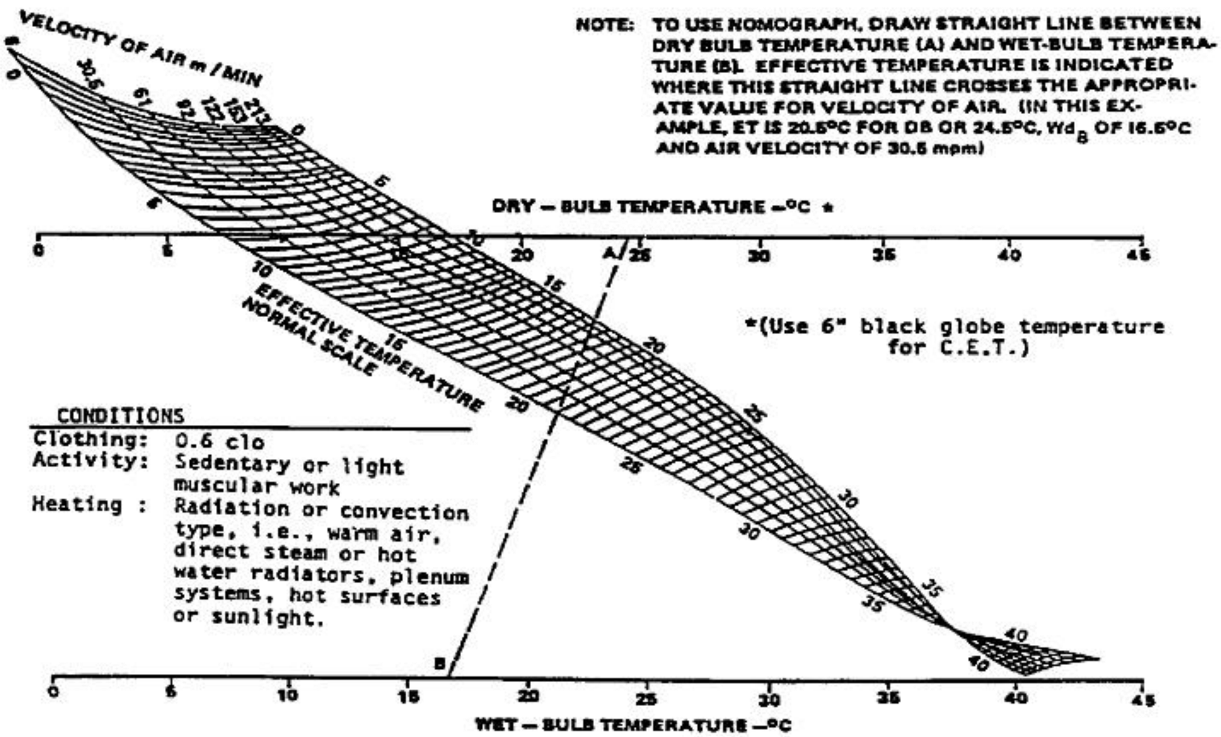


Figure 11. Effective temperature or corrected effective temperature (MIL-STD-1472 G).

Recommended work/break times in extreme temperatures are shown in Table 10 (ACGIH, 1992). These temperature recommendations were made in consideration of different workload conditions such as light, moderate, and heavy. Heavy workload conditions permit comparatively low heat exposures while light workload scenarios allow relatively high exposures.

Table 10. Permissible Heat Exposure Threshold Limit Value (TLV) (ACGIH, 1992).

	Work Load*		
Work/rest regimen	**Light**	**Moderate**	**Heavy**
Continuous work	30.0°C (86.0°F)	26.7°C (80.0°F)	25.0°C (77.0°F)
75% work, 25% rest/hr	30.6°C (87.1°F)	28.0°C (82.4°F)	25.9°C (78.6°F)
50% work, 50% rest/hr	31.4°C (88.5°F)	29.4°C (84.9°F)	27.9°C (82.2°F)
25% work, 75% rest/hr	32.2°C (90.0°F)	31.1°C (88.0°F)	30.0°C (86.0°F)

*Values are in °C, Wet Bulb Globe Temperature Index (WBGT). These TLVs are based on the assumption that nearly all acclimatized, fully clothed workers with adequate water and salt intake should be able to function effectively under the given working conditions without exceeding a deep body temperature of 38 °C (100.4°F). They are also based on the assumption that the WBGT of the resting place is the same or very close to that of the workplace. Where the WBGT of the work area is different from that of the rest area, a time-weighted average should be used (consult the ACGIH TLVs for Chemical Substances and Physical Agents and Biological Exposure Indices). These TLVs apply to physically fit and acclimatized individuals wearing light summer clothing. For other clothing types, again consult the ACGIH for correction factors.

In any workplace, fresh air should be circulated for ensuring adequate ventilation. If the enclosure volume is 4.25 m³ (150 ft³) or less per person, at least 0.85 m³ (30 ft³) ventilation air per minute per person should be provided into the enclosure. At a minimum, two-thirds (2/3) of the ventilated air should be outdoor air (MIL-STD-1472 G). For other enclosure volumes, minimum ventilation levels are prescribed in the Figure 12. The maximum prescribed limit for air velocity is 30 meters (100 feet) per minute (0.5 m/s or 1.7 ft/s) at any space of measurement except the places where personnel require spot cooling (note similar references referring to spot heating were not found). Also, the spot cooling air velocity will not exceed 60 meters (200 feet) per minute (1.0 m/s or 3.33 ft/s). In the case of workspaces where loose papers are used, the maximum air velocity should be no more than 20 meters (65 feet) per minute (MIL-STD-1472 G).

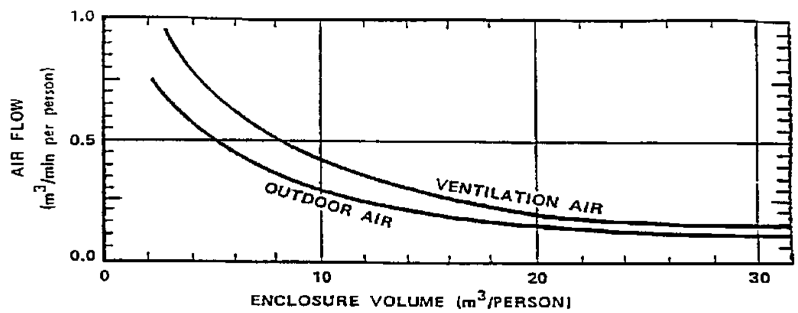


Figure 12. Minimum ventilation requirements (MIL-STD-1472 G).

The HVAC system should maintain the temperature uniformity of the air at floor level and head level of the workplace. The permissible temperature difference of air between floor level and head level of any personnel position is a maximum 5.5°C (10°F); though, a less than 3.0°C (6°F) difference is preferred (MIL-STD-1472 G). Relative humidity of 30-70% should be maintained by any heating, ventilation, and air conditioning (HVAC) system, the preferred level is 40-45% in this case. Overall, HVAC system's design goal should be 45% humidity (preferred), with temperatures maintained 21 - 25°C (70 - 77°F) (MIL-STD-1472 G). Moreover, the temperature and humidity exposure should not exceed the effective temperature limits as prescribed in Figure 11 while correcting for air velocity according to Figure 12 (MIL-STD-1472 G).

5.4 NOISE

In control rooms, the ambient noise levels should be kept below 45 dBA. The background noise level should be between 30 dB and 35 dB in order to maintain the privacy of conversations. In general, ambient noise level should be at least 30 dB (ISO 11064-6,2005). The audible alarms should be 10 dB above the background sound level to be audible and at most 15 dB higher than background sound to avoid both surprising staff and affecting speech communication. If there is reverberation, the -mid-frequency reverberation times should not be more than 0.75s and it is better if kept closer to 0.4s (ISO 11064-6,2005).

Individuals should not be exposed to more than 90 dBA for an eight hour day (OSHA 1910.95, 29 CFR). Ear protection should be provided, at no cost, when exposed to 85 dBA or greater for an eight hour period. Individuals should be exposed to greater sound levels for lower amounts of time as described in the Table 11 (OSHA 1910.95, 29 CFR).

Table 11. Permissible Noise Exposure (OSHA Occupational Noise Exposure-1910.95).

Duration per day, hours	Sound level dBA
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
.05	110
0.25 or less	115

NOTE: When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: $\frac{C1}{T1} + \frac{C2}{T2} + \cdots + \frac{Cn}{Tn}$ exceeds unity, then the mixed exposure should be considered to exceed the limit value. Cn indicates the total time of exposure at a specified noise level, and Tn indicates the total time of exposure permitted at that level. Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

5.5 INGRESS/EGRESS

A number of standards will determine ingress/egress access depending on where the building is situated, including state and local building codes, federal standards, and other relevant standards and/or guidelines. What follows are general minimum standards for ingress/egress for rooms/buildings. The minimum number of exits, or access to exits per story, is determined by the occupant load, "the number of occupants for whom means of egress facilities are provided," which is detailed in Table 12 below (IBC, 2015-1006.3.1). There should be at least two accessible means of egress where two or more means of egress is required (ADA Standards, 2010- Advisory 105.2.4 ICC/IBC).

Table 12. Minimum Number of Exits or Access to Exits per Story (IBC, 2015-1006.3.1).

Occupant Load per Story	Minimum Number of Exits or Access to Exits from Story
1-500	2
501-1000	3
More than 1,000	4

Egress doors should be pivoted or side-hinge swinging (IBC, 2015-1010.1.2). Door openings should have a height of no less than 203.2 cm (80.0 in) (IBC, 2015-1003.3.1) with door stops and closers at least 198 cm (78.0 in) above the floor (IBC, 2015-1010.1.1.1). Door openings should have a width of at least 81.3 cm (32.0 in) (IBC, 2015-1010.1.1) with horizontal projections only within the range of 86.5 - 203 cm (34.1 – 79.9 in) above the floor and not exceeding 10.2 cm (4.0 in) into the clear area (IBC,2015-1010.1.1.1). The ceiling of the exit route should be at least 230 cm (90.6 in) in height (OSHA-29 CFR- 1910.36(g)(1)) and 91.4 cm (36.0 in) in width (IBC, 2015-1020.2). The pushing or pulling force to open an interior swinging egress door, not including fire doors, should not exceed 22 N (4.95 Pound-force (lbf)) (IBC, 2015-1010.1.3). For other doors, including swinging, folding, and sliding doors, the 2015 International Building code suggests a door should be "set in motion" when 133 N (30 lbf) of force are applied to the door, and

67 N (15.06 lbf) should be sufficient to cause the door to swing to a full-open position (IBC, 2015-1010.1.3). Exits and areas of refuge should be marked by easily visible signs that incorporate both visual and tactile characters that are able to be read by touch (ADA Standards, 2010-703). When the exit or way to the exit is not immediately visible, access to exits and areas of refuge should be marked with signs (OSHA-29 CFR-1926.34(b)). Visible signals should be centered at least 183 cm (48.0 in) above the surface of the floor (ADA Standards, 2010-407.2.2.2). The tactile characters on signs should be located 122.0 - 152.5 cm (48.0 – 60.0 in) above the ground (ADA Standards, 2010-703.4.1). The means of egress should be illuminated at all times, and the space should be occupied by no less than 10.76 lux (IBC, 2015-1008.2-1008.2.1). Means of egress should adhere to section 1003.2.13 of the International Building Code (2000 edition and 2001 Supplement) or section 1007 of the International Building Code (2003 Edition).

5.6 WALKING SURFACES

Walking surfaces can be part of the route or floor or ground surfaces. The walking surfaces of a route can have running slopes not steeper than the ratio 1:20 (ADA Standards,2010, Advisory 402.2) which means for every unit of height change, there should be 20 units of route run. The cross slope of walking surfaces shall not be steeper than the ratio 1:48 (ADA Standards, 2010-403.3). The cross slope is the slope that is measured in the direction perpendicular to the pedestrian travel on the other hand running slope is the slope measured in the direction of pedestrian travel. Apart from this, ramps or curb ramps of accessible routes or walkways are allowed to be steeper, for example, the slope of ramp runs may be comparatively higher up to the ratio 1:12 (ADA Standards, 2010, Advisory 402.2). The clearances or the clear width of walking surfaces should be at least 91.5 cm (36 in) (ADA Standards, 2010-403.5.1). If there is a 180° turn around an element that is less than 122.0 cm (48 in) wide in an accessible route, the clearance width should be at least 106.5 cm (42 in) while approaching the turn (ADA Standards, 2010-403.5.2). Clearance standards provided are within the scope for trip hazards. The route measure is then a minimum 122.0 cm (48 in) at the turn and then returns to 106.5 cm (42 inches) when leaving the turn (ADA Standards, 2010-403.5.2). The width of accessible route with turn is shown in Figure 13 and Figure 14.

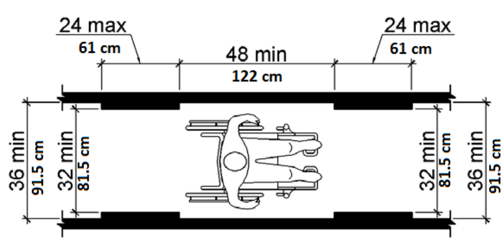


Figure 13. Clear width of an accessible route (ADA Standards 2010, Figure 403.5.1)

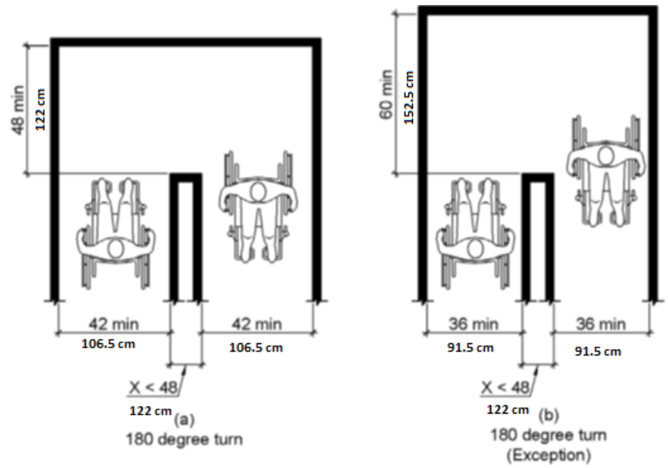


Figure 14. Clear width at turn.(ADA Standards 2010, Figure 403.5.2)

The ground surface or floor should be stable which means it will not change by contaminants and applied forces, such as indentation or particles moving on the floor surface (ADA Standards, 2010-302.1). The ground surface or floor should also be firm and slip resistant which includes the capability to resist deformation by force and provide adequate frictional counterforces against the forces that are exerted upon the floor while walking (ADA Standards, 2010, Advisory 302.1). Ground surfaces can be both clear floor type (no additional materials (e.g., rugs) on them) or equipped with mats or carpets, but all ground surfaces should possess the prior mentioned attributes (i.e. stability, firmness, and slip resistance). Permanently fixed mats and carpets on the walking surface may significantly increase the quantity of force (roll resistance) required to drive a wheelchair (or other rolling device) over the surface; however, increased firmness of carpeting and carpet backing will reduce the forces required for operating a wheelchair or other rolling device. The pile thickness (measured to the carpet backing) should be a maximum of 1.3 cm (0.5 in) as shown in Figure 15. Carpet paddings under carpets are not preferred as these increases the roll resistance, but if used the padding should be firm other than soft (ADA Standards, 2010, Advisory 302.2).

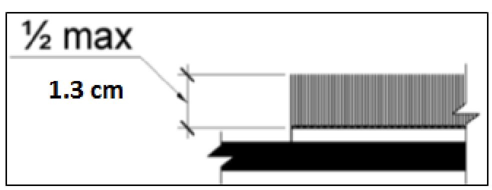


Figure 15. Carpet Pile Height Titles (ADA Standards, Figure 302.2).

Any openings on the floor or ground surfaces should not allow passage of objects comparable to a sphere with the diameter of more than 1.3 cm (0.5 inch) (ADA Standards, 2010, 302.3). The openings on the floor shall be elongated in a way that the long dimension is placed in perpendicular to the dominant direction of travel. A picture of an opening is shown in Figure 16 (ADA Standards, 2010, 302.3).

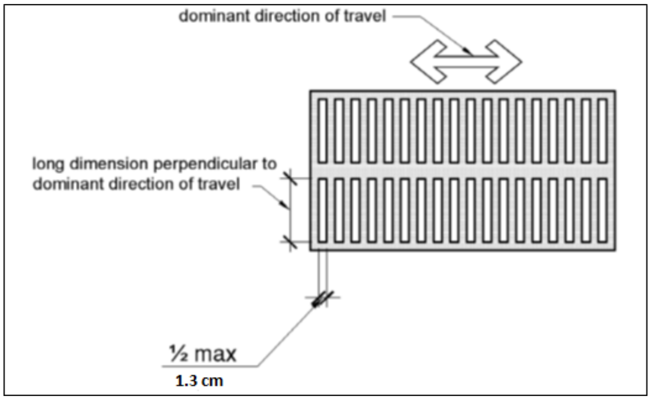


Figure 16. Elongated openings in floor or ground surfaces (ADA Standards, 2010, Figure 302.3).

Stairways must be protected with a stair rail or guardrail system if employees are exposed to an unprotected edge of a stairway with a height of 121.92 cm (48 inches) or above (OSHA 1910.28, 29 CFR). The handrail requirement is dependent of stair width and the number of open sides of the stairway. Handrail requirements are detailed in Table 13 (OSHA 1910.28,29 CFR).

Table 13. Stairway Handrail Requirements (OSHA 1910.28, 29 CFR).

Stair width	**Enclosed**	**One open side**	**Two open sides**	**With earth built up on both sides**
Less than 111.76 cm (44 inches)	At least one handrail	One stair rail system with handrail on open side.	One stair rail system each open side.	N/A
111.76 cm (44 inches) to 223.52 cm (88 inches)	One handrail on each enclosed side	One Stair rail system with handrail on open side and one handrail on enclosed side.	One stair rail system with handrail on each open side.	N/A
Greater than 223.52 cm (88 inches)	One handrail on each enclosed side and one intermediate handrail located in the middle of the stair	One stair rail system with handrail on open side, one handrail on enclosed side, and one intermediate handrail located in the middle of the stair.	One stair rail system with handrail on each open side and one intermediate handrail located in the middle of the stair.	N/A
Exterior stairs less than 4.4 inches (1.1 m).	N/A	N/A	N/A	One handrail on least one side.
Note: The width of the stair must be clear of all obstructions except handrails.				

5.7 OFFICE OCCUPANCY

Maximal occupancy is established by the city or state and typically accounts for the floor area necessary for each individual. Although the maximum occupancy may vary, minimal area recommendations have been developed based on typical office occupancy which can be seen in Table 14.

Table 14. Minimal office area recommendations (Zelnik & Panero, 1979, CCOHS, 2015).

Application	**Minimum Requirement Ranges**	
	Inches	Centimeters
Two people can meet in an office with a table or desk between them.	60.0-72.0 x 90.0-126.0	152.0-183.0 x 228.0-230.0
A worker has a primary desk and a secondary surface such as a credenza.	60.0 -72.0 x 60.0-84.0	152.0-183.0 x 152.0-213.0
Executive office: 3-4 people can meet around a desk.	105.0-130.0 x 96.0-123.0	267.0-330.0 x 244.0-313.0
A basic workstation such as a call center.	42.0-52.0 x 60.0-72.0	107.0-132.0 x 152.0-183.0

5.8 ENVIRONMENT-RPIC INPUT

RPICs reported the control station could become very loud due to generators, lamps, radios, aircraft en-gines (in the case of an unmanned RPIC working within in an aircraft capable of taking control of the one or multiple other aircraft in the fleet), and other people speaking. All loud and irritating noise could be mitigated by hearing protection; however, SMEs also reported that a control station with no noise was distracting and RPICs preferred to be able to hear the noise of the aircraft to ensure its proper function. One RPIC recommended the option of piping in sound of the aircraft into the control room to create a better awareness of the aircraft in operation.

Multiple RPICs reported that the entering of personnel into the control station was distracting as this increased noise levels as well as changes in lighting levels due to an opened door or turning on the over-head lighting. A curtain to separate the operators from the remainder of the control station was suggest-ed as a way to alleviate some of the distractions due to environmental changes. Finally, it was suggested the control station rooms were uncomfortable because the surrounding equipment such as racked servers required a lower temperature.

5.9 ENVIRONMENTAL FINAL RECOMMENDATIONS

The following tables provide the final recommendations for the work environment.

Table 15. Workplace Environment Recommendations

Source	Illumination level based on task and work area	Minimum Lux (fc)	Preferred Lux (fc)
	Workstations		
(MIL-STD 1472G)	Control rooms general lighting	325.0 (30.0)	540.0 (50.0)
(MIL-STD 1472G) (OSHA "Working safely with video display terminals", 1997)	Computer workstation[2]	300.0 (28.0)	540.0 (50.0)
(MIL-STD 1472G)	Faint signal detection task	<2.7 (0.25)	< 2.7 (0.25)
(GSA, 2003)	Conference rooms	300.0 (28.0)	300.0 (28.0)
(MIL-STD 1472G)	Radio room	540.0 (50.0)	540.0 (50.0)
(MIL-STD 1472G)	Offices (general)	540.0 (50.0)	755.0 (70.0)
	Other areas		
(MIL-STD 1472G)	Stairs and ladders	110.0 (10.0)	215.0 (20.0)
(MIL-STD 1472G)	Passageways (walkways, hallways)	150.0 (14.0)	215.0 (20.0)
(MIL-STD 1472G)	Elevators	215.0 (20.0)	325.0 (30.0)
(MIL-STD 1472G)	Emergency lighting	30.0 (3.0)	55.0 (5.0)
	Other illumination considerations	**Minimum**	**Preferred**
(MIL-STD-1472G)	Display luminance ratio	50:1	50:1
(ANSI/IESNA RP-1-1993; MIL-STD-1472G)	Contrast ratio between bright and dark surface within task	5:1	5:1
(ANSI/IESNA RP-1-1993; MIL-STD-1472G)	Contrast ratio between task and adjacent surrounding	3:1 (if reflection can be controlled) 5:1 (if reflection cannot be controlled and environmental conditions are difficult to alter)	3:1 (if reflection can be controlled) 5:1 (if reflection cannot be controlled and environmental conditions are difficult to alter)
(ANSI/IESNA RP-1-1993; MIL-STD-1472G)	Contrast ratio between task and more remote surfaces	10:1 (if reflection of entire space can be controlled) 20:1 (if reflection off the immediate area can be controlled and remote surrounding conditions cannot be altered)	10:1 (if reflection of entire space can be controlled) 20:1 (if reflection off the immediate area can be controlled and remote surrounding conditions cannot be altered)
(ANSI/IESNA RP-1-1993; MIL-STD-1472G)	Contrast ratio between luminaries and adjacent surfaces	20:1 (if reflection of entire space can be controlled)	20:1 (if reflection of entire space can be controlled)

Source	Illumination level based on task and work area	Minimum	Preferred
		Lux (fc)	**Lux (fc)**
(ANSI/IESNA RP-1-1993; MIL-STD-1472G)	Contrast ratio between immediate work area and rest of the environment	40:1 (if reflection of entire space can be controlled)	40:1 (if reflection of entire space can be controlled)
	Workplace HVAC System attributes		
Source	**Temperature**	**Permissible Range**	**Preferred Range**
(Fairfax, 2003; Seppanen, Fisk, & Lei, 2006)	Comfortable workplace temperature	20.0-24.0ºC (68-75.2°F)	21.0-22.0ºC (69.8-71.6°F) (for optimal worker performance)
(MIL-STD-1472 G)	Effective temperature or Corrected effective temperature requirement maintained by heating system	≥18.0ºC (64.4°F)	≥18.0ºC (64.4°F)
(MIL-STD-1472 G)	Effective temperature or Corrected effective temperature for detailed work	≤29.5ºC (85.1°F)	≤25.5ºC (77.9°F)
(MIL-STD-1472 G)	Interior dry bulb temperature for detailed work	≥10.0ºC (50.0°F)	≥10.0ºC (50.0°F)
(MIL-STD-1472 G)	Temperature Difference between head and floor level of any person	≤ 5.5ºC (41.9°F)	≤3.0ºC (37.4°F)
	Ventilation		
(MIL-STD-1472 G)	Ventilation air flow (enclosure volume 4.25m^3 per person)	≥ 0.85 m^3 (30.0 ft^3) per person	≥ 0.85 m^3 (30.0 ft^3) per person
(MIL-STD-1472 G)	Ventilation air source	≥ Two third (2/3) of total air should be outdoor air	≥ Two third (2/3) of total air should be outdoor air
(MIL-STD-1472 G)	Ventilation air velocity	≤ 0.5 m/s (1.6 ft/s)	≤ 0.5 m/s (1.6 ft/s)
(MIL-STD-1472 G)	Ventilation air velocity where loose papers are used	≤ 0.33 m/s (1.1 ft/s)	≤ 0.33 m/s (1.1 ft/s)
(MIL-STD-1472 G)	Spot cooling air velocity	≤ 1.0 m/s (3.3 ft/s)	≤ 1.0 m/s (3.3 ft/s)
(MIL-STD-1472 G)	**Humidity**	30-70%	40-45%
	Workplace Noise Exposure		
Source	**Noise**	**Permissible limits**	**Preferred limits**
(ISO 11064-6, 2005)	Noise level in control rooms	45 dB	<45 dB
(ISO 11064-6, 2005)	Background minimum noise level for conversation privacy	30-35 dB	30-35 dB
(ISO 11064-6, 2005)	Audible alarm	Must be 10-15 dB above background sound level	10 dB above background sound level
Source	**Noise**	**Permissible limits**	**Preferred limits**
(ISO 11064-6, 2005)	Mid frequency reverberation time	≤0.75s	0.4s
	Ingress/ Egress		
		Minimum	**Preferred**

Source	Dimensions of Egress	(unless otherwise specified) cm (in)	(unless otherwise specified) cm (in)
(IBC-1010.1.1/1003.3.1)	Door/exit discharge height	203.2 cm (80.0) (1010.1.1) Door closers should not reduce door height to less than 198 cm (1003.3.1)	
(ADA Standards-404.2.3)	Door/exit discharge height	Door closers and stoppers must be at least 198 cm (78) above the surface of the floor	
(IBC-1010.1.1)	Door/exit discharge width	81.3 cm Horizontal projections are allowed between 86.5 cm (34.1) and 203 cm (79.9) above the floor with a total projection of no more than 10.2 cm	
(OSHA-29 CFR-(1910.36(g)(1))	Exit access corridor/route height	230 cm (90.6) No projections less than 203.2 cm (80.0) above the surface of the floor	
(IBC-1003.2/1003.3.1)	Exit access corridor/route height	228.6 cm (90.0) (1003.2) No projections less than 203.2 cm (80.0) above the surface of the floor and no more than 50% of the ceiling area of the means of egress should be reduced in height by protrusions. (1003.3.1)	
(IBC-1020.2)	Exit access corridor/route width	91.4 cm (36.0) with an occupant load less than 50	
(IBC-1010.1.3)	Force to open door	Interior swinging door 22 N (4.9 lbf) 30 N (6.7 lbf) to set "other than interior doors" in motion 67 N (15.1 lbf) to cause "other than interior doors" to swing completely open	
(MIL-STD-1472G-5.7.6.2)	Force to open door	44 N (9.9 lbf) to 133 N (29.9 lbf) (emergency door)	
(ADA Standards, 2010-407.2.2.2)	Visual Sign Height	183.0 (72.0)	
(ADA Standards, 2010-703.4.1)	Tactile Sign Height	122.0 (48.0)	152.5 (60.0) (maximum)
Source	**Dimensions of Egress**	**Minimum (cm)**	**Preferred (unless otherwise specified) cm**
(IBC, 2015-1008.2-1008.2.1)	Egress/exit illumination	10.76 lux	
(IBC, 2015-1006.3.1)	Occupant Load per Story		

		1-500 occupants	2 exits	
		501-1000 occupants	3 exits	
		More than 1000 occupants	4 exits	
(ADA Standards- Advisory 105.2.4 ICC/IBC)	Accessible Means of Egress		At least two accessible means of egress where two or more means of egress is required	
		Walking Surfaces		
Source	**General Walking surfaces or floor**		**Minimum cm (in)**	**Preferred cm (in)**
(ADA Standards, 2010-302.1)		Surface quality	Firm, stable, and slip resistant	Firm, stable, and slip resistant
(ADA Standards, 2010-302.2)		Surface type	Clear floor or with mats or carpets	Clear floor or with mats or carpets
		Carpet pile thickness (if surface is covered with carpets)	$\leq$1.3 cm (0.51) (measured to the carpet backing)	$\leq$1.3 cm (0.51) (measured to the carpet backing)
(ADA Standards, Advisory 302.2)		Carpet padding type	Firm	Carpet paddings are generally not recommended
(ADA Standards, 302.3)		Small dimension of openings on floor	$\leq$ 1.3 (0.51)	$\leq$ 1.3 cm (0.51)
	Routes			
(ADA Standards Advisory 402.2)		Running slope ratio	$\leq$1:20	$\leq$1:20
(ADA Standards, 2010-403.3)		Cross slope	$\leq$1:48	$\leq$1:48
(ADA Standards- Advisory 402.2)		Slope of ramp run	$\leq$1:12	$\leq$1:12
(ADA Standards, 2010-403.5.1)		Clearance or clear width	$\geq$91.5 (36.0)	$\geq$91.5 (36.0)
(ADA Standards, 2010-403.5.2)		Clear width at 180º turn	$\geq$122.0 (48.0) (at the turn)	$\geq$122 cm (48.0) (at the turn)
	Stairway Handrail/ Stair rail requirements			
(OSHA 1910.28, 29 CFR)		Stair width <111.76 cm (enclosed)	At least 1 handrail	At least 1 handrail
(OSHA 1910.28, 29 CFR)		Stair width <111.76 cm (One open side)	One stair rail system with handrail on open side.	One stair rail system with handrail on open side.
(OSHA 1910.28, 29 CFR)		Stair width <111.76 cm (two open sides)	One stair rail on each open side.	One stair rail on each open side.
(OSHA 1910.28, 29 CFR)		Stair width between 111.76 cm and 223.52cm (enclosed)	One handrail on each enclosed side	One handrail on each enclosed side
	Stairway Handrail/ Stair rail requirements			
(OSHA 1910.28, 29 CFR)		Stair width between 111.76 cm and 223.52cm (one open side)	One Stair rail system with handrail on open side and one handrail on enclosed side.	One Stair rail system with handrail on open side and one handrail on enclosed side.

(OSHA 1910.28, 29 CFR)	Stair width between 111.8 cm (44.0) and 223.5 cm (88.0) (two open sides)	One stair rail system with handrail on each open side.	One stair rail system with handrail on each open side.
(OSHA 1910.28, 29 CFR)	Stair width >223.5 cm (88.0) (enclosed)	One handrail on each enclosed side and one intermediate handrail located in the middle of the stair	One handrail on each enclosed side and one intermediate handrail located in the middle of the stair
(OSHA 1910.28, 29 CFR)	Stair width >223.5 cm (88.0) (one open side)	One stair rail system with handrail on open side, one handrail on enclosed side, and one intermediate handrail located in the middle of the stair.	One stair rail system with handrail on open side, one handrail on enclosed side, and one intermediate handrail located in the middle of the stair.
(OSHA 1910.28, 29 CFR)	Stair width >223.5 cm (88.0) (two open sides)	One stair rail system with handrail on each open side and one intermediate handrail located in the middle of the stair.	One stair rail system with handrail on each open side and one intermediate handrail located in the middle of the stair.
(OSHA 1910.28, 29 CFR)	Stairway allowable height without handrail/ stair rail	Up to 121.9 cm (48.0)	Up to 121.9 cm (48.0)
Office Occupancy			
Source	**Area recommendations per person based on application**	**Minimum recommendation cm^2 (in^2)**	**Preferred cm^2 (in^2)**
Panero and Zelnik, 1979, CCOHS, 2015	Two people can meet in an office with a table or desk between them.	152.0-183.0 x 228.0-230.0 (23.6-28.4 x 35.3-35.7)	152.0 x 228.0 (23.6 x 35.3)
(Panero and Zelnik, 1979, CCOHS, 2015)	A worker has a primary desk and a secondary surface such as a credenza.	152.0-183.0 x 152.0-213.0 (23.6-28.4 x 23.6-33.0)	152.0 x 152.0 (23.6 x 23.6)
(Panero and Zelnik, 1979, CCOHS, 2015)	Executive office: 3-4 people can meet around a desk.	267.0-330.0 x 244.0-313.0 (41.4-51.2 x 37.8-48.5)	267.0 x 244.0 (41.4 x 37.8)
(Panero and Zelnik, 1979, CCOHS, 2015)	A basic workstation such as a call center.	107.0-132.0 x 152.0-183.0 (16.6-20.5 x 23.6-28.4)	107.0 x 152.0 (16.6 x 23.6)

5.10 ADDITIONAL RPIC INPUT INFORMATION

5.10.1 Number of Operators-RPIC Input

The majority of RPICs (64%) reported there were usually two individuals in the control station. One RPIC stated that there could be up to five other individuals performing necessary UAS functions in the control station. Individuals in the control station typically included RPICs, payload operators, air crew, mission commanders, and mission non-critical individuals entering to view the operation. RPICs indi-cated the need to maintain a sterile cockpit that only allowed necessary individuals into the control sta-tion because entering individuals were distracting due to the reasons previously mentioned regarding noise and lighting.

5.10.2 Piloting Duration-RPIC Input

Over 90% of RPICs indicated they fly for six hours or less in a given day and 64% reported piloting 20 hours or less in a given week. Interview responses provided details including that RPICs may be in-volved in flights that last one or several days, but they pilot for two, four, or even six-hour shifts and longer at a time. RPICs typically start each flight with a half-hour to an hour briefing and conclude each flight with a debriefing of approximately the same length. An RPIC may fly a complete mission from take-off to landing or just a portion of the mission. During flight, if an RPIC must use the restroom (or break from piloting for any reason), the mission commander or stand-by pilot may take control. If the mission is complex, the pilot taking over must "become smart" on the mission before taking control even if the original RPIC is leaving for only a few minutes.

6. MOBILITY

As it is likely that control of UASs will extend beyond a fixed location, two levels of mobility were considered: mobile control station and a mobile operator. Literature was reviewed to provide guidance on modifications to the above recommendations to allow for mobility of the control station and/or the operator. Only those changes required for mobility are included here. The reader should refer to the previous sections for information not included here.

6.1 DISPLAYS

The use of a laptop computer, with a display size of 38cm (15 in) or larger, as part of a UAS control station has been proposed and implemented (Mouloua, Gilson, Daskarolis-Kring, & Hancock, 2001). Table 16 lists the average size and weights for general laptop options.

Table 16. Laptop size and weight options (Kyrnin, 2017).

Laptop Options	**Size** **cm (in)**	**Weight** **kg (lb)**
Ultrabook/Chromebook	22.86-34.29 x 20.32-27.94 x <2.54 (9.0-13.5 x 8.0-11.0 x <1.0)	~.91-1.4 (2.0-3.0)
Ultraportable	22.86-33.02 x 20.32-22.86 x 0.508-3.302 (9.0-13.0 x 8.0-9.0 x 0.20-1.3)	~.91-2.3 (2.0-5.0)
Thin and Light	27.94-38.1x <27.94 x 2.54-5.08 (11.0-15.0 x <11.0 x 1.0-2.0)	~1.4-2.7 (3.0-6.0)
Desktop Replacement	>38.1 x >27.94 x 2.54-5.08 (>15.0 x >11.0 x 1.0-2.0)	> 1.8 (4.0)
Luggables	>45.72 x 33.02 x 2.54 (>18.0 x 13.0 x 1.0)	> 3.6 (8.0)

Alternatively, newer technology, such as virtual keyboards, can also be used. Key size in general has been a large area of research. Key sizes vary on whether you use a full, portable, etc. but they are about 18 x 18 mm (1.8 cm) for a full standard keyboard. Recent research found that performance on a virtual keyboard is 60% slower than on a standard keyboards. A study completed by Kim focused on the effects on productivity, usability and typing biomechanics using tablets with virtual keyboard key sizes of 1.3 cm (0.51 in), 1.6 cm (0.63 in), 1.9 cm (0.75 in) and 2.2 cm (0.87 in). Kim's research concluded that key sizes below 1.6 cm (0.63 in) would result in slower productivity (Kim, J. H., Aulck, L., Thamsuwan, O., Bartha, M. C., & Johnson, P. W., 2014). As key sizes get larger and or smaller or the spacing changes, performance is affected. Virtual keyboards have other factors that may impact this for example there is no auditory feedback that a key has been pressed/activated. Lai studied how pointing and typing tasks were affected by the size of tablet devices (8.1, 10.1, 11.6 in). Lai found that the operation time was shorter for tablets that had a touchscreen keyboard with keys closer to size of generic laptop keyboards. Finally, a tablet size of 25.654 cm (10.1 inches) was recommended because of the preference of portability without sacrificing how well a task is completed (Lai, C., Kuo, L., & Chuang, T., 2015).

Ergonomic research has shown that laptop usage has negative effects on the musculoskeletal system due to poor posture assumed by users during laptop operation. Laptop use has been associated with increased neck flexion (i.e., chin-to-chest postures) and head tilt; however, using a desk surface or docking station as opposed to using the lap as the desk surface mitigates some of the negative effects (Asundi, Odell, Luce, & Dennerlein, 2010; Moffet, Hagberg, Hansson-Risberg, & Karlqvist; 2002; Straker, Jones, & Miller, 1997). If a laptop is necessary for UAS control, using it in conjunction with a proper workstation (sit-only, stand-only, sit-to-stand) is recommended to minimize discomfort and musculoskeletal injury risk if possible. If a laptop is used by an individual on the move it is recommended that the person takes breaks between laptop uses, and uses the terrain and surroundings as the work surface when possible.

Smart Fuel Cells (SFC) are an option for providing power while the operator is mobile. One such example is the a portable fuel cell that weighs 3.7lbs with dimensions of 25.4 x 17.78 x 7.62 cm (10 x 7 x 3 in) and is 31 lbs lighter than other batteries that provide equivalent power supply. The portable Jenny fuel cell is currently being used by many military organizations to charge secondary batteries and provides 25W of continuous nominal power to electrical devices (Davis, 2010). Soldiers also use a lightweight fuel-cell/battery-hybrid system solution for non-stop usage of operation equipment. This system adapts to the individual voltages of different devices attached and provides constant information of each devices battery state (Davis, 2010). Both systems are representative products that can be used (exact devices can be found in the referenced literature.). No recommendation on a single product is being made, rather these products are used to illustrate the advantages of such devices.

6.1.1 Displays-RPIC Input

In mobile environments, SMEs recommended that each person have their own display. Experienced UAS controllers in a mobile environment have used laptops, goggle heads-up-displays, phones, and tab-lets to control the aircraft. Display sizes for the tablet device ranged from 8-10 in (20.32 – 25.40 cm), a camera operator used a 22 in (55.88 cm) monitor, and the 17in (43.18 cm) display for the laptop. An SME mentioned that they are starting to experiment with using augmented reality for future displayed information as it allows RPICs to maintain a view of the aircraft during critical functions such as taking off and landing.

Glare and antenna direction (e.g. keeping a strong connection to the aircraft) can put the RPIC in a less-than-optimal position for clearly seeing the display. Also, transitioning from looking at the RC controller mounted display to the sky to see the aircraft can be difficult. With a smart device RC, the screen to the actual control sticks can be seen simultaneously so RPIC time can be spent maintaining visual line of sight. With a laptop and RC controller, the laptop sits on the ground, on top of a case, or somewhere nearby. The RPIC could be four or five feet away from laptop screen and the RC controller which may not have a connected display offering a variation in flight operations. One of the SMEs mentioned their flights happen during both day and night. Due to this, they have to be concerned about day and night adaptation for screens and other displays.

6.2 VIBRATION

Multi-axis whole body vibration exposures, which may be found in a ground based vehicle or aircraft, negatively affect typing speed and increase typing errors at a vibration magnitude of just 0.4 m/s^2 (1.31 ft/s^2). To minimize vibration, control stations should be located as far as possible from sources of vibration (ISO 11064-4-5.5). Insulation should be used to protect control station operators and equipment from the environment. Vibration absorbers should be used in the control room floor, walls, and ceiling to isolate the user away from the vibration sources, if necessary. High-intensity whole-body vibration may cause lumbar spine and connected nervous system damage (ISO 2631-1-B2). User level of comfort while in public transport can be expected to follow the values in Table 17. These values are meant to provide human reactions to specific vibration levels found in vehicles to provide a basic understanding of how human comfort changes when exposed to whole body vibration produced by vehicles. However, these values may not be specific to the vibration that may be found in vehicles transporting UAS control stations.

Table 17. User Comfort Relative to Vibration on Public Transport (ISO 2631-1-C2.3).

Vibration Level	Comfort Level
Less than 0.315 m/s^2 (Less than 1.03 ft/s^2)	Not uncomfortable
0.315 m/s^2 to 0.63 m/s^2 (1.03 ft/s^2 to 2.07 ft/s^2)	A little uncomfortable
0.5 m/s^2 to 1 m/s^2 (1.64 ft/s^2 to 3.28 ft/s^2)	Fairly uncomfortable
0.8 m/s^2 to 1.6 m/s^2 (2.62 ft/s^2 to 5.25 ft/s^2)	Uncomfortable
1.25 m/s^2 to 2.5 m/s^2 (4.1 ft/s^2 to 8.2 ft/s^2)	Very uncomfortable
Greater than 2 m/s^2 (Greater than 6.56 ft/s^2)	Extremely uncomfortable

Guidelines for exposure to whole-body vibration have been developed based on four- to eight-hour exposure durations (ISO 2631-1-B3). A graphical representation of the data can be found in Figure 17. Either equation represented in Figure 17 can be utilized to determine health risks associated with exposure to whole body vibration which has been most notably related to musculoskeletal and neurological disorders of the spine (Johanning, 2015). The area between the two dashed lines for equation 1 and dotted lines for equation 2 represent potential health risks. (Note the four to eight-hour period is the same for both equations.) Health risks are likely above the highest line for each equation.

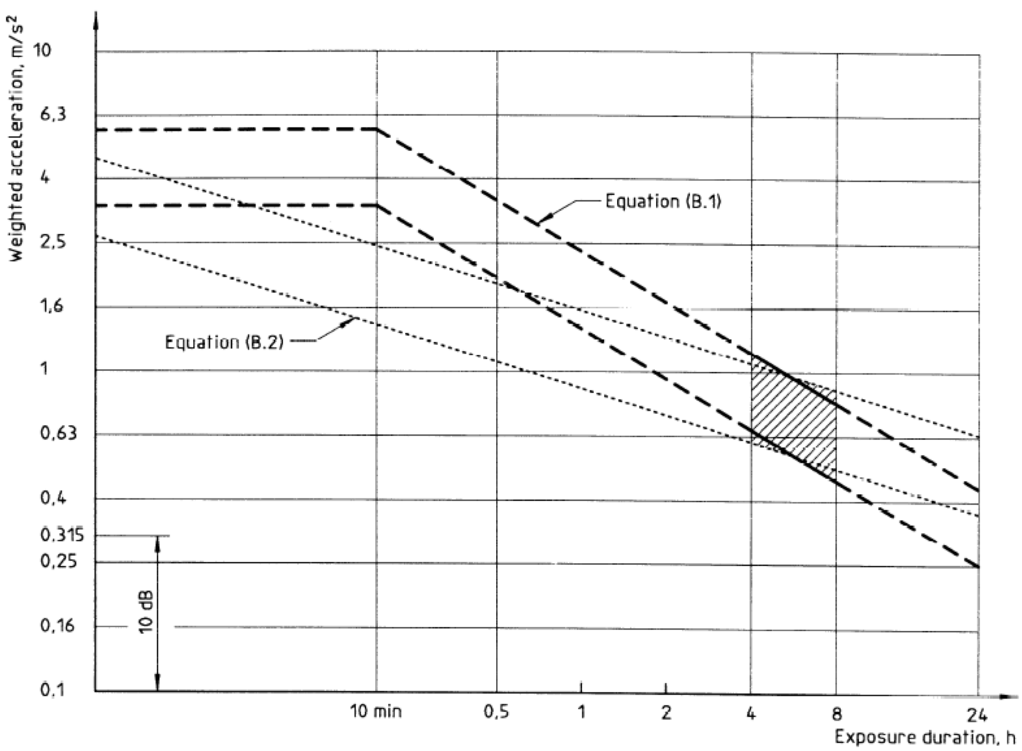


Figure 17. Vibration Health Guidance Caution Zones (ISO 2631-1-B3-Figure B).

Two equations were utilized to provide the vibration exposure health guidelines in Figure 17.

Equation B.1 $a_{w1}*T_1^{1/2}= a_{w2}*T_2^{1/2}$

Equation B.2 $a_{w1}*T_1^{1/4}= a_{w2}*T_2^{1/4}$

a_{w1} and a_{w2} are the weighted r.m.s acceleration values for the first and second exposures, respectively.

Weighted acceleration is expressed in meters per second squared (m/s^2) for translational vibration.

$$a_w = \left[\frac{1}{T} \int_0^T a_w^2(t)\, dt \right]^{\frac{1}{2}}$$

T_1 and T_2 are the corresponding durations for the first and second exposures (ISO 2631-1-B3).

6.3 MASS OF LOAD CARRIAGE

In order to effectively carry laptops and other potential control devices for UAS, it will be necessary for pilots and/or crew to carry these controls in a pack. Back packs weighing one-third of the wearer's body weight or less have been found to allow efficient load carriage (Haisman, 1988). Individuals can carry packs loaded to 45% body weight for three hours (about 14 km/ 8.7 mi) and packs loaded to 25% body weight for an entire day's trek (about 28 km/ 17.4 mi) (Bastien, Schepens, Williems, & Heglund, 2005) when walking at 1.3 m/s (4.3 ft/s). In order to allow for efficient short and long duration load carriage, back pack weight should remain at or below one-third of the wearer's body weight. If the load is carried on the back, the load should be placed higher on the back to reduce metabolic costs (Abe, Muraki, & Yasukouchi, 2008) and allow for a more upright posture (Bloom & Woodhull-McNeal, 1987). However, low or mid-back placement should be utilized when encountering unstable terrains or environments (Knapik, Reynolds, Santee, & Friedl, 2012). When possible, front packs (worn on the front instead of the back) should be worn in lieu of back packs to provide a more upright posture during gait (Fiolkowski et al., 2006), unless the pack obstructs the user's task performance (Knapik, Reynolds, & Harman, 2004). Double packs (pack on front and back) should be utilized in lieu of a single back pack or front pack when feasible as they allow for more symmetrical weight distribution resulting in lower energy expenditure, increased comfort, and a gait kinematics similar to unloaded walking (Knapik, Harman, & Reynolds, 1996). Moreover, weight distributed on both the front and back should be carried at the level of the waist to allow for the greatest level of physical performance (Holewun & Lotens, 1992). Asymmetrical loads (e.g. using a satchel) should be avoided, especially at or beyond 20% of bodyweight, due to causing unbalanced use of the trunk muscles which may lead to injuries (DeVita, Hong, & Hamill, 1991).

6.3.1 Mass of Load Carriage-RPIC Input

Approximately 72% of the survey SMEs have used a backpack or other portable solution to transport UAS specific items when controlling a UAS in an out-and-about mobile environment. The results from the survey showed that about 70% of the SMEs carry up to 30 lbs (13.61 kg) of weight in their portable solution. Some alternative portable solutions given in the surveys and interviews were pelican cases, harnesses, and utility-task vehicles.

SMEs stated that backpacks are for smaller supplies necessary for missions such as laptops, power supplies, additional cables, adapters, back up controllers and GPS, extra propellers, and spare motors—essentially any type of redundancy that might be needed when out in an outdoors environment. Some negatives identified about backpacks included that they can get wet and there was a potential increase of injury if the backpack was worn during flight. A common type of injury was experienced when the RPIC forgot about the additional weight on their body caused by the backpack increasing the tendency to trip when moving.

During one of the interviews the SME talked about wearing a harness like a reverse backpack (Figure 18). Attached to the harness was a tray that the operator placed the controller and monitor or display. The preferred weight of the tray connected to the harness and all of the equipment was approximately 10 to 12 pounds (4.54 to 5.44 kg). All equipment on the tray was Velcro strapped down to the tray's surface but there was still a potential for things to fall from the tray and harness configuration while walking down hills or other uneven terrain.

Figure 18. Example of a front load harness that may be used for portable control stations (Connect-A-Desk).

Pelican cases were also recommended because of their waterproof and rugged properties. These cases can also be used as an ad hoc desk or chair. Some of these ruggedized casing solution options included those used to transport laptops. Figure 19 presents one option of how SMEs will use Pelican cases for their equipment. The SMEs that have used these types of cases explained that they can only carry them for a short distance due to weight and possible bulk and would recommended that two people carry them to the site.

Figure 19. Example pelican case UAS control station (Pelican Case Control Station).

Table 18 provides a summary of the final recommendations for mobile workstations or control stations.

Table 18. Mobility Recommendations.

Mobility Recommendations			
	Dimensions	**Minimum**	**Preferred**
Source		**cm (in) (unless otherwise specified)**	**cm (in) (unless otherwise specified)**
	Laptop		
(Mouloua, et al, 2001)	Display	38.0 (15 in)	
	Tablet		
(Lai, et al 2015; Kim, et al 2014)	Display	25.654 (10.1 in)	
	Key Size	1.6 (0.63 in)	
	Vibration		
(ISO 2631-1-C2.3)	Not uncomfortable	Less than 0.315 m/s^2 (Less than 1.03 ft/s^2)	
(ISO 2631-1-C2.3)	A little uncomfortable	0.315 m/s^2 to 0.63 m/s^2 (1.03 ft/s^2 to 2.07 ft/s^2)	
(ISO 2631-1-C2.3)	Fairly uncomfortable	0.5 m/s^2 to 1 m/s^2 (1.64 ft/s^2 to 3.28 ft/s^2)	
(ISO 2631-1-C2.3)	Uncomfortable	0.8 m/s^2 to 1.6 m/s^2 (2.62 ft/s^2 to 5.25 ft/s^2)	
(ISO 2631-1-C2.3)	Very uncomfortable	1.25 m/s^2 to 2.5 m/s^2 (4.1 ft/s^2 to 8.2 ft/s^2)	
(ISO 2631-1-C2.3)	Extremely uncomfortable	Greater than 2 m/s^2 (Greater than 6.56 ft/s^2)	
(Haisman, 1988)	Backpack Weight		No greater than 1/3 user body weight

6.4 ENVIRONMENTAL CONDITION CONSIDERATIONS FOR MOBILE SETTINGS

In winter conditions, the operative temperature for performing sedentary tasks should be between 20°C (68°F) and 24°C (75.2°F) (ISO 11064-6,2005). The vertical air temperature difference measured between 110 cm (43.3 inches) and 10 cm (3.93 inches) above the floor, referred to as the head and ankle level of a seated person respectively, should be less than 3°C (5.4°F). The average air speed should not exceed 0.15 m/s (0.49ft/s). Additionally, the surrounding relative humidity level should be between 30% and 70% (ISO 11064-6, 2005). If the individuals are exposed to cold weather or cold working conditions repeatedly, they should be protected so that the deep body temperature does not fall below 36°C (96.8°F) ensuring no cold injury occurs to the body extremities (ACGIH, 2012). Deep body temperature is the core temperature of the body determined through conventional methods for rectal temperature measurements. If cold air exposure occurs for prolonged periods, whole body protection must be provided. When the air temperature in any work environment fall below 4°C (40°F), adequate insulating dry clothing should be provided in order to maintain core body temperature above 36°C (96.8°F) (ACGIH, 2012). Higher wind speeds can cause temperature reductions and, if this occurs in any work environment, the protective clothing provided to the individuals should be more insulating (ACGIH, 2012). Older persons may need special protection such as extra insulating clothing or reduced exposure durations. The clothing weight should be considered while estimating the weight to be lifted by any individual (ACGIH, 2012). The permissible exposure times for properly clothed workers working below freezing point are shown in Table 19 (CCOHS "Cold Environments- Working in the Cold", 2017).

Table 19. Threshold Limit Values (TLVs) Work/Warm-up Schedule for Outside Workers based on a Four-Hour Shift* (CCOHS "Cold Environments- Working in the Cold", 2017).

Air Temperature- Sunny Sky		No Noticeable Wind		Wind 8 km/h (5 mph)		Wind 16 km/h (10 mph)		Wind 24 km/h (15 mph)		Wind 32 km/h (20 mph)	
°C (approx.)	°F (approx.)	Max Work Period	No. of Breaks	Max Work Period	No. of Breaks	Max Work Period	No. of Breaks	Max Work Period	No. of Breaks	Max Work Period	No. of Breaks
-26° to -28°	-15° to -19°	(Norm Breaks) 1		(Norm Breaks) 1		75 min.	2	55 min.	3	40 min.	4
-29° to -31°	-20° to -24°	(Norm Breaks) 1		75 min.	2	55 min.	3	40 min.	4	30 min.	5
-32° to -34°	-25° to -29°	75 min.	2	55 min.	3	40 min.	4	30 min.	5	Non-emergency work should cease	
-35° to -37°	-30° to -34°	55 min.	3	40 min.	4	30 min.	5	Non-emergency work should cease			
-38° to -39°	-35° to -39°	40 min.	4	30 min.	5	Non-emergency work should cease					
-40° to -42°	-40° to -44°	30 min.	5	Non-emergency work should cease							
-43° and below	-45° and below	Non-emergency work should cease									
*2013 TLVs® and BEIs®- Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. Cincinnati: American Conference of Governmental Industrial Hygienists (ACGIH), 2013, page 202.											

If work needs to be performed with bare or exposed hands for more than 10 to 20 minutes within surrounding temperature below 16°C (60.8°F), proper measures should be taken to keep hands warm such as warm air jets, radiant heaters (fuel burner or electric radiator), or contact warm plates. While performing sedentary tasks when the air temperature is below 16°C (60.8°F), gloves should be provided. At a working environment at or below 4°C (39.2°F) cold protective clothing should be used as appropriate considering the level of cold. For example, if the air velocity at the work site is increased by wind, draft, or artificial ventilating equipment, the work area should be shielded or personnel should wear wind breaking garments to remain unaffected from the cooling effect of wind. The clothing should not be wet in any case while working in cold areas. If continuous work is required at a surrounding equivalent temperature of -7°C (19.4°F) or below, heated warming shelters such as tents, cabins, rest rooms etc. should be provided in nearby locations (ACGIH, 2012).

In hot environments, the operative temperature for performing sedentary tasks should be between 23°C (73.4°F) and 26°C (78.8°F) (ISO 11064-6,2005). Body core temperature should be maintained within + 1°C (1.8°F) of normal body temperature (37°C or 98.6°F) (ACGIH, 2012). As with the winter condition requirements, the vertical air temperature difference measured between 110 cm (43.3 inches) and 10 cm (3.93 inches) above floor should be less than 3°C (5.4°F). The average air speed and surrounding relative humidity level thresholds should be same as that is mentioned for winter conditions in this section (ISO 11064-6,2005). Clothing should permit the movement of cool, dry air over the wearer's skin surface allowing heat removal through convection and evaporation (ACGIH, 2012). In extreme hot temperatures, recommended work/break times can be seen in Table 19 discussed in section 5.2 of this document (ACGIH, 2012; ACGIH, 1992). With the increase in metabolic rates (e.g. increase in work demands), the TLVs in Table 19 decrease to ensure that the core body temperature remains at a maximum 38°C (100.4°F) (ACGIH, 2012).

If personnel are required to occupy a vehicle cabin for a period exceeding 30 minutes in ambient temperature greater than 24°C (75 °F), air conditioning should be provided in accordance to the general air conditioning design goals as stated in section 5.2 (MIL-STD 1472G). Mobile personnel enclosures that are occupied for more than three hours in a cold environment should have a sufficient heating system to maintain temperatures above 20°C (68°F). The heater should be capable to achieve this minimum temperature limit within one hour after being turned on (MIL-STD 1472G). Table 20 provides a summary of these recommendations.

6.4.1 Environmental Condition Considerations for Mobile Settings-RPIC Input

Approximately 70% of SMEs from the survey said that that glare and temperature are the top two differences between a fixed and mobile ground control station. Follow up interviews with the SMEs were used to obtain feedback on how they address issues such as glare and temperature while using an out-and-about mobile control station.

With glare being the more common issue, one SME recommended his RPICs find shade at their mission sites while operating UAS. Operators will make adjustments to accommodate glare by looking for shade while still maintaining their line of sight to the aircraft for critical functions. The use of privacy filters on phones, tablets, and laptops are recommended to provide minimal help for reducing glare but SMEs noted that the use of privacy filters did not offer a dramatic difference for glare prevention. Sunglasses were another suggestion for mitigating glare but that polarized glasses were to be avoided. Polarized glasses do not work well when operating a UAS as they effect RPIC depth perception. Other operators have tried purchasing harden laptops with daylight readable screens and different kinds of shade options created for tablets to prevent glare.

SMEs have found ways to minimize glare on their smart devices through department store shade options or building their own. One SME mentioned that current smart devices are “abysmal” concerning anti-glare screens and how these solutions don’t offer matte screens for different device sizes. To compensate, this SME (RPIC) utilized a hood made for 8 in (20.32 cm) or 10 in (25.4 cm) tablets and fabricated one for a 22 in (55.88) monitor that could also be used on a laptop. Other SMEs mentioned finding an enclosed fabric box in a department store that could be folded during transport and unfolded to create a small shadow box where the system could be placed enabling the SME to more easily view the screen. Another SME mentioned using a sun hood to provide shade for the screen. Figure 20 shows an example of a sun hood attached to a tablet. However, while on a mission during midday when using this particular harness control station setup, the sun hood did not completely shade the screen. As a result, the SME had to make adjustments with his body position and lift up the controls slightly to provide additional shade. Two options mentioned to fix this problem included mounting the monitor on a vertical pole so that the sun hood is at a ninety-degree angle running parallel to the ground or to simply get a bigger sun hood which leads to other potential issues such as portability.

Figure 20. Example of a sun hood used to protect the screen from glare (Sun Hood Screen Protection).

Environmental factors such as temperature can also cause laptops, smartphones, tablets and other controller types to stop functioning. An SME (RPIC) described working in a hot environment where flights are flown in over 100^{o} F temperatures. The SME described a common scenario where smartphones and other controllers overheat in the vehicle on the way to flight site and shut down in midflight. One of the challenges for out-and-about mobile stations is that a higher level of hardening and ruggedization should be incorporated to handle vibrations, dust/water ingress protection, and extreme hot and cold temperatures. The same concern applies to laptops, tablets, and other control equipment where redundancy of equipment might not be easily handled or even possible.

Table 20. Outdoor/Mobile Environmental Recommendations

Source	Temperature	Permissible Range/ recommendations in literature	Preferred Range
	Cold environment		
(ISO 11064-6,2005)	Operating temperature for sedentary task (in winter)	20-24ºC (68.0-75.2°F)	22°C
(ACGIH, 2012)	Body protection in repeated cold weather exposure	Deep body temperature ≥36°C (96.8°F) should be maintained through body protection	Deep body temperature ≥36°C (96.8°F) should be maintained through body protection
(ACGIH, 2012)	Working temperature below 16ºC	Gloves should be provided	Gloves should be provided
(ACGIH, 2012)	Bare handed fine works in temperature below 16ºC	Hand warming systems should be applied if exposure time is greater than 10-20min	Hand warming systems should be applied if exposure time is greater than 10-20min
(ACGIH, 2012)	Working temperature below -7ºC	Clothes should not be wet at any time. Heated warming shelters should be available nearby	Clothes should not be wet at any time. Heated warming shelters should be available nearby
(ISO 11064-6,2005)	Vertical air temperature difference between head (110cm) and ankle level (10cm) of any seated person	≤ 3.0°C (37.4°F)	≤3.0°C (37.4°F)
(MIL-STD 1472G)	Mobile enclosure temperature requirement while occupied more than 3 hours in cold environment	Heating system is needed to maintain temperature above 20.0°C (68.0°F)	Heating system is needed to maintain temperature above 20˚C (68.0°F)
	Hot environment		
(ISO 11064-6,2005)	Operating temperature for sedentary task (in summer)	23-26°C (73.4 -78.8°F)	24.5°C (76.1°F)
(ACGIH, 2012)	Body temperature requirements in hot weather	Core body temperature should be maintained within maximum 38ºC	Core body temperature should be maintained within maximum 38°C
(ISO 11064-6,2005)	Vertical air temperature difference between head (110cm) and ankle level (10cm) of any seated person	≤ 3.0°C (37.4°F)	≤3.0°C (37.4°F)
(MIL-STD 1472G)	Vehicle cabin temperature requirement while occupied more than 30 minutes in temperature above 24ºC	Air conditioning with general HVAC requirements	Air conditioning with general HVAC requirements
	Ventilation		
ISO 11064-6,2005	Average air velocity	≤ 0.15 m/s (.49 ft/s)	≤ 0.15 m/s (.49 ft/s)
(ISO 11064-6,2005; MIL-STD 1472G)	**Humidity**	30-70%	40-45%

6.5 REPRESENTATIVE DIMENSIONS OF MOBILE CONTROL ROOMS/STATIONS

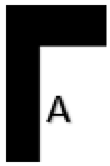
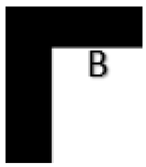
Measurements for mobile workstations was collected using examples of mobile stations used by the Starkville Police Department (SPD), Starkville, MS, are presented in Table 21 (photos were not permitted). These mobile workstations included three trailers used as mobile command centers for police work (non-UAS work); these were a S.W.A.T. tactical trailer (single axle), a D.U.I. enforcement trailer (big dual axle trailer), and a mobile command center used as a mobile office space (dual axle RV). No publically available reference was found for mobile control station or control room work area. Therefore, these are provided as baseline suggestions upon which formal recommendations can be developed through additional research. The mobile control rooms were housed within a single axle trailer and two dual axle trailers of different sizes. Input from the SPD on suggested modifications included:

1. Increase shelving size (single axle trailer).
2. Use of laptops vs desktops for data entry purposes.

Table 21. Representative Mobile Control Room Dimensions

Units	**CM**	**In**
Single Axle Trailer		
Trailer		
Length	240.03	94.5
Width	144.78	57.0
Height of Inside	168.91	66.5
Table		
Height	74.93	29.5
Depth	60.96	24.0
Length	237.49	93.5
Shelving		
Total Height	129.54	51.0
Bottom Shelf	49.53	19.5
Shelf Height	25.4	10.0
Space		
Between Table & Wall	82.55	32.5
Power Supply		
Length	104.14	41.0
Lighting		
Fluorescent light	121.92	48.0
Dual Axle RV		
Trailer		
Outside Length	848.36	334.0
Outside Width	246.38	97.0
Inside Height	193.04	76.0
Inside Width	238.76	94.0
Doors		
Outside Height	182.88	72.0
Outside Width	66.04	26.0
Inside Height	191.135	75.25
Inside Width	58.42	23.0

Counter		
Height	87.63	34.5
Depth	60.96	24.0
Width	82.55	32.5
Space		
Between Counter and Cabinet	62.865	24.75
Entrance	76.2	30.0
Windows		
Four	73.66 x 48.895	29.0 x 19.25
Two	118.11 x 53.34	46.5 x 21.0
Two	71.755 x 53.34	28.25 x 21.0
Cabinet		
Height	43.18	17.0
Depth	40.64	16.0
Distance off the Floor	149.86	59.0
Table		
Height	73.66	29.0
Length	91.44	36.0
Width	66.04	26.0
Seating		
Height	54.61	21.5
Depth	53.34	21.0
Back of Seat	33.02	13.0
Lighting		
4	12.7 x 11.43	5.0 x 4.5
8	27.94 x 11.43	11.0 x 4.5
Air Conditioner		
Length	55.88	22.0
Width	48.26	19.5
Mobile Workstation Big Dual Axle Trailer		
Trailer		
Outside Length	612.14	241
Outside Width	251.46	99
Inside Height	231.14	91
Space		
Floor	198.12 x 241.30	78.0 x 95.0
Bathroom		
Space	121.92 x 240.03	48.0 x 94.5
Counter Height	91.44	36.0
Counter Depth	60.96	24.0
Door Height	200.025	78.75
Door Width	61.595	24.25
L- Shaped Desk		
Height	74.295	29.25
Depth	60.325	23.75
Leg Clearance	71.755	28.25
Length of A:	178.435	70.25

		
Length of B: 	137.16	54.0
Cabinet		
Distance above Desk	66.04	26.0
Width	75.565	29.75
Height	30.48	12.0
Interior Square Opening	22.86 x 30.48	9.0 x 12.0.
Lighting		
Fluorescent Lights (4)	121.92	48.0
Window		
One	61.595 x 74.295	24.25 x 29.25
Door		
Outside Height	205.74	81.0
Outside Width	92.075	36.25

6.6 ADDITIONAL RPIC INPUT INFORMATION

6.6.1 Controls-RPIC Input

The top two controls identified for use in out-and-about mobile control stations from the survey are joysticks and touchscreens. Through additional feedback collected in the SME interviews, other controls used in a mobile setting are RC controllers, game controllers, keyboards, mice, and toggles. One SME described a toggle as simply: “a box with sticks coming out of it with one controlling the power and other controlling the direction. More along the lines of an RC controller.” A combination of smartphones and RC controllers (Figure 21) were the most popular with the RPICs. Feedback was also received from the SMEs that touchscreens are hard to use because of the difficultly in responding quickly to changes in events. Also, feedback was provided that smartphones are the worst way to control any type of flight. An interviewer said that smartphones are for communication and if someone calls in the middle of a flight, controls for the flight could be interrupted or momentarily obscured.

Figure 21. Example of an RC controller used in mobile environment (FrSky Taranis X9 X9D Plus RC Controller).

There is a push from clients and major aerospace firms to incorporate game controllers to control UASs. Through the follow up interviews, it was discovered that the use of game controllers for flying UAS is very polarizing therefore there are a variety of opinions about this change in control type. One opinion was that the use of this controller would reduce the cognitive load on RPICs familiar with using game controllers thereby allowing them to focus more on the airspace and aircraft. In other interviews, SMEs discussed that if game controllers are used, they should be operated like an RC controller and that they should be separated from controlling the payload. There was also discussion that there have been notable delays in control of the UAS system because of this implementation of game controllers.

SMEs want critical controls to be separated from none critical controls. SMEs have also asked for tactile feel to avoid needing to look down and haptic feedback to be tied to specific events with the aircraft in order to heighten their awareness of what's occurring during the flight. A SME said a control system with haptic feedback is needed if flying a full tele operated system where exact precision through feel is necessary; however, if the RPIC is simply providing orders to a UAS about where to go when the aircraft itself is providing most of the controls, then haptic feedback is not necessary.

6.6.2 Operators-RPIC Input

In a mobile environment, there are usually two people working, the RPIC and a visual observer or pay-load operator. The primary job of the visual observer is to watch the camera view from their own, sepa-rate display and to capture images and other data. The job of the visual observer is often extended to include telling the RPIC when objects are close in order to provide a great sense of environmental awareness and layout. Also, the observer's role includes protecting the RPIC from distractions such as curious people and dangerous animals.

7. FINAL RECOMMENDATIONS

Throughout the document, tables with consolidated recommendations are provided for UAS control stations. Table 22 below is an aggregate consolidation of all of these tables. While there is a wealth of literature on UASs, there is very little that is directly related to the physical design of the control station, apart from the information to be displayed to the operator. Therefore, general office and workplace standards and guidelines provide the basis for the majority of these recommendations (Waraich et al., 2013).

While these recommendations are based on existing standards and recent literature, there remains a need to formally test and evaluate these recommendations as well as compare them with existing control stations to identify areas for modification, either in the design of the control station or in the recommendation.

Table 22. Final Control Station Design Recommendations

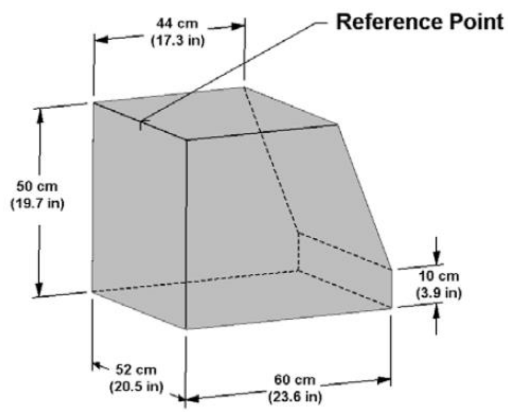
Table 22. is a compilation of all the recommendation tables presented in each subsection. Before producing "Final Recommendations," all recommendations reviewed from ergonomic standards and scholarly literature were compiled and can be found in Appendix A. From the table in Appendix A, the minimum dimensions accommodating the anthropometrics of the 5th to 95th percentile male and female were chosen and are presented below.

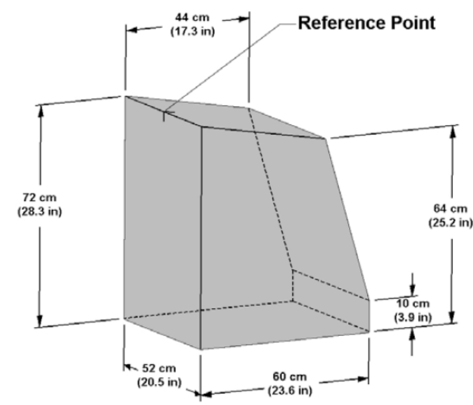
Seated Workstation			
Source	**Dimensions**	**Minimum**	**Adjustment (unless otherwise specified)**
		cm (in)	**cm (in)**
(MIL-STD-1472G-Table XLVII)	Kneehole depth (at knee height)	38.1 (15.0)	
(ADA, 2010-306.3.5)	Knee clearance width	76.0 (29.9)	
(MIL-STD-1472G-Figure 63)	Kneehole height (standard office)	63.5 (25.0)	
(MIL-STD-1472G-Table XLVII)	Desk to wall	81.3 (32.0)	
(MIL-STD-1472G-Table XLVII)	Chair to wall	38.1 (15.0)	
(MIL-STD-1472G-Figure 63)	Armrest to wall	61.0 (24.0)	
(MIL-STD-1472G-Figure 63)	Lateral Work Clearance		
(MIL-STD-1472G-Figure 63)	Shoulders	58.5 (23.0)	
(MIL-STD-1472G-Figure 63)	Elbows	63.5 (25.0)	
(MIL-STD-1472G-Figure 63)	Best Overall	100.0 (39.4)	
(MIL-STD-1472G-Figure 63)	Height of work surface	73.5 (28.9)	76.0 (29.9) (preferred)
(ADA AG, 2002-4.32.3)	Surface height		71.0-86.5 (28.0 – 34.1)
(Chengalur et al., 2003)	Keyboard distance from front of desk surface		10.0-25.0 (3.9 – 9.8) (range)
(ANSI/HFES 100-2007-8.3.2.4.1)	Input device work surface tilt		Adjustable from -15° to +20°
(ANSI/HFES 100-2007- 8.3.4.2)	Wrist/Palm, Forearm support depth	3.8 (1.5)	
	Width of work surface		
(MIL-STD-1472G-Table XLVII)	Work surface width	61.0 (24.0)	
(MIL-STD-1472G-Table XLVII)	Work surface depth	61.0 (24.0)	76.2 (30) (preference)
	Maximum overhead reach for gripping reach (above seated surface)		

(MIL-STD-1472G-5.10.3.4.9)	Females		116.8 (46.0) (maximum)
	Kick space		
(MIL-STD-1472G-5.10.2.3)	Height	10.0 (3.9)	
(MIL-STD-1472G-5.10.2.3)	Depth	10.0 (3.9)	
	Toe clearance		
(ADA, 2010-306.2)	Depth (distance from front surface of the element)	43.0 (16.9)	63.5 (25.0) (maximum)
(ADA, 2010-306.2)	Width	76.0 (29.9)	
	Display mounting heights		
(MIL-STD-1472G-Figure 68)	Height (seated)	15.2 (6.0) / (35.6 (14.0)pre-ferred) from seat height	111.8 (44.0) / (90.0 (35.4) preferred)
(MIL-STD-1472G-Figure 68)	Maximum height for vision over top (seated)		68.6 (27.0) (maximum)
	Laptop Specific Dimensions		
(Nanthavanij et al., 2016)	Tilt angle of laptop keyboard		20° (preferred)
(Nanthavanij et al., 2016)	Laptop keyboard-screen angle		119° (preferred)
(Nanthavanij et al., 2016)	Distance from body to laptop		41.0 (16.1) (preferred)

*Refer to Upright, Reclined, and Declined Seated Clearances (ANSI/HFES 100-2007-Figure 8.3b)

Upright, Reclined, and Declined Seated Clearances





(ANSI/HFES 100-2007-Figure 8.3b)

Sit-to Stand Workstation

Source	Dimensions	Minimum	Adjustment
		cm	cm (unless otherwise specified)

(ANSI/HFES 100-2007- 8.3.2.1)	Clearances	Comply with seated standards in Section 8.3.2.1	
	Work surface		
(ANSI/HFES 100-2007-8.3.2.4.3)	Height (height adjustable only)		56.0 – 118.0 (22.0 – 46.5) from floor to front edge of support
(ANSI/HFES 100-2007-8.3.2.4.3)	Height (height and tilt adjustable)		Some portion of range 56.0 – 72.0 (22.0 – 28.3) from floor to front edge of support/ additional height (greater than 72.0 (28.3)) for standing when combined with tilt
(ANSI/HFES 100-2007-8.3.2.4.3)	Tilt (height and tilt adjustable)		+20° to -40°, to include 0°

Chair Recommendations

Source	Dimensions	Fixed/Minimum cm	Adjustment cm (unless otherwise specified)
	Armrest		
(MIL-STD-1472G-Table XLVII)	Length	25.4 (10.0)	
(MIL-STD-1472G-Table XLVII)	Width	5.0 (2.0)	
(ANSI/HFES 100-2007- 8.3.4.1)	Height (adjustable)		17.0 – 27.0 (6.7 – 10.6) above compressed seat height
(ANSI/HFES 100-2007- 8.3.4.1)	Clearance between armrests	46.0 (18.1)	
	Seat pan		
(MIL-STD-1472G-Table XLVII)	Width	40.6 (16.0)	
(ANSI/HFES 100-2007- 8.3.3.1)	Height		38.0 – 56.0 (15.0 – 22.0) and adjustable over a minimum range of 11.4 (4.5)
(MIL-STD-1472G-Table XLVII)	Depth	38.1 (15.0)	Up to 43.2
(ANSI/HFES 100-2007- 8.3.3.4)	Angle		Range of 4° that includes a reclined position of 3°
(MIL-STD-1472G-Table XLVII)	Pan-backrest angle		90° - 100°
(Leuder, 1986)	Front edge	waterfall	
(Kroemer & Grandjean, 1997)	Distance to desk surface		27.0-30.0 (10.6- 11.8) (preferred)

Input controls

Source	Control	Minimum cm (in)	Maximum cm (in)
	Keyboard		
	Key Width	1.2 (0.47)	1.5 (0.59)

(ANSI, 1988, 2007; NUREG 0700, 2002; Pereira, Hsieh, Laroche, & Rempel, 2014; ISO, 2008; Simoneau & Marklin, 2001)	Vertical Spacing between keys	1.6 (0.63)	2.0 (0.79)
	Horizontal Spacing between keys	1.7 (0.67)	2.0 (0.79)
	Slope	0°	20°
(HF-STD-001B – Exhibit 5.7.3.2.4)	Mouse		
	Width	4.0 (1.6)	7.0 (2.8)
	Length	7.0 (2.8)	12.0 (4.7)
	Thickness	2.5 (1.0)	4.0 (1.6)
(MIL-STD-1472G, 2012)	Joystick		
	Handgrip length	11.0 (4.33)	18.0 (7.08)
	Handgrip diameter	5.0 (2.0)	
	Side Clearance	10.0 (4.0)	
	Rear Clearance	5.0 (2.0)	

Environmental Conditions			
Source	**Illumination level based on task and work area**	**Minimum**	**Preferred**
		Lux (fc)	**Lux (fc)**
	Workstations		
(MIL-STD 1472G)	Control rooms general lighting	325.0 (30.0)	540.0 (50.0)
(MIL-STD 1472G) (OSHA "Working safely with video display terminals", 1997)	Computer workstation[2]	300.0 (28.0)	540.0 (50.0)
(MIL-STD 1472G)	Faint signal detection task	<2.7 (0.25)	< 2.7 (0.25)
(GSA, 2003)	Conference rooms	300.0 (28.0)	300.0 (28.0)
(MIL-STD 1472G)	Radio room	540.0 (50.0)	540.0 (50.0)
(MIL-STD 1472G)	Offices (general)	540.0 (50.0)	755.0 (70.0)
	Other areas		
(MIL-STD 1472G)	Stairs and ladders	110.0 (10.0)	215.0 (20.0)
(MIL-STD 1472G)	Passageways (walkways, hallways)	150.0 (14.0)	215.0 (20.0)
(MIL-STD 1472G)	Elevators	215.0 (20.0)	325.0 (30.0)
(MIL-STD 1472G)	Emergency lighting	30.0 (3.0)	55.0 (5.0)
	Other illumination considerations	**Minimum**	**Preferred**
(MIL-STD-1472G)	Display luminance ratio	50:1	50:1
(ANSI/IESNA RP-1-1993; MIL-STD-1472G)	Contrast ratio between bright and dark surface within task	5:1	5:1

(ANSI/IESNA RP-1-1993; MIL-STD-1472G)	Contrast ratio between task and adjacent surrounding	3:1 (if reflection can be controlled) 5:1 (if reflection cannot be controlled and environmental conditions are difficult to alter)	3:1 (if reflection can be controlled) 5:1 (if reflection cannot be controlled and environmental conditions are difficult to alter)
(ANSI/IESNA RP-1-1993; MIL-STD-1472G)	Contrast ratio between task and more remote surfaces	10:1 (if reflection of entire space can be controlled) 20:1 (if reflection off the immediate area can be controlled and remote surrounding conditions cannot be altered)	10:1 (if reflection of entire space can be controlled) 20:1 (if reflection off the immediate area can be controlled and remote surrounding conditions cannot be altered)
(ANSI/IESNA RP-1-1993; MIL-STD-1472G)	Contrast ratio between luminaries and adjacent surfaces	20:1 (if reflection of entire space can be controlled)	20:1 (if reflection of entire space can be controlled)
Source	**Illumination level based on task and work area**	**Minimum**	**Preferred**
		Lux (fc)	**Lux (fc)**
(ANSI/IESNA RP-1-1993; MIL-STD-1472G)	Contrast ratio between immediate work area and rest of the environment	40:1 (if reflection of entire space can be controlled)	40:1 (if reflection of entire space can be controlled)
Workplace HVAC System attributes			
Source	**Temperature**	**Permissible Range**	**Preferred Range**
(Fairfax, 2003; Seppanen, Fisk, & Lei, 2006)	Comfortable workplace temperature	20.0-24.0ºC (68-75.2°F)	21.0-22.0ºC (69.8-71.6°F) (for optimal worker performance)
(MIL-STD-1472 G)	Effective temperature or Corrected effective temperature requirement maintained by heating system	≥18.0ºC (64.4°F)	≥18.0ºC (64.4°F)
(MIL-STD-1472 G)	Effective temperature or Corrected effective temperature for detailed work	≤29.5ºC (85.1°F)	≤25.5ºC (77.9°F)
(MIL-STD-1472 G)	Interior dry bulb temperature for detailed work	≥10.0ºC (50.0°F)	≥10.0ºC (50.0°F)
(MIL-STD-1472 G)	Temperature Difference between head and floor level of any person	≤ 5.5ºC (41.9°F)	≤3.0ºC (37.4°F)
	Ventilation		
(MIL-STD-1472 G)	Ventilation air flow (enclosure volume 4.25m^3 per person)	≥ 0.85 m^3 per person	≥ 0.85 m^3 per person
(MIL-STD-1472 G)	Ventilation air source	≥ Two third (2/3) of total air should be outdoor air	≥ Two third (2/3) of total air should be outdoor air
(MIL-STD-1472 G)	Ventilation air velocity	≤ 0.5 m/s (1.6 ft/s)	≤ 0.5 m/s (1.6 ft/s)
(MIL-STD-1472 G)	Ventilation air velocity where loose papers are used	≤ 0.33 m/s (1.1 ft/s)	≤ 0.33 m/s (1.1 ft/s)
(MIL-STD-1472 G)	Spot cooling air velocity	≤ 1.0 m/s (3.3 ft/s)	≤ 1.0 m/s (3.3 ft/s)

(MIL-STD-1472 G)	**Humidity**	30-70%	40-45%
Workplace Noise Exposure			
Source	**Noise**	**Permissible limits**	**Preferred limits**
(ISO 11064-6, 2005)	Noise level in control rooms	45 dB	<45 dB
(ISO 11064-6, 2005)	Background minimum noise level for conversation privacy	30-35 dB	30-35 dB
(ISO 11064-6, 2005)	Audible alarm	Must be 10-15 dB above background sound level	10 dB above background sound level
Source	**Noise**	**Permissible limits**	**Preferred limits**
(ISO 11064-6, 2005)	Mid frequency reverberation time	$\leq$0.75s	0.4s
Ingress/ Egress			
Source	**Dimensions of Egress**	**Minimum (cm)**	**Preferred (unless otherwise specified) cm**
(IBC-1010.1.1/1003.3.1)	Door/exit discharge height	203.2 cm (80.0) (1010.1.1) Door closers should not reduce door height to less than 198 cm (1003.3.1)	
(ADA Standards-404.2.3)	Door/exit discharge height	Door closers and stoppers must be at least 198 cm (78) above the surface of the floor	
(IBC-1010.1.1)	Door/exit discharge width	81.3 cm Horizontal projections are allowed between 86.5 cm (34.1) and 203 cm (79.9) above the floor with a total projection of no more than 10.2 cm	
(OSHA-29 CFR-(1910.36(g)(1))	Exit access corridor/route height	230 cm (90.6) No projections less than 203.2 cm (80.0) above the surface of the floor	
(IBC-1003.2/1003.3.1)	Exit access corridor/route height	228.6 cm (90.0) (1003.2) No projections less than 203.2 cm (80.0) above the surface of the floor and no more than 50% of the ceiling area of the means of egress should be reduced in height by protrusions. (1003.3.1)	

(IBC-1020.2)	Exit access corridor/route width	91.4 cm (36.0) with an occupant load less than 50	
(IBC-1010.1.3)	Force to open door	Interior swinging door 22 N (4.9 lbf) 30 N (6.7 lbf) to set "other than interior doors" in motion 67 N (15.1 lbf) to cause "other than interior doors" to swing completely open	
(MIL-STD-1472G-5.7.6.2)	Force to open door	44 N (9.9 lbf) to 133 N (29.9 lbf) (emergency door)	
(ADA Standards, 2010-407.2.2.2)	Visual Sign Height	183.0 (72.0)	
(ADA Standards, 2010-703.4.1)	Tactile Sign Height	122.0 (48.0)	152.5 (60.0) (maximum)
Source	**Dimensions of Egress**	**Minimum (cm)**	**Preferred (unless otherwise specified) cm**
(IBC, 2015-1008.2-1008.2.1)	Egress/exit illumination	10.76 lux	
(IBC, 2015-1006.3.1)	Occupant Load per Story		
	1-500 occupants	2 exits	
	501-1000 occupants	3 exits	
	More than 1000 occupants	4 exits	
(ADA Standards- Advisory 105.2.4 ICC/IBC)	Accessible Means of Egress	At least two accessible means of egress where two or more means of egress is required	
Walking Surfaces			
Source	**General Walking surfaces or floor**	**Minimum**	**Preferred**
(ADA Standards, 2010-302.1)	Surface quality	Firm, stable, and slip resistant	Firm, stable, and slip resistant
(ADA Standards, 2010-302.2)	Surface type	Clear floor or with mats or carpets	Clear floor or with mats or carpets
	Carpet pile thickness (if surface is covered with carpets)	≤1.3 cm (0.51) (measured to the carpet backing)	≤1.3 cm (0.51) (measured to the carpet backing)
(ADA Standards, Advisory 302.2)	Carpet padding type	Firm	Carpet paddings are generally not recommended
(ADA Standards, 302.3)	Small dimension of openings on floor	≤ 1.3 (0.51)	≤ 1.3 cm (0.51)
	Routes		
(ADA Standards Advisory 402.2)	Running slope ratio	≤1:20	≤1:20
(ADA Standards, 2010-403.3)	Cross slope	≤1:48	≤1:48

(ADA Standards- Advisory 402.2)		Slope of ramp run	≤1:12	≤1:12
(ADA Standards, 2010-403.5.1)		Clearance or clear width	>91.5 (36.0)	≥91.5 (36.0)
(ADA Standards, 2010-403.5.2)		Clear width at 180° turn	≥122.0 (48.0) (at the turn)	≥122 cm (48.0) (at the turn)
	Stairway Handrail/ Stair rail requirements			
(OSHA 1910.28, 29 CFR)		Stair width <111.76 cm (enclosed)	At least 1 handrail	At least 1 handrail
(OSHA 1910.28, 29 CFR)		Stair width <111.76 cm (One open side)	One stair rail system with handrail on open side.	One stair rail system with handrail on open side.
(OSHA 1910.28, 29 CFR)		Stair width <111.76 cm (two open sides)	One stair rail on each open side.	One stair rail on each open side.
(OSHA 1910.28, 29 CFR)		Stair width between 111.76 cm and 223.52cm (enclosed)	One handrail on each enclosed side	One handrail on each enclosed side
	Stairway Handrail/ Stair rail requirements			
(OSHA 1910.28, 29 CFR)		Stair width between 111.76 cm and 223.52cm (one open side)	One Stair rail system with handrail on open side and one handrail on enclosed side.	One Stair rail system with handrail on open side and one handrail on enclosed side.
(OSHA 1910.28, 29 CFR)		Stair width between 111.76 cm and 223.52cm (two open sides)	One stair rail system with handrail on each open side.	One stair rail system with handrail on each open side.
(OSHA 1910.28, 29 CFR)		Stair width >223.52 cm (enclosed)	One handrail on each enclosed side and one intermediate handrail located in the middle of the stair	One handrail on each enclosed side and one intermediate handrail located in the middle of the stair
(OSHA 1910.28, 29 CFR)		Stair width >223.52 cm (one open side)	One stair rail system with handrail on open side, one handrail on enclosed side, and one intermediate handrail located in the middle of the stair.	One stair rail system with handrail on open side, one handrail on enclosed side, and one intermediate handrail located in the middle of the stair.
(OSHA 1910.28, 29 CFR)		Stair width >223.52 cm (two open sides)	One stair rail system with handrail on each open side and one intermediate handrail located in the middle of the stair.	One stair rail system with handrail on each open side and one intermediate handrail located in the middle of the stair.
(OSHA 1910.28, 29 CFR)	Stairway allowable height without handrail/ stair rail		Up to 121.9 cm (48.0)	Up to 121.9 cm (48.0)
		Office Occupancy		
Source	**Area recommendations per person based on application**		**Minimum recommendation (cm^2)**	**Preferred (cm^2)**
Panero and Zelnik, 1979, CCOHS, 2015		Two people can meet in an office with a table or desk between them.	152.0-183.0 x 228.0-230.0 (23.6-28.4 x 35.3-35.7)	152.0 x 228.0 (23.6 x 35.3)

(Panero and Zelnik, 1979, CCOHS, 2015)	A worker has a primary desk and a secondary surface such as a credenza.	152.0-183.0 x 152.0-213.0 (23.6-28.4 x 23.6-33.0)	152.0 x 152.0 (23.6 x 23.6)
(Panero and Zelnik, 1979, CCOHS, 2015)	Executive office: 3-4 people can meet around a desk.	267.0-330.0 x 244.0-313.0 (41.4-51.2 x 37.8-48.5)	267.0 x 244.0 (41.4 x 37.8)
(Panero and Zelnik, 1979, CCOHS, 2015)	A basic workstation such as a call center.	107.0-132.0 x 152.0-183.0 (16.6-20.5 x 23.6-28.4)	107.0 x 152.0 (16.6 x 23.6)
Mobility Recommendations			
Source		**Minimum cm (in)**	**Maximum cm (in)**
(Mouloua, et al, 2001)	Laptop		
	Display	38.0 (15.0)	
(Lai, et al 2015; Kim, et al 2014)	Tablet		
	Display	25.654 (10.1)	
	Key Size	1.6 (0.63)	
	Vibration		
(ISO 2631-1-C2.3)	Not uncomfortable	Less than 0.315 m/s^2 (Less than 1.03 ft/s^2)	
(ISO 2631-1-C2.3)	A little uncomfortable	0.315 m/s^2 to 0.63 m/s^2 (1.03 ft/s^2 to 2.07 ft/s^2)	
(ISO 2631-1-C2.3)	Fairly uncomfortable	0.5 m/s^2 to 1 m/s^2 (1.64 ft/s^2 to 3.28 ft/s^2)	
(ISO 2631-1-C2.3)	Uncomfortable	0.8 m/s^2 to 1.6 m/s^2 (2.62 ft/s^2 to 5.25 ft/s^2)	
(ISO 2631-1-C2.3)	Very uncomfortable	1.25 m/s^2 to 2.5 m/s^2 (4.1 ft/s^2 to 8.2 ft/s^2)	
(ISO 2631-1-C2.3)	Extremely uncomfortable	Greater than 2 m/s^2 (Greater than 6.56 ft/s^2)	
(Haisman, 1988)	Backpack Weight		No greater than 1/3 user body weight
Outdoor/Mobile Environment Recommendations			
Source	**Temperature**	**Permissible Range/ recommendations in literature**	**Preferred Range**
	Cold environment		
(ISO 11064-6,2005)	Operating temperature for sedentary task (in winter)	20-24ºC (68.0-75.2°F)	22°C
(ACGIH, 2012)	Body protection in repeated cold weather exposure	Deep body temperature ≥36°C (96.8°F) should be maintained through body protection	Deep body temperature ≥36°C (96.8°F) should be maintained through body protection
(ACGIH, 2012)	Working temperature below 16ºC	Gloves should be provided	Gloves should be provided

(ACGIH, 2012)		Bare handed fine works in temperature below 16ºC	Hand warming systems should be applied if exposure time is greater than 10-20min	Hand warming systems should be applied if exposure time is greater than 10-20min
(ACGIH, 2012)		Working temperature below -7ºC	Clothes should not be wet at any time. Heated warming shelters should be available nearby	Clothes should not be wet at any time. Heated warming shelters should be available nearby
(ISO 11064-6,2005)		Vertical air temperature difference between head (110cm) and ankle level (10cm) of any seated person	≤ 3.0°C (37.4°F)	≤3.0°C (37.4°F)
(MIL-STD 1472G)		Mobile enclosure temperature requirement while occupied more than 3 hours in cold environment	Heating system is needed to maintain temperature above 20.0°C (68.0°F)	Heating system is needed to maintain temperature above 20˚C (68.0°F)
	Hot environment			
(ISO 11064-6,2005)		Operating temperature for sedentary task (in summer)	23-26°C (73.4 -78.8°F)	24.5°C (76.1°F)
(ACGIH, 2012)		Body temperature requirements in hot weather	Core body temperature should be maintained within maximum 38ºC	Core body temperature should be maintained within maximum 38°C
(ISO 11064-6,2005)		Vertical air temperature difference between head (110cm) and ankle level (10cm) of any seated person	≤ 3.0°C (37.4°F)	≤3.0°C (37.4°F)
(MIL-STD 1472G)		Vehicle cabin temperature requirement while occupied more than 30 minutes in temperature above 24ºC	Air conditioning with general HVAC requirements	Air conditioning with general HVAC requirements
	Ventilation			
ISO 11064-6,2005		Average air velocity	≤ 0.15 m/s (.49 ft/s)	≤ 0.15 m/s (.49 ft/s)
(ISO 11064-6,2005; MIL-STD 1472G)	**Humidity**		30-70%	30-70%

8. REFERENCES

1. *2010 ADA standards for accessible design. [electronic resource]*. (2010). [Washington, D.C.] : Dept. of Justice, [2010].
2. Abe, D., Muraki, S., & Yasukouchi, A. (2008). Ergonomic effects of load carriage on the upper and lower back on metabolic energy cost of walking. *Applied Ergonomics, 39*(3), 392-398.
3. Alkhajah, T. A., Reeves, M. M., Eakin, E. G., Winkler, E. A., Owen, N., & Healy, G. N. (2012). Sit–Stand workstations: a pilot intervention to reduce office sitting time. *American Journal of Preventive Medicine*, 43(3), 298-303.
4. Ahlstrom, V. (2016). Human Factors Design Standard (DOT/FAA/HF-STD-001B). Atlantic City International Airport, NJ: Federal Aviation Administration William J. Hughes Technical Center.
5. American Conference of Governmental Industrial Hygienists (ACGIH). 1992. 1992-1993 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. Cincinnati: American Conference of Governmental Industrial Hygienists
6. American Conference of Governmental Industrial Hygienists (ACGIH). 2012. Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. Cincinnati: American Conference of Governmental Industrial Hygienists.
7. American Conference of Governmental Industrial Hygienists (ACGIH). 2013. Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. Cincinnati: American Conference of Governmental Industrial Hygienists
8. Anshel, J. (Ed.). (2005). Visual ergonomics handbook. CRC Press.
9. ANSI/HFS 100. 1988. American national standard for human factors engineering of visual display terminal workstations. Human Factors and Ergonomics Society, Santa Monica, CA.
10. ANSI/HFES 100. 2007. Human Factors Engineering of Computer Workstations. Human Factors and Ergonomics Society, Santa Monica, CA.
11. ANSI/IESNA [2004]. IESNA Office Lighting Committee. American national standard practice for office lighting. RP-1-04.
12. Arnold, K. P. (2016). The UAV Ground Control Station: Types, Components, Safety, Redundancy, and Future Applications. *International Journal of Unmanned Systems Engineering*, *4*(1), 37.
13. Asundi, K., Odell, D., Luce, A., & Dennerlein, J. T. (2010). Notebook computer use on a desk, lap and lap support: effects on posture, performance and comfort. *Ergonomics*, 53(1), 74-82.
14. Atkinson, S., Woods, V., Haslam, R. A., & Buckle, P. (2004). Using Non-Keyboard Input Devices: Interviews with Users in the Workplace. International Journal of Industrial Ergonomics, 571-579.
15. Bailey, R., Hostetler, R., Barnes, K., Belcastro, C., & Belcastro, C. (2005, January). Experimental validation: Subscale aircraft ground facilities and integrated test capability. In *AIAA Guidance, Navigation, and Control Conference and Exhibit* (p. 6433).
16. Barr, A. E., Oezkaya, N., Nordin, M., & Lee, E. (1996). Effect of VDT Mouse Design on CTD Risk and User Skill. NASA, (19980003943).
17. Bastien, G. J., Schepens, B., Willems, P. A., & Heglund, N. C. (2005). Picking the best speed-load combination in backpack load carrying. *Computer Methods in Biomechanics and Biomedical Engineering, 8*(S1), 19-20.
18. Bloom, D., & Woodhull-Mcneal, A. P. (1987). Postural adjustments while standing with two types of loaded backpack∗. *Ergonomics*, *30*(10), 1425-1430.
19. Brand, J. L., & Orenstein, H. B. (1998). Does display configuration affect information sampling performance?. *Ergonomics*, *41*(3), 286-301.
20. Callaghan, J. P., De Carvalho, D., Gallagher, K., Karakolis, T., & Nelson-Wong, E. (2015). Is standing the solution to sedentary office work?. *Ergonomics in Design: The Quarterly of Human Factors Applications*, 23(3), 20-24.
21. Canadian Centre for Occupational Health and Safety (CCOHS). 2015. Office Ergonomics. Retrieved 12.15.16 from: http://www.ccohs.ca/oshaanswers/ergonomics/office/.
22. Canadian Centre for Occupational Health and Safety (CCOHS). 2017. Cold Environments- Working in the Cold. Retrieved from http://www.ccohs.ca/oshanswers/phys_agents/cold_working.html

23. Carletti, C., Sciurpi, F., Pierangioli, L., Asdrubali, F., Pisello, A. L., Bianchi, F., Guattari, C. (2016). Thermal and lighting effects of an external venetian blind: Experimental analysis in a full scale test room. *Building and Environment*, 106, 45-56.
24. Chaffin, D. B., & Andersson, G. (1984). Occupational biomechanics (2nd ed.). New York: Wiley Inter-science.
25. Chengalur, S. N., Rodgers, S. H., and Bernard, T. E. (2003). Kodak's ergonomic design for people at work. Ho-boken, New Jersey: John Wiley & Sons, Inc.
26. Cholewicki, J., & McGill, S. M. (1996). Mechanical stability of the in vivo lumbar spine: implications for injury and chronic low back pain. *Clinical Biomechanics*, 11(1), 1-15.
27. Connect-A-Desk. Digital Image. Quadcopter Drone. Web. 27 July 2017. http://quadcopterdrone.net/prod-uct/connect-a-desk-drone-remote-control-harness-for-dji-phantom-123-inspire-1-syma-and-others
28. Conte, C., Ranavolo, A., Serrao, M., Silvetti, A., Orengo, G., Mari, S., Forzano, F., Iavicoli, S., Draicchio, F. (2014). Kinematic and electromyographic differences between mouse and touchpad use on laptop computers. *International Journal of Industrial Ergonomics*, 413-420.
29. Davis, S. (2010). Military Operations Command More from Mobile Power Sources. *Power Electronics Tech-nology*, 32-363.
30. Dennerlein, J. T., & Johnson, P. W. (2006). Changes in Upper Extremity Biomechanics Across Different Mouse Positions in a Computer Workstation. *Ergonomics*, 1456-1469.
31. DeVita, P., Hong, D., & Hamill, J. (1991). Effects of asymmetric load carrying on the biomechanics of walk-ing. *Journal of Biomechanics*, *24*(12), 1119-1129.
32. Dieen, J. H. V. (1998). Evaluation of work-rest schedules with respect to the effects of postural workload in standing work. Ergonomics, 41(12), 1832-1844.
33. Displays in Control Station. Digital Image. DEFENSETECH. 17 July 2014. Web. 3 August 2017. https://www.defensetech.org/2014/07/17/general-atomics-unveils-enhanced-drone-cockpit/
34. Dixon, S. R., Wickens, C. D., & Chang, D. (2005). Mission control of multiple unmanned aerial vehicles: A workload analysis. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 47*(3), 479-487.
35. DOD-HFDG-ATCCS (1992). *Human Factors Design Guidelines for the Army Tactical Command and Control System Soldier-Machine Interface Version 2.0*, US Army Tactical Command and Control System Experimenta-tion Site, Fort Lewis, Washington 98433 (DTIC AD-A252 410).
36. DOE, Human factors/ergonomics handbook for the design for ease of maintenance, Department of Energy Handbook DOE-HDBK-1140-2001, 2001.
37. Fairfax, R. E. (2003). OSHA policy on indoor air quality: office temperature/humidity and environmental to-bacco smoke. Memorandum to regional administrators.
38. Fiolkowski, P., Horodyski, M., Bishop, M., Williams, M., & Stylianou, L. (2006). Changes in gait kinematics and posture with the use of a front pack. *Ergonomics*, *49*(9), 885-894.
39. FrSky Taranis X9 X9D Plus RC Controller. Digital Image. Drone Insider. 23 April 2016. Web. 27 July 2017. http://droneinsider.org/top-5-best-radio-transmitters/
40. Game Controller. Digital Image. Make Use Of. 17 December 2013. Web. 2 August 2017. http://www.makeuseof.com/tag/controller-wars-ps3-vs-ps4-xbox-360-vs-xbox-one/
41. Goel, V. K., Kong, W., Han, J. S., Weinstein, J. N., & Gilbertson, L. G. (1993). A combined finite element and optimization investigation of lumbar spine mechanics with and without muscles. *Spine*, *18*(11), 1531-1541.
42. Haisman, M. F. (1988). Determinants of load carrying ability. *Applied Ergonomics*, *19*(2), 111-121.
43. Healy, G. N., Dunstan, D. W., Salmon, J., Cerin, E., Shaw, J. E., Zimmet, P. Z., & Owen, N. (2008). Breaks in sedentary time. *Diabetes care*, *31*(4), 661-666.
44. Healy, G. N., Winkler, E. A., Owen, N., Anuradha, S., & Dunstan, D. W. (2015). Replacing sitting time with standing or stepping: associations with cardio-metabolic risk biomarkers. *European Heart Journal*.
45. HF-STD-001B (2016) *U.S. Department of Transportation Federal Aviation Administration Human Factors De-sign*
46. Holewun, M., & Lotens, W. A. (1992). The influence of backpack design on physical performance. *Ergonom-ics*, *35*(2), 149-157.

47. Hu, F. B., Leitzmann, M. F., Stampfer, M. J., Colditz, G. A., Willett, W. C., & Rimm, E. B. (2001). Physical activity and television watching in relation to risk for type 2 diabetes mellitus in men. *Archives of Internal Medicine*, *161*(12), 1542-1548.
48. Illuminating Engineering Society of North America (IESNA). (1993). American national standard practice for office lighting (ANSI/IESNA RP-1 1993). New York: IESNA.
49. International Code Council. (2014). *2015 international building code*. Country Club Hills, Ill: ICC.
50. ISO 9241-410:2008. Ergonomics of human–system interaction: Part 410. Design criteria for physical input devices. Geneva, Switzerland.
51. ISO 11064-4:2013. Ergonomic Design of Control Centres Part 4: Layout and Dimensions of Workstations. International Organization for Standardization, pp. 1-37.
52. ISO 11064-6: 2005. Ergonomic Design of Control Centres Part 6: Environmental Requirements for Control Centres. International Organization for Standardization, pp. 1-16.
53. ISO 2631-1:1997. Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole-Body Vibration. Part 1: General Requirements. ISO, Geneva.
54. Jans, M. P., Proper, K. I., & Hildebrandt, V. H. (2007). Sedentary behavior in Dutch workers: differences between occupations and business sectors. *American Journal of Preventive Medicine*, *33*(6), 450-454.
55. Johanning, E. (2015). Whole-body vibration-related health disorders in occupational medicine–an international comparison. *Ergonomics*, *58*(7), 1239-1252.
56. Katzmarzyk, P. T., Church, T. S., Craig, C. L., & Bouchard, C. (2009). Sitting time and mortality from all causes, cardiovascular disease, and cancer. *Medicine and Science in Sports and Exercise*, *41*(5), 998-1005.
57. Kim, J. H., Aulck, L., Thamsuwan, O., Bartha, M. C., & Johnson, P. W. (2014). The Effect of Key Size of Touch Screen Virtual Keyboards on Productivity, Usability, and Typing Biomechanics. *Human Factors*, *56*(7), 1235-1248.
58. Knapik, J. J., Reynolds, K. L., & Harman, E. (2004). Soldier load carriage: historical, physiological, biomechanical, and medical aspects. *Military Medicine*, *169*(1), 45.
59. Knapik, J., Harman, E., & Reynolds, K. (1996). Load carriage using packs: a review of physiological, biomechanical and medical aspects. *Applied Ergonomics*, *27*(3), 207-216.
60. Knapik, J., Reynolds, K., Santee, W. R., & Friedl, K. E. (2012). Load carriage in military operations: a review of historical, physiological, biomechanical and medical aspects. *Military quantitative physiology: problems and concepts in military operational medicine. Office of the Surgeon General and the Borden Institute, Ft. Detrick, MD*, 303-337.
61. Kroemer, K. E., & Grandjean, E. (1997). *Fitting the task to the human : a textbook of occupational ergonomics*. London ; Bristol, PA : Taylor & Francis, [1997].
62. Kyrnin, M. (2017, March 14). Guide to Laptop Size and Weight. Retrieved from Lifewire: https://www.lifewire.com/guide-to-laptop-size-and-weight-832312
63. Lai, C., Kuo, L., & Chuang, T. (2015). Size Effects on the Usability of Tablets in Pointing and Typing Tasks. *Procedia Manufacturing*, *3*(6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015), 6183-6189.
64. Laird, R. T., Kramer, T. A., Cruickshanks, J. R., Curd, K. M., Thomas, K. M., & Moneyhun, J. (2006, May). FIRRE command and control station (C2). In *Defense and Security Symposium* (pp. 623023-623023). International Society for Optics and Photonics.
65. Lueder, R. (1986). *The ergonomics payoff: Designing the electronic office*. Nichols Pub Co.
66. Madeleine, P., Voigt, M., & Arendt-Nielsen, L. (1997). Subjective, physiological and biomechanical responses to prolonged manual work performed standing on hard and soft surfaces. *European journal of applied physiology and occupational physiology*, *77*(1), 1-9.
67. Makhsous, M., Lin, F., Bankard, J., Hendrix, R. W., Hepler, M., & Press, J. (2009). Biomechanical effects of sitting with adjustable ischial and lumbar support on occupational low back pain: evaluation of sitting load and back muscle activity. *BMC Musculoskeletal Disorders*, *10*(1), 1.
68. Makhsous, M., Lin, F., Hanawalt, D., Kruger, S. L., & LaMantia, A. (2012). The effect of chair designs on sitting pressure distribution and tissue perfusion. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *54*(6), 1066-1074.
69. MIL-HDBK-759C Department of Defense. (1995). *Human engineering design guidelines* (MIL-HDBK-759C). Philadelphia, PA: Navy Publishing and Printing Office.

70. MIL-STD-1472G Department of Defense. (2012). *Design criteria standard-human engineering* (MIL-STD-1472G). Philadelphia, PA: Navy Publishing and Printing Office.
71. Moffet, H., Hagberg, M., Hansson-Risberg, E., & Karlqvist, L. (2002). Influence of laptop computer design and working position on physical exposure variables. *Clinical Biomechanics*, 17(5), 368-375.
72. Moray, N., & Rotenberg, I. (1989). Fault management in process control: eye movements and action. *Ergonomics, 32*(11), 1319-1342.
73. Mouloua, M., Gilson, R., Daskarolis-Kring, E., Kring, J., & Hancock, P. (2001, October). Ergonomics of UAV/UCAV mission success: Considerations for data link, control, and display issues. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 45, No. 2, pp. 144-148). SAGE Publications.
74. Murray, S. A., & Caldwell, B. S. (1996). Human performance and control of multiple systems. *Human Factors, 38*(2), 323-329.
75. Nanthavanij, S. (1996). Body height-workstation settings matrix: A practical tool for ergonomic VDT workstation adjustment. *International Journal of Industrial Ergonomics*, *18*(2), 215-219.
76. Nanthavanij, S., Prae-Arporn, K., Chanjirawittaya, S., Paripoonyo, S., & Rodloy, S. (2016). Novel method of computing recommended settings of notebook computer and office workstation for ergonomic work posture. *Maejo International Journal of Science and Technology*, *10*(1), 13.
77. NUREG-0700 (2002). *Human-system interface design review guidelines*. Washington, DC: United States Nuclear Regulatory Commission.
78. O'Sullivan, P. B., Grahamslaw, K. M., Kendell, M., Lapenskie, S. C., Möller, N. E., & Richards, K. V. (2002). The effect of different standing and sitting postures on trunk muscle activity in a pain-free population. *Spine, 27*(11), 1238-1244.
79. Occupational Health and Safety Council of Ontario. (2008b). Part3B: MSD prevention toolbox. Beyond the basics (Musculoskeletal Disorders Prevention Series #5159A). Ontario, Canada.
80. Occupational Safety and Health Administration. (1997). *Working safely with video display terminals*. U.S. Department of Labor, Washington, DC.
81. Occupational Safety and Health Administration. (2003). Computer Workstation eTool.
82. Occupational Safety and Health Administration. (2017) Occupational safety and health standards: (29 CFR 1910.28). Retrieved from https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9720
83. Occupational Safety and Health Administration. (2017). Occupational safety and health standards: (29 CFR 1910.95). Retrieved from https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=9735
84. Occupational Safety and Health Administration. (2017). Occupational safety and health standards: (29 CFR 1926). Retrieved from https://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARDS&p_toc_level=1&p_keyvalue=Construction
85. Occupational Safety and Health Administration. (2017). Occupational safety and health standards: (29 CFR 1910). Retrieved from https://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARDS&p_toc_level=1&p_keyvalue=1910
86. Odell, D., Barr, A., Goldberg, R., Chung, J., & Rempel, D. (2007). Evaluation of a dynamic arm support for seated and standing tasks: a laboratory study of electromyography and subjective feedback. *Ergonomics, 50*(4), 520-535.
87. Paul, R. D. (1995). Foot swelling in VDT operators with sitting and sit-stand workstations. In *Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting* (pp. 568–572). Santa Monica, CA: Human Factors and Ergonomics Society.
88. Paul, R. D., & Helander, M. G. (1995). Effect of sit-stand schedule on spinal shrinkage in VDT operators. In *Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting* (pp. 563–567). Santa Monica, CA: Human Factors and Ergonomics Society.
89. Pelican Case Control Station. Digital Image. DIY DRONES. 7 February 2013. Web. 2 August 2017. http://diydrones.com/m/blogpost?id=705844%3ABlogPost%3A1118581&maxDate=2013-02-08T22%3A53%3A36.593Z
90. Pereira, A., Hsieh, C.-M., Laroche, C., & Rempel, D. (2014). The Effect of Keyboard Key Spacing on Typing Speed, Error, Usability, and Biomechanics, Part 2: Vertical Spacing. Human Factors, 752-759.
91. Pronk, N., Katz, A., Lowry, M., & Payfer, J. (2012). Reducing occupational sitting time and improving worker health: The take-a-stand project, 2011. *Preventing Chronic Disease*, *9*(10).

92. Seppanen, O., Fisk, W. J., & Lei, Q. H. (2006). *Effect of temperature on task performance in office environment*. Lawrence Berkeley National Laboratory.
93. Simoneau, G. G., & Marklin, R. W. (2001). Effect of computer keyboard slope and height on wrist extension angle. *Human Factors, 43*(2), 287-298.
94. Straker, L., Abbott, R. A., Heiden, M., Mathiassen, S. E., & Toomingas, A. (2013). Sit–stand desks in call centres: Associations of use and ergonomics awareness with sedentary behavior. *Applied Ergonomics, 44*(4), 517-522.
95. Straker, L., Jones, K. J., & Miller, J. (1997). A comparison of the postures assumed when using laptop computers and desktop computers. *Applied Ergonomics*, 28(4), 263-268.
96. Sun Hood Screen Protection. Digital Image. AliExpress. Web. 27 July 2017. https://www.aliexpress.com/store/product/8-inch-iPad-Mini-Sun-Shade-Sunshade-Hood-Cover-Anti- dust-for-DJI-Inspire-1/1158967_32314694984.html
97. Tan, D. S., Gergle, D., Scupelli, P., & Pausch, R. (2006). Physically large displays improve performance on spatial tasks. *ACM Transactions on Computer-Human Interaction* (TOCHI), 13(1), 71-99.
98. Touchscreen. Digital Image. Alibaba. Web. 3 August 2017. https://guide.alibaba.com/shop/asus-vivotab-tf600tl-b1-gr-with-wifi-10-1-touchscreen-tablet-pc-featuring-windows-8-rt-operating-system-gray_10051447.html
99. Trackball. Digital Image. Web. 3 August 2017. https://www.kensington.com/us/us/4493/k64327f/orbit-optical-trackball
100. U.S. General Services Administration (GSA). (2003). 2003 facility standards: 6.15 lighting. Retrieved from https://www.gsa.gov/portal/content/101308.
101. Vasconcelos, G., Carrijo, G., Miani, R., Souza, J., & Guizilini, V. (2016, October). The Impact of DoS Attacks on the AR. Drone 2.0. In *Robotics Symposium and IV Brazilian Robotics Symposium (LARS/SBR), 2016 XIII Latin American* (pp. 127-132). IEEE.
102. Vlaović, Z., Domljan, D., Župčić, I., & Grbac, I. (2016). Evaluation of Office Chair Comfort. *Drvna industrija*, *67*(2), 171-176.
103. Wiegand, D. M. (2013). Lighting, Indoor Environmental Quality Concerns, and Job Stress at a Call Center–California.
104. Wilks, S., Mortimer, M., & Nylén, P. (2006). The introduction of sit–stand worktables; aspects of attitudes, compliance and satisfaction. Applied Ergonomics, 37(3), 359-365.
105. Yamaguchi, H.,Yoshida, H., Kamijo, M., Fujimaki, G., & Naruse, T. (2014). Effect of Footrest Angle on Decrement of Leg Swelling while Sitting. *International Journal of Affective Engineering*, *13*(3), 197-203.
106. Yau, Y.-J., Chao, C.-J., & Hwang, S.-L. (2008). Effects of Input Device and Motion Type on a Cursor-Positioning Task. Perceptual and Motor Skills, 76-90.
107. Yoo, W. G. (2015). Effect of a suspension seat support chair on the trunk flexion angle and gluteal pressure during computer work. *Journal of Physical Therapy Science*, *27*(9), 2989-2990.
108. Zelnik, M., & Panero, J. (1979). Human dimension and interior space. *New York: Whitney Library of Design*.

9. APPENDIX A: ADDITIONAL RECOMMENDATIONS AS OUTLINED IN THE LITERATURE

The following tables are a compilation of all recommendations found in standards and the literature for workstations and the chair. The first column of each table provides the source from which each recommendation was discovered. The second column lists the design element for which the recommendation is provided. The third column houses a minimum dimension in centimeters. Finally, the fourth column lists adjustable ranges, if applicable, for the element. Adjustable ranges are not available in the literature for all design elements; however, authors included adjustable ranges as a reference for adjustable furniture.

MINIMAL RECCOMENDATIONS AVAILABLE IN THE LITERATURE			
Seated Workstation Dimensions			
Workspace			
Source	Dimensions	Minimum cm (in)	Adjustment (unless other-wise specified) cm (in)
(MIL-STD-1472G-Figure 63)	Kneehole depth	46.0 (18.1)	
(ANSI/HFES 100-2007-8.3.2.1.2*)	Depth at knee level	44.0 (17.3)	
(ADA, 2010-306.3.3)	Knee clearance depth (when element is 23.0 cm above the floor)	28.0 (11.0)	63.5 (25.0) (maximum)
(ADA, 2010-306.3.3)	Knee clearance depth (when element s 68.5 cm above the floor)	20.5 (8.1)	
(MIL-STD-1472G-Table XLVII)	Kneehole depth (at knee height)	38.1 (15.0)	
(MIL-STD-1472G-Table XLVII)	Kneehole depth (at deck level)	59.7 (23.5)	
(MIL-STD-1472G-Figure 63)	Kneehole width	51.0 (20.1)	
(MIL-STD-1472G-Table XLVII)	Kneehole width	50.8 (20.0)	61.0 (24.0) (Preferred)
(ADA, 2010-306.3.5)	Knee clearance width	76.0 (29.9)	
(ANSI/HFES 100-2007-8.3.2.1.2*)	Width (workstation width below surface height)	52.0 (20.5)	
(MIL-STD-1472G-Figure 63)	Kneehole height (standard office)	63.5 (25.0)	
(MIL-STD-1472G-Table XLVII)	Kneehole height	63.4 (25.0)	
(MIL-STD-1472G-Figure 63)	Desk to wall	81.0 (31.9)	
(MIL-STD-1472G-Table XLVII)	Desk to wall	81.3 (32.0)	
(MIL-STD-1472G-Table XLVII)	Chair to wall	38.1 (15.0)	
(MIL-STD-1472G-Figure 63)	Armrest to wall	61.0 (24.0)	
(MIL-STD-1472G-Figure 63)	Lateral Work Clearance		
(MIL-STD-1472G-Figure 63)	Shoulders	58.5 (23.0)	
(MIL-STD-1472G-Figure 63)	Elbows	63.5 (25.0)	
(MIL-STD-1472G-Figure 63)	Best Overall	100.0 (39.4)	
(MIL-STD-1472G-Figure 63)	Height of work surface	73.5 (28.9)	76.0 (29.9) (preferred)

(ANSI/HFES 100-2007- 8.3.2.1.2*)	Height at edge of work surface closest to operator		50.0 – 72.0 (19.7 – 28.3)
(ANSI/HFES 100-2007- 8.3.2.1.2*)	Height at horizontal position of the knee		50.0 – 64.0 (19.7 – 25.2)
(ADA AG, 2002-4.32.3)	Surface height		71.0-86.5 (28.0 – 34.1)
(ANSI/HFES 100-2007- 8.3.2.4.1)	Surface height		52.0 – 72.0 (19.7 – 28.3)
(MIL-STD-1472G-Table XLVII)	Height of work surface (fixed)	76.2 (30.0)	Fixed keyboard work surface (preference)
(MIL-STD-1472G-Table XLVII)	Height of work surface keyboard (adjustable)		61.0 cm – 71.1 cm (24.0 – 28.0) independent adjustable keyboard work surface (preference)
(Chengalur et al., 2003)	Keyboard distance from front of desk surface		10.0-25.0 (3.9 – 9.8)(range)
(ANSI/HFES 100-2007- 8.3.2.4.1)	Input device work surface tilt		Adjustable from -15° to +20°
(ANSI/HFES 100-2007- 8.3.4.2)	Wrist/Palm, Forearm support depth	3.8 (1.5)	
	Width of work surface		
(MIL-STD-1472G-Table XLVII)	Desk width	137.2 (54.0)	
(MIL-STD-1472G-Table XLVII)	Work surface width	61.0 (24.0)	
(MIL-STD-1472G-Figure 63)	Elbow rest alone	10.0 (3.9)	20.0 (7.9) (preference)
(MIL-STD-1472G-Figure 63)	Writing surface	30.5 (12.0)	40.5 (15.9) (preference)
(MIL-STD-1472G-Figure 63)	Desk work area		91.0 (35.8) (preference)
(MIL-STD-1472G-Table XLVII)	Desk depth	76.2 (30.0)	91.4 (36.0) (preference)
(MIL-STD-1472G-Table XLVII)	Work surface depth	61.0 (24.0)	76.2 (30.0) (preference)
	Maximum extended overhead reach (above seated surface)		
(MIL-STD-1472G-5.10.3.4.9)	Males		132.1 (52.0) (maximum)
(MIL-STD-1472G-5.10.3.4.9)	Females		124.5 (49.0) (maximum)
(MIL-STD-1472G-5.10.3.4.9)	Maximum overhead reach for gripping reach (above seated surface)		
(MIL-STD-1472G-5.10.3.4.9)	Males		127.0 (50.0) (maximum)
(MIL-STD-1472G-5.10.3.4.9)	Females		116.8 (46.0) (maximum)
	Kick space		

(ANSI/HFES 100-2007-8.3.2.1.2*)		Height at position of the foot	10.0 (3.9)	
(MIL-STD-1472G-5.10.2.3)		Height	10.0 (3.9)	
(MIL-STD-1472G-5.10.2.3)		Depth	10.0 (3.9)	
	Toe clearance			
(ANSI/HFES 100-2007-8.3.2.1.2*)		Depth at foot level	60.0 (23.6)	
(ADA, 2010-306.2)		Depth (distance from front surface of the element)	43.0 (16.9)	63.5 (25.0) (maximum)
(ADA, 2010-306.2)		Width	76.0 (29.9)	
	Display mounting heights			
(MIL-STD-1472G-Figure 68)		Height (seated)	15.2 (6.0) (35.6 (14.0) preferred) from seat height	111.8 (44.0) (90.0 (35.4) preferred)
(MIL-STD-1472G-Figure 68)		Maximum height for vision over top (seated)		68.6 (27.0) (maximum)
	Laptop Specific Dimensions			
(Nanthavanij et al., 2016)		Tilt angle of laptop keyboard		20° (preferred)
(Nanthavanij et al., 2016)		Laptop keyboard-screen angle		119° (preferred)
(Nanthavanij et al., 2016)		Distance from body to laptop		41.0 (16.1) (preferred)
*Refer to Upright, Reclined, and Declined Seated Clearances (ANSI/HFES 100-2007-Figure 8.3b)				

MINIMAL RECOMMENDATIONS AVAILABLE IN THE LITERATURE				
Standing Workstation Dimensions				
	Dimensions		Minimum	Adjustment (unless otherwise specified)
			cm (in)	cm (in)
Work benches				
(MIL-STD-1472G-Figure 62)	Standard type			
(MIL-STD-1472G-Figure 62)		Height		91.0 (35.8) above floor (preferred)
(MIL-STD-1472G-Figure 62)		Width		99.0 (39.0) (preferred)
(MIL-STD-1472G-Figure 62)	Podium type			
(MIL-STD-1472G-Figure 62)		Height		104.0 (40.9) above floor (preferred)
(MIL-STD-1472G-Figure 62)		Width		91.0 (35.8) (preferred)
Work clearances				
(MIL-STD-1472G-Figure 62)	Passing body depth		33.0 (13.0)	38.0 (15.0) (preferred)
(MIL-STD-1472G-Figure 62)	Standing space		76.0 (29.9)	91.0 (35.8) (preferred)
(MIL-STD-1472G-Figure 62)	Overhead clearance		185.5 (73.0)	203.0 (79.9) (preferred)
(MIL-STD-1472G-Figure 62)	Maximum overhead reach			68.5 (27.0) (preferred)
(MIL-STD-1472G-Figure 62)	Maximum depth of reach			58.5 (23.0) (preferred)

(MIL-STD-1472G-Figure 62)	Walking space width	30.5 (12.0)	38.0 (15.0) (preferred)
(MIL-STD-1472G-Figure 62)	Passing body width	51.0 (20.1)	81.0 (31.9) (preferred)
	Kick space/Foot Clearances		
(MIL-STD-1472G-5.10.2.3)	Height	10.0 (3.9)	
(MIL-STD-1472G-5.10.2.3)	Depth	10.0 (3.9)	
	Work surface		
(ANSI/HFES 100-2007-8.3.2.4.2)	Height (height adjustable only)		95.0 – 118.0 (37.4 – 46.5) from floor to front edge of support
(ANSI/HFES 100-2007-8.3.2.4.2)	Height (height and tilt adjustable)		Some portion of range 78.0 – 118.0 (30.7 – 46.5) including adjustability in the range 89.0 – 110.0 (35.0 – 43.3) from floor to front edge of support
(ANSI/HFES 100-2007-8.3.2.4.2)	Tilt (height and tilt adjustable)		Some portion of range +20° to -45° including the range 0° to -15°
(ANSI/HFES 100-2007-8.3.2.4.2)	Tilt (tilt adjustable)		+20° to -45°
(ANSI/HFES 100-2007-8.3.2.4.2)	Height (tilt adjustable)		78.0 – 118.0 (30.7 – 46.5) from floor to front edge of support
(MIL-STD-1472G-Figure 68)	Display mounting heights		
(MIL-STD-1472G-Figure 61)	Height	104.0 (40.9) (139.7 (55.0) preferred) from seat height	177.8 (70.0) (165.1 (65.0) preferred)
(MIL-STD-1472G-Figure 61)	Height for vision over top		150.1 (59.1) (preferred)

MINIMAL RECOMMENDATIONS AVAILABLE IN THE LITERATURE			
Chair			
Source	Dimensions	Fixed/Minimum cm	Adjustment cm (unless otherwise specified)
	Armrest		
(MIL-STD-1472G-Table XLVII)	Length	25.4 (10.0)	
(MIL-STD-1472G-Table XLVII)	Width	5.0 (2.0)	
(MIL-STD-1472G-Table XLVII)	Height	21.6 (8.5)	19.1 – 27.9 (7.5 – 11.0)

(ANSI/HFES 100-2007- 8.3.4.1)		Height (adjustable)		17.0 – 27.0 (6.7 – 10.6) above compressed seat height
(ANSI/HFES 100-2007- 8.3.4.1)		Height (fixed)		18.0 – 27.0 (7.1 – 10.6) above compressed seat height
(MIL-STD-1472G-Table XLVII)		Separation	45.7 (18.0)	
(ANSI/HFES 100-2007- 8.3.4.1)		Clearance between armrests	46.0 (18.1)	
	Seat pan			
(MIL-STD-1472G-Table XLVII)		Width	40.6 (16.0)	
(ANSI/HFES 100-2007- 8.3.3.3)		Width	45.0 (17.7)	
(MIL-STD-1472G-Table XLVII)		Height	38.1 (15.0)	Adjustable from minimum up to 12.7 cm (5.0) in increments no larger than 2.5 cm (1.0)
(ANSI/HFES 100-2007- 8.3.3.1)		Height		38.0 – 56.0 (15.0 – 22.0) and adjustable over a minimum range of 11.4 (4.5)
(MIL-STD-1472G-Table XLVII)		Depth	38.1 (15.0)	Up to 43.2 (17.0)
(ANSI/HFES 100-2007- 8.3.3.2)		Depth	43.0 (16.9) if nonadjustable	Include 43.0 (17.0) if adjustable
(MIL-STD-1472G-Table XLVII)		Angle from horizontal		0° - 10°
(ANSI/HFES 100-2007- 8.3.3.4)		Angle		Range of 4° that includes a reclined position of 3°
(MIL-STD-1472G-Table XLVII)		Pan-backrest angle		90° - 100°
(Leuder, 1986)		Front edge	waterfall	
(Kroemer & Grandjean, 1997)		Distance to desk surface		27.0-30.0 (10.6 – 11.8) (preferred)
	Backrest			
(ANSI/HFES 100-2007- 8.3.3.5)		Angle		Adjustment range of 15° or more within the range of 90° - 120° relative to horizontal

(ANSI/HFES 100-2007- 8.3.3.5)		Recline angle		If greater than 120° should provide a headrest
(MIL-STD-1472G-Table XLVII)		Vertical space between seat pan and backrest	15.2 (6.0)	It is preferred there is no space between seat pan and bottom of backrest.
(MIL-STD-1472G-Table XLVII)		Height	38.0 (15.0)	Height should be adjustable unless it is solid from seat pan to minimum height. Adjustments should be in increments no larger than 2.5 cm (1.0)
(ANSI/HFES 100-2007- 8.3.3.6)		Height	45.0 (17.7) above compressed seat	
(MIL-STD-1472G-Table XLVII)		Width	40.6 (16.0)	46.2 cm (18.2) preferred
(ANSI/HFES 100-2007- 8.3.3.6)		Width	36.0 (14.2)	
(ANSI/HFES 100-2007- 8.3.3.6)		Lumbar support height		15.0 – 25.0 (5.9 – 9.8) above compressed seat height
(Nanthanvanij, 1996)		Distance to keyboard home row		39.0-50.0 (15.4 – 19.7) (preferred)
(MIL-HDBK-759C-5.7.3.5)	Footrests		Should be provided when user is seated in seats of height 46.0 (18.1) or higher for extended durations or with work surfaces higher than 76.0 (29.9).	
(MIL-HDBK-759C-Table 20)		From center	18.0 (7.1)	
(MIL-HDBK-759C-Table 20)		Depth	15.0 (5.9)	
(ANSI/HFES 100-2007- 8.3.4.3)		Depth	20.0 (7.9)	
(MIL-HDBK-759C-Table 20)		Width	25.5 (10.0)	
(ANSI/HFES 100-2007- 8.3.4.3)		Width	51.0 (20.1)	
(ANSI/HFES 100-2007- 8.3.4.3)		Height		Up to 22.0 (8.7)
	Chair Design			
(MIL-HDBK-759C, 1995- 5.7.3.3)		Contact Surface Material	Cushioning	
(Vlaović et al., 2016)		Contact Surface Material	Net-like material and suspension design	

MINIMAL RECCOMENDATIONS IN LITERATURE			
Workplace Illumination			
Source	**Illumination level based on task and work area**	**Minimum**	**Preferred**
		Lux (fc)	**Lux (fc)**
	Workstations		
(MIL-STD 1472G)	Computer workstation general lighting	300 (28)	540 (50)
(MIL-STD 1472G)	Control rooms general lighting	325 (30)	540 (50)
(MIL-STD 1472G)	Computer work	300 (28)	300 (28)
(MIL-STD 1472G) (OSHA “Working safely with video display terminals”, 1997)	Computer workstation[2]	300 (28)	540 (50)
(MIL-STD 1472G)	Consoles (front)	325 (30)	540 (50)
(MIL-STD 1472G)	Consoles (rear)	110 (10)	325 (30)
(MIL-STD 1472G)	Ordinary visual tasks	325 (30)	540 (50)
(MIL-STD 1472G)	Faint signal detection task	<2.7 (0.25)	<2.7 (0.25)
(MIL-STD 1472G)	Reading (large print)	110 (10)	325 (30)
(MIL-STD 1472G)	Reading (news print)	325 (30)	540 (50)
(MIL-STD 1472G)	Reading (small type reading)	540 (50)	755 (70)
(GSA, 2003)	Conference rooms	300 (28)	300 (28)
(MIL-STD 1472G)	Radio room	540 (50)	540 (50)
(MIL-STD 1472G)	Offices (general)	540 (50)	755 (70)
(GSA, 2003)	Office (closed)	500 (46)	500 (46)
	Other areas		
(MIL-STD 1472G)	Stairs and ladders	110 (10)	215 (20)
(MIL-STD 1472G)	Passageways (walkways, hallways)	150 (14)	215 (20)
(MIL-STD 1472G)	Elevators	215 (20)	325 (30)
(MIL-STD 1472G)	Emergency lighting	30 (3)	55 (5)
	Other illumination considerations	**Minimum**	**Preferred**
(MIL-STD-1472G)	Display luminance ratio	50:1	50:1
(ANSI/IESNA RP-1-1993; MIL-STD-1472G)	Contrast ratio between bright and dark surface within task	5:1	5:1
(ANSI/IESNA RP-1-1993; MIL-STD-1472G)	Contrast ratio between task and adjacent surrounding	3:1 (if reflection can be controlled) 5:1 (if reflection cannot be controlled and environmental conditions are difficult to alter)	3:1 (if reflection can be controlled) 5:1 (if reflection cannot be controlled and environmental conditions are difficult to alter)

(ANSI/IESNA RP-1-1993; MIL-STD-1472G)	Contrast ratio between task and more remote surfaces	10:1 (if reflection of entire space can be controlled) 20:1 (if reflection off the immediate area can be controlled and remote surrounding conditions cannot be altered)	10:1 (if reflection of entire space can be controlled) 20:1 (if reflection off the immediate area can be controlled and remote surrounding conditions cannot be altered)
(ANSI/IESNA RP-1-1993; MIL-STD-1472G)	Contrast ratio between luminaries and adjacent surfaces	20:1 (if reflection of entire space can be controlled)	20:1 (if reflection of entire space can be controlled)
(ANSI/IESNA RP-1-1993; MIL-STD-1472G)	Contrast ratio between immediate work area and rest of the environment	40:1 (if reflection of entire space can be controlled)	40:1 (if reflection of entire space can be controlled)
Workplace HVAC System attributes			
Source	**Temperature**	**Permissible Range**	**Preferred Range**
(Fairfax, 2003; Seppanen, Fisk, & Lei, 2006)	Comfortable workplace temperature	20.0-24.0ºC (68-75.2°F)	21.0-22.0ºC (69.8-71.6°F) (for optimal worker performance)
(MIL-STD-1472 G)	Effective temperature or Corrected effective temperature requirement maintained by heating system	≥18.0ºC (64.4°F)	≥18.0ºC (64.4°F)
(MIL-STD-1472 G)	Effective temperature or Corrected effective temperature for detailed work	≤29.5ºC (85.1°F)	≤25.5ºC (77.9°F)
(MIL-STD-1472 G)	Interior dry bulb temperature for detailed work	≥10.0ºC (50.0°F)	≥10.0ºC (50.0°F)
(MIL-STD-1472 G)	Temperature Difference between head and floor level of any person	≤ 5.5ºC (41.9°F)	≤3.0ºC (37.4°F)
(ACGIH, 1992)	Permissible heat exposure TLVs	See table in 5.2	See table in 5.2
	Ventilation		
(MIL-STD-1472 G)	Ventilation air flow (enclosure volume 4.25m^3 per person)	≥ 0.85 m^3 (30.0 ft^3) per person	≥ 0.85 m^3 (30.0 ft^3) per person
(MIL-STD-1472 G)	Ventilation air source	≥ Two third (2/3) of total air should be outdoor air	≥ Two third (2/3) of total air should be outdoor air
(MIL-STD-1472 G)	Ventilation air velocity	≤ 0.5 m/s (1.6 ft/s)	≤ 0.5 m/s (1.6 ft/s)
(MIL-STD-1472 G)	Ventilation air velocity where loose papers are used	≤ 0.33 m/s (1.1 ft/s)	≤ 0.33 m/s (1.1 ft/s)
(MIL-STD-1472 G)	Spot cooling air velocity	≤ 1.0 m/s (3.3 ft/s)	≤ 1.0 m/s (3.3 ft/s)
(MIL-STD-1472 G)	**Humidity**	30-70%	40-45%
Workplace Noise Exposure			
Source	**Considerations for noise level**	**Permissible limits**	**Preferred limits**
(ISO 11064-6, 2005)	Noise level in control rooms	45 dB	<45 dB

(ISO 11064-6, 2005)	Background minimum noise level for conversation privacy	30-35 dB	30-35 dB
(ISO 11064-6, 2005)	Audible alarm	Must be 10-15 dB above background sound level	10 dB above background sound level
(ISO 11064-6, 2005)	Mid frequency reverberation time	$\leq$0.75s	0.4s
	Noise exposures based on working hours	**Permissible limits (dB)**	**Preferred limits (dB)**
(OSHA 1910.95, 29 CFR; OSHA, 1996)	8 hours work shift per day	90	$\leq$90
(OSHA 1910.95, 29 CFR)	6 hours work shift per day	92	$\leq$92
(OSHA 1910.95, 29 CFR)	4 hours work shift per day	95	$\leq$95
(OSHA 1910.95, 29 CFR)	3 hours work shift per day	97	$\leq$97
(OSHA 1910.95, 29 CFR)	2 hours work shift per day	100	$\leq$100
(OSHA 1910.95, 29 CFR)	1.5 hours work shift per day	102	$\leq$102
(OSHA 1910.95, 29 CFR)	1 hours work shift per day	105	$\leq$105
(OSHA 1910.95, 29 CFR)	.05 hours work shift per day	110	$\leq$110
(OSHA 1910.95, 29 CFR)	0.25 hours or less work shift per day	115	$\leq$115
Ingress /Egress			
Source	**Dimensions of Egress**	**Minimum cm (in)**	**Preferred (unless otherwise specified) cm (in)**
(IBC-1010.1.1/1003.3.1)	Door/exit discharge height	203.2 cm (80.0) (1010.1.1) Door closers should not reduce door height to less than 198 cm (1003.3.1)	
(MIL-STD-1472G-5.11.2.3.4)	Door/exit discharge height	195.6 (77.0)	
(ADA Standards-404.2.3)	Door/exit discharge height	Door closers and stoppers must be at least 198 cm (78) above the surface of the floor	
(OSHA-29 CFR-1910.36(g)(2&4))	Door/exit discharge width	71.1 cm (28.0) (1910.36(g)(2)) Objects should not reduce the width to less than 71.1 cm (1910.36(g)(4))	
(IBC-1010.1.1)	Door/exit discharge width	81.3 cm (32.0) Horizontal projections are allowed between 86.5 cm (34.1) and 203 cm (79.9) above the floor with a total	

		projection of no more than 10.2 cm (4.0)	
(MIL-STD-1472G-5.11.2.3.4)	Door/exit discharge width	137.2 cm (54.0) (to accommodate two people exiting at the same time)	
(ADA Standards-404.2.3)	Door/exit discharge width	81.5 cm (32.1) No horizontal projections below 86.5 cm (34.1) above the floor surface and no horizontal projections exceeding 10 cm (3.9) between 86.5 cm (34.1) and 203 cm (79.9) about the floor surface (404.2.3)	
(OSHA-29 CFR-(1910.36(g)(1))	Exit access corridor/route height	230 cm (90.6) No projections less than 203.2 cm (80.0) above the surface of the floor	
(IBC-1003.2/1003.3.1)	Exit access corridor/route height	228.6 cm (90.0) (1003.2) No projections less than 203.2 cm (80.0) above the surface of the floor and no more than 50% of the ceiling area of the means of egress should be reduced in height by protrusions. (1003.3.1)	
(MIL-STD-1472G-5.7.6.5)	Exit access corridor/route height	No items should hang below 203.2 cm (80.0) above the surface of the floor	
(OSHA-29 CFR-1910.36(g)(2))	Exit access corridor/route width	71.1 cm (28.0)	
(IBC-1020.2)	Exit access corridor/route width	91.4 cm (36.0) with an occupant load less than 50	
(MIL-STD-1472G)	Exit access corridor/route width	See “Minimum Passageway Widths” (Figure 6)	
(ADA Standards-403.5.1)	Exit access corridor/route width	The clear width of a walking surface should be at least 91.5 cm (36.0) in width but may be reduced to 81.5 cm (32.1) for a maximum length of 61 cm (24.0)	

(IBC-1010.1.3)	Force to open door	Interior swinging door 22 N (4.9 lbf) 30 N (6.7 lbf) to set "other than interior doors" in motion 67 N (15.1 lbf) to cause "other than interior doors" to swing completely open	
(MIL-STD-1472G-5.7.6.2)	Force to open door	44 N (9.9 lbf) to 133 N (29.9 lbf) (emergency door)	
(ADA Standards-404.2.9)	Force to open door	Fire doors should have the minimum that is allowable by the "administrative authority"	
(ADA Standards, 2010-407.2.2.2)	Visual Sign Height	183.0 (72.0)	
(ADA Standards, 2010-703.4.1)	Tactile Sign Height	122.0 (48.0)	152.5 (60.0) (maximum)
(IBC, 2015-1008.2-1008.2.1)	Egress/exit illumination	10.76 lux	
(IBC, 2015-1006.3.1)	Occupant Load per Story		
	1-500 occupants	2 exits	
	501-1000 occupants	3 exits	
	More than 1000 occupants	4 exits	
(ADA Standards- Advisory 105.2.4 ICC/IBC)	Accessible Means of Egress	At least two accessible means of egress where two or more means of egress is required	
Walking Surfaces			
Source	**General Walking surfaces or floor**	**Minimum**	**Preferred**
(ADA Standards, 2010-302.1)	Surface quality	Firm, stable, and slip resistant	Firm, stable, and slip resistant
(ADA Standards, 2010-302.2)	Surface type	Clear floor or with mats or carpets	Clear floor or with mats or carpets
	Carpet pile thickness (if surface is covered with carpets)	≤1.3 cm (0.51) (measured to the carpet backing)	≤1.3 cm (0.51) (measured to the carpet backing)
(ADA Standards, Advisory 302.2)	Carpet padding type	Firm	Carpet paddings are generally not recommended
(ADA Standards, 302.3)	Small dimension of openings on floor	≤ 1.3 (0.51)	≤ 1.3 cm (0.51)
	Routes		

(ADA Standards Advisory 402.2)	Running slope ratio	≤1:20	≤1:20
(ADA Standards, 2010-403.3)	Cross slope	≤1:48	≤1:48
(ADA Standards- Advisory 402.2)	Slope of ramp run	≤1:12	≤1:12
(ADA Standards, 2010-403.5.1)	Clearance or clear width	>91.5 (36.0)	≥91.5 (36.0)
(ADA Standards, 2010-403.5.2)	Clear width at 180° turn	≥122.0 (48.0) (at the turn)	≥122 cm (48.0) (at the turn)
	Stairway Handrail/ Stair rail requirements		
(OSHA 1910.28, 29 CFR)	Stair width <111.76 cm (enclosed)	At least 1 handrail	At least 1 handrail
(OSHA 1910.28, 29 CFR)	Stair width <111.76 cm (One open side)	One stair rail system with handrail on open side.	One stair rail system with handrail on open side.
(OSHA 1910.28, 29 CFR)	Stair width <111.76 cm (two open sides)	One stair rail on each open side.	One stair rail on each open side.
(OSHA 1910.28, 29 CFR)	Stair width between 111.76 cm and 223.52cm (enclosed)	One handrail on each enclosed side	One handrail on each enclosed side
(OSHA 1910.28, 29 CFR)	Stair width between 111.76 cm and 223.52cm (one open side)	One Stair rail system with handrail on open side and one handrail on enclosed side.	One Stair rail system with handrail on open side and one handrail on enclosed side.
(OSHA 1910.28, 29 CFR)	Stair width between 111.76 cm and 223.52cm (two open sides)	One stair rail system with handrail on each open side.	One stair rail system with handrail on each open side.
(OSHA 1910.28, 29 CFR)	Stair width >223.52 cm (enclosed)	One handrail on each enclosed side and one intermediate handrail located in the middle of the stair	One handrail on each enclosed side and one intermediate handrail located in the middle of the stair
(OSHA 1910.28, 29 CFR)	Stair width >223.52 cm (one open side)	One stair rail system with handrail on open side, one handrail on enclosed side, and one intermediate handrail located in the middle of the stair.	One stair rail system with handrail on open side, one handrail on enclosed side, and one intermediate handrail located in the middle of the stair.
(OSHA 1910.28, 29 CFR)	Stair width >223.52 cm (two open sides)	One stair rail system with handrail on each open side and one intermediate handrail located in the middle of the stair.	One stair rail system with handrail on each open side and one intermediate handrail located in the middle of the stair.
(OSHA 1910.28, 29 CFR)	Stairway allowable height without handrail/ stair rail	Up to 121.9 cm (48.0)	Up to 121.9 cm (48.0)
	Office Occupancy		
	Area recommendations per person based on application	**Minimum recommendation**	**Preferred cm^2 (in^2)**

			cm² (in²)	
Panero and Zelnik, 1979, CCOHS, 2015		Two people can meet in an office with a table or desk between them.	152.0-183.0 x 228.0-230.0 (23.6-28.4 x 35.3-35.7)	152.0 x 228.0 (23.6 x 35.3)
(Panero and Zelnik, 1979, CCOHS, 2015)		A worker has a primary desk and a secondary surface such as a credenza.	152.0-183.0 x 152.0-213.0 (23.6-28.4 x 23.6-33.0)	152.0 x 152.0 (23.6 x 23.6)
(Panero and Zelnik, 1979, CCOHS, 2015)		Executive office: 3-4 people can meet around a desk.	267.0-330.0 x 244.0-313.0 (41.4-51.2 x 37.8-48.5)	267.0 x 244.0 (41.4 x 37.8)
(Panero and Zelnik, 1979, CCOHS, 2015)		A basic workstation such as a call center.	107.0-132.0 x 152.0-183.0 (16.6-20.5 x 23.6-28.4)	107.0 x 152.0 (16.6 x 23.6)

MINIMAL RECCOMENDATIONS IN LITERATURE				
Workplace HVAC System attributes				
Source	**Temperature**		**Permissible Range/ recommendations in literature**	**Preferred Range**
	Cold environment			
(ISO 11064-6,2005)		Operating temperature for sedentary task (in winter)	20-24ºC (68.0-75.2°F)	22°C (71.6°F)
(ACGIH, 2012)		Body protection in repeated cold weather exposure	Deep body temperature ≥36°C (96.8°F) should be maintained through body protection	Deep body temperature ≥36°C (96.8°F) should be maintained through body protection
(ACGIH, 2012)		Body protection for prolonged cold weather exposure	Whole body protection needed	Whole body protection needed
(ACGIH, 2012)		In working temperature below 4ºC	Insulating dry clothing needed to maintain core body temperature ≥36ºC (96.8°F)	Insulating dry clothing needed to maintain core body temperature ≥36ºC (96.8°F)
(ACGIH, 2012)		If high speed air reduces temperature of working environment in winter	Protective clothing should be more insulating	Protective clothing should be more insulating
(ACGIH, 2012)		Working temperature below 16ºC	Gloves should be provided	Gloves should be provided
(ACGIH, 2012)		Bare handed fine works in temperature below 16ºC	Hand warming systems should be applied if exposure time is greater than 10-20min	Hand warming systems should be applied if exposure time is greater than 10-20min
(ACGIH, 2012)		Working temperature below -7ºC	Clothes should not be wet at any time. Heated warming shelters should be available nearby	Clothes should not be wet at any time. Heated warming shelters

			should be available nearby
(ISO 11064-6,2005)	Vertical air temperature difference between head (110cm) and ankle level (10cm) of any seated person	≤ 3.0°C (37.4°F)	≤3.0°C (37.4°F)
(MIL-STD 1472G)	Mobile enclosure temperature requirement while occupied more than 3 hours in cold environment	Heating system is needed to maintain temperature above 20ºC (68.0°F)	Heating system is needed to maintain temperature above 20ºC (68.0°F)
	Hot environment		
(ISO 11064-6,2005)	Operating temperature for sedentary task (in summer)	23-26°C (73.4 -78.8°F)	24.5°C (76.1°F)
(ACGIH, 2012)	Body temperature requirements in hot weather	Core body temperature should be maintained within maximum 38ºC (100.4°F)	Core body temperature should be maintained within maximum 38ºC (100.4°F)
(ISO 11064-6,2005)	Vertical air temperature difference between head (110cm) and ankle level (10cm) of any seated person	≤ 3.0°C (37.4°F)	≤3.0°C (37.4°F)
(MIL-STD 1472G)	Vehicle cabin temperature requirement while occupied more than 30 minutes in temperature above 24ºC	Air conditioning with general HVAC requirements	Air conditioning with general HVAC requirements
	Ventilation		
ISO 11064-6,2005	Average air velocity	≤ 0.15 m/s (.49 ft/s)	≤ 0.15 m/s (.49 ft/s)
(ISO 11064-6,2005; MIL-STD 1472G)	**Humidity**	30-70%	40-45%

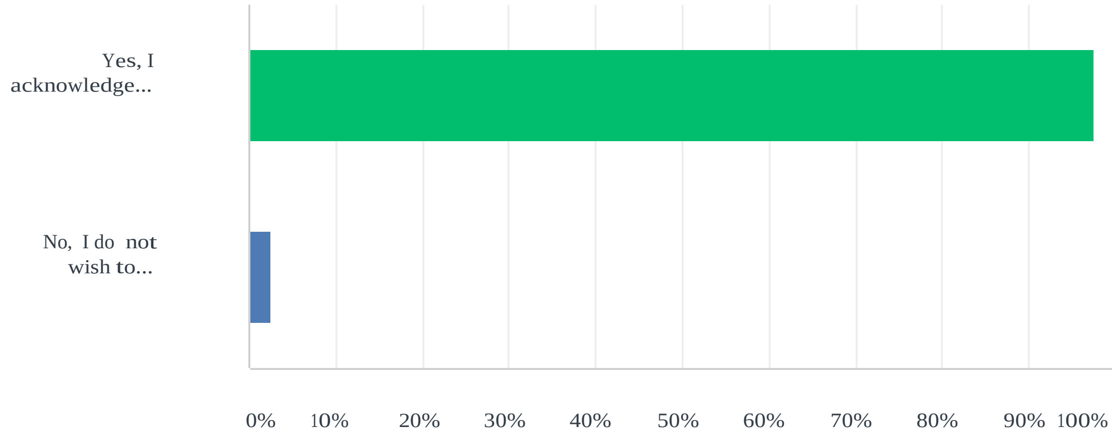
10. APPENDIX B: SURVEY DATA

The survey data collected is represented by three sets of questions and answers. The first set of data represents the entire sample population who completed the survey. The second set of data represents the portion of the sample population who identified with UAS Groups 1 and 2. The third set of data represents the portion of the sample population who identified with UAS Groups 3, 4, and 5.

10.1 SURVEY DATA: ENTIRE SAMPLE POPULATION

Q1 Would you like to proceed with the survey?

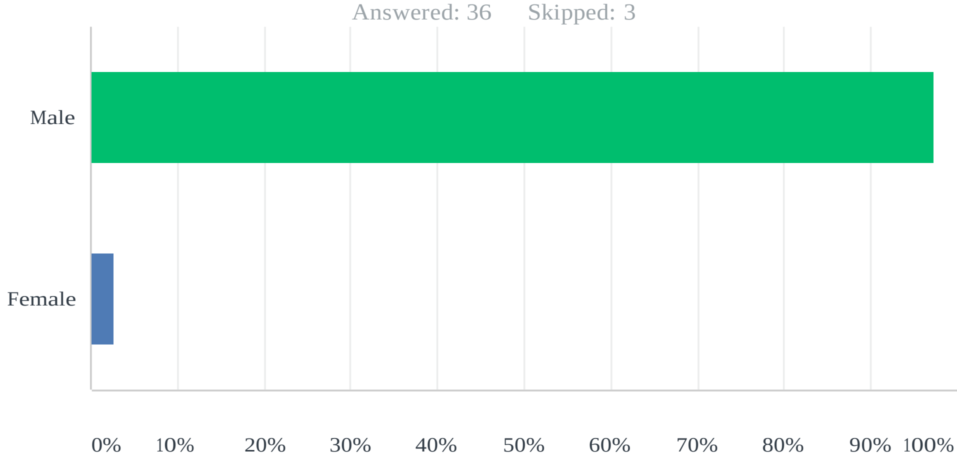
Answered: 39 Skipped: 0



Answer Choices	Responses	
Yes, I acknowledge that I have read the above information and would like to take the survey	97.44%	38
No, I do not wish to participate at this time	2.56%	1
Total		39

Q2 Gender:

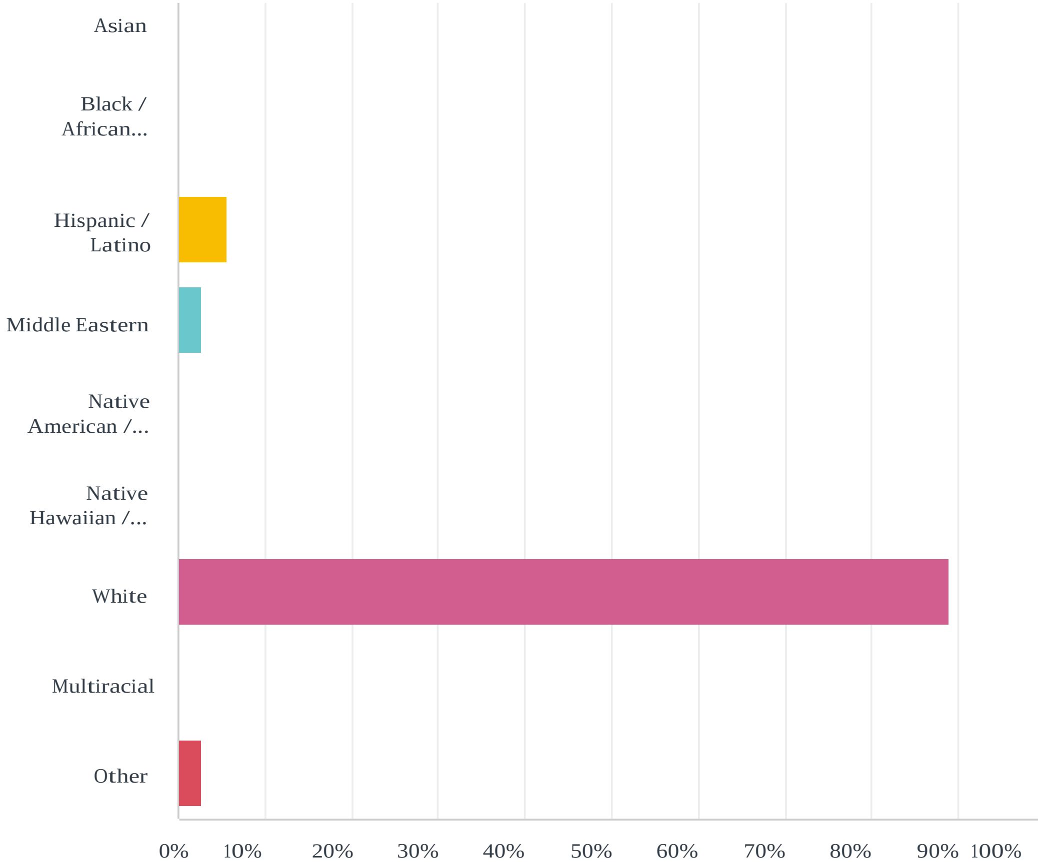
Answered: 36 Skipped: 3



Answer Choices	Responses	
Male	97.22%	35
Female	2.78%	1
Total		36

Q3 Ethnicity:

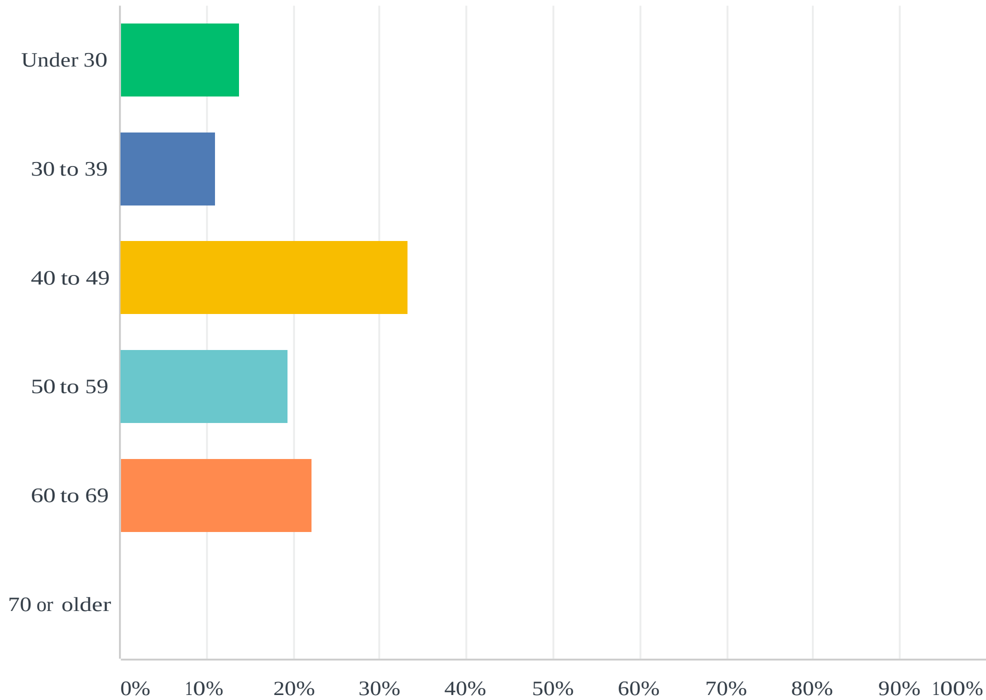
Answered: 36 Skipped: 3



Answer Choices	Responses	
Asian	0.00%	0
Black / African American	0.00%	0
Hispanic / Latino	5.56%	2
Middle Eastern	2.78%	1
Native American / Alaska Native	0.00%	0
Native Hawaiian / Other Pacific Islander	0.00%	0
White	88.89%	32
Multiracial	0.00%	0
Other	2.78%	1
Total		36

Q4 Age:

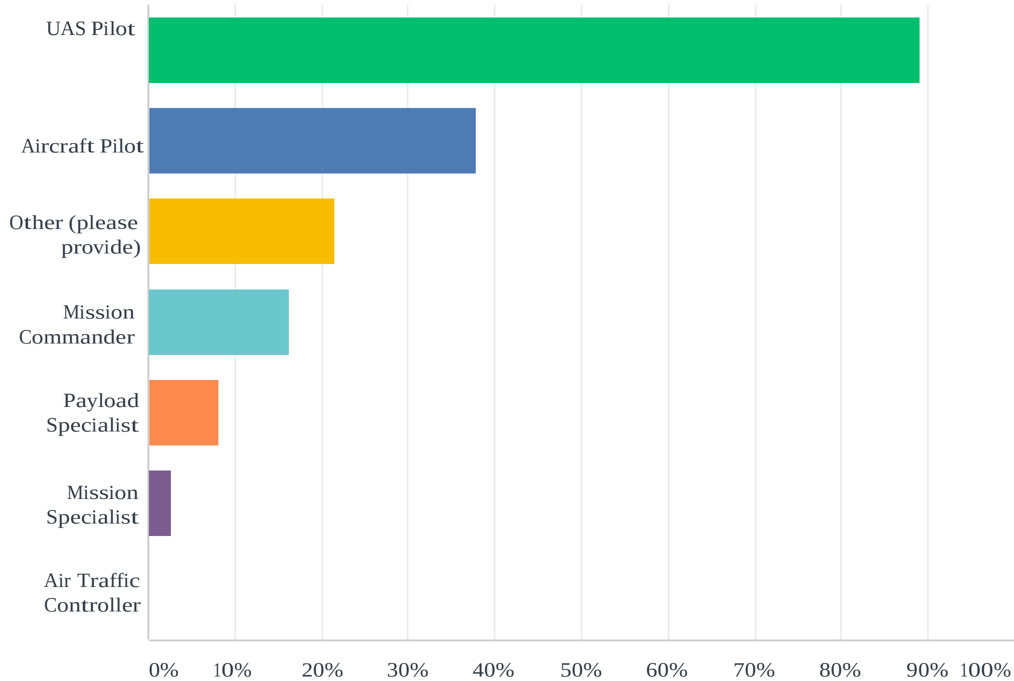
Answered: 36 Skipped: 3



Answer Choices	Responses	
Under 30	13.89%	5
30 to 39	11.11%	4
40 to 49	33.33%	12
50 to 59	19.44%	7
60 to 69	22.22%	8
70 or older	0.00%	0
Total		36

Q5 I am a (select all that apply):

Answered: 37 Skipped: 2

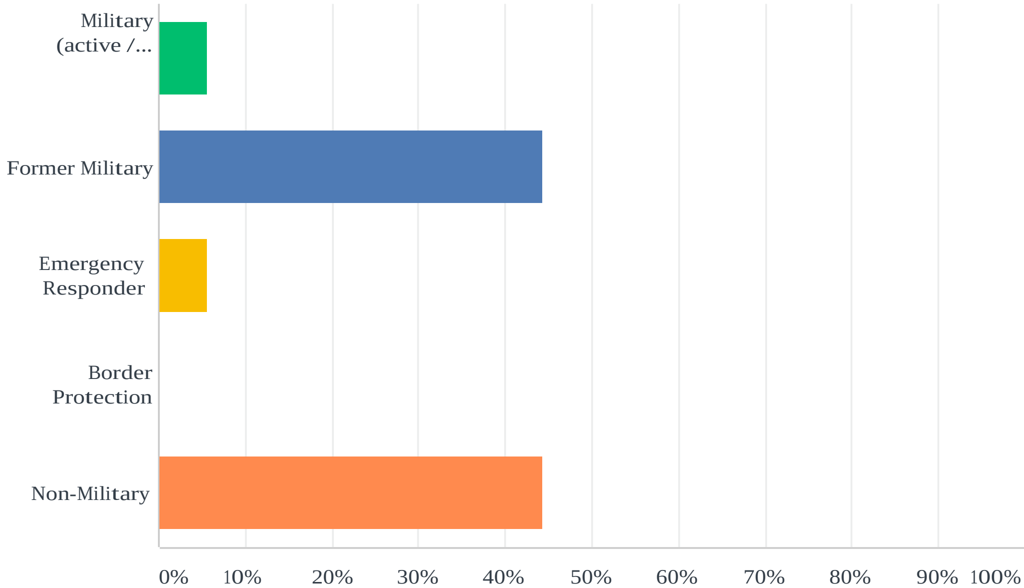


Answer Choices	Responses	
UAS Pilot	89.19%	33
Aircraft Pilot	37.84%	14
Other (please provide)	21.62%	8
Mission Commander	16.22%	6
Payload Specialist	8.11%	3
Mission Specialist	2.70%	1
Air Traffic Controller	0.00%	0
Total Respondents: 37		

#	Other (please provide)
1	Engineer
2	Interoperability Certification Testing of Army UAS
3	Flight Test
4	Aircraft Technician/ Student Pilot/ Industrial Engineering Student
5	Instructor and Evaluator in both UAS and Aircraft
6	UAS Mission Commander Instructor, UAS Test
7	Detective in Charge of Drone Operations
8	UAS instructor

Q6 I am currently:

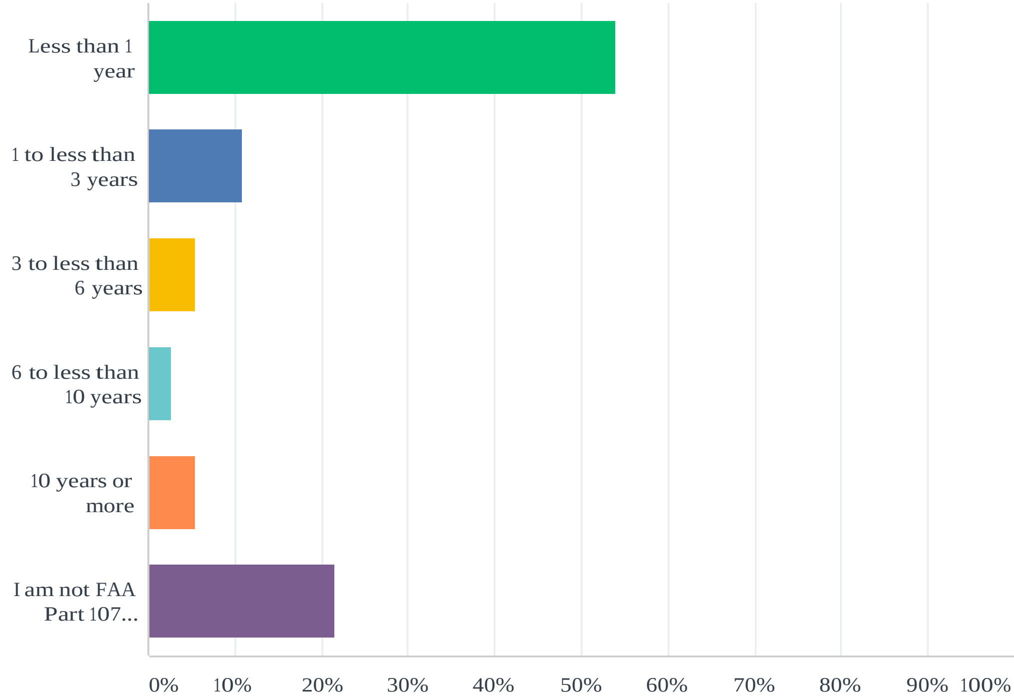
Answered: 36 Skipped: 3



Answer Choices	Responses	
Military (active / reserves)	5.56%	2
Former Military	44.44%	16
Emergency Responder	5.56%	2
Border Protection	0.00%	0
Non-Military	44.44%	16
Total		36

Q7 I have held a FAA Part 107 certification or DOD equivalent to fly Unmanned Aircraft Systems [UAS] and drones for:

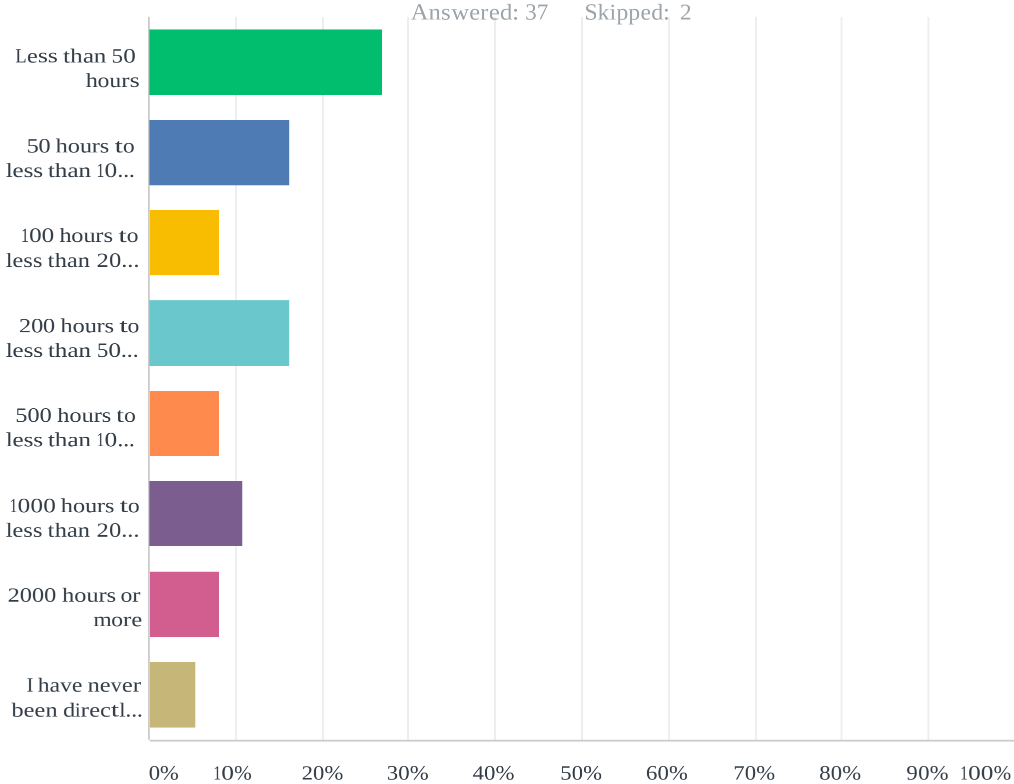
Answered: 37 Skipped: 2



Answer Choices	Responses	
Less than 1 year	54.05%	20
1 to less than 3 years	10.81%	4
3 to less than 6 years	5.41%	2
6 to less than 10 years	2.70%	1
10 years or more	5.41%	2
I am not FAA Part 107 certified	21.62%	8
Total		37

Q8 I have flown/controlled unmanned flight operations for:

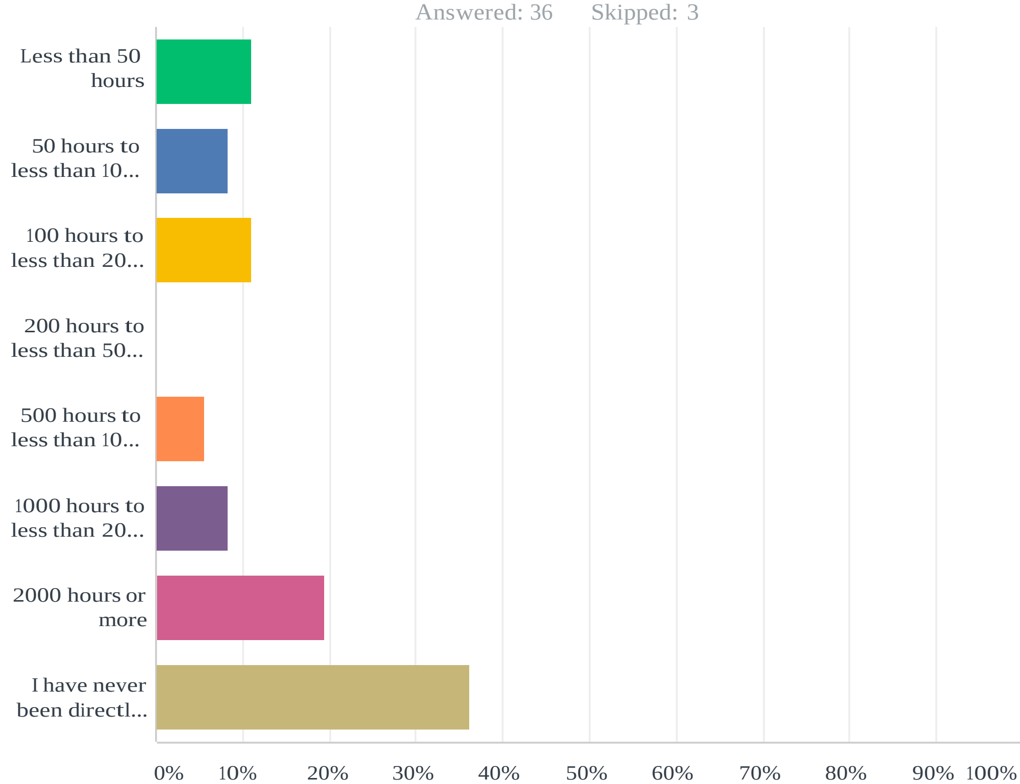
Answered: 37   Skipped: 2



Answer Choices	Responses	
Less than 50 hours	27.03%	10
50 hours to less than 100 hours	16.22%	6
100 hours to less than 200 hours	8.11%	3
200 hours to less than 500 hours	16.22%	6
500 hours to less than 1000 hours	8.11%	3
1000 hours to less than 2000 hours	10.81%	4
2000 hours or more	8.11%	3
I have never been directly involved with unmanned flight operations	5.41%	2
Total		37

Q9 I have flown/controlled manned flight operations for:

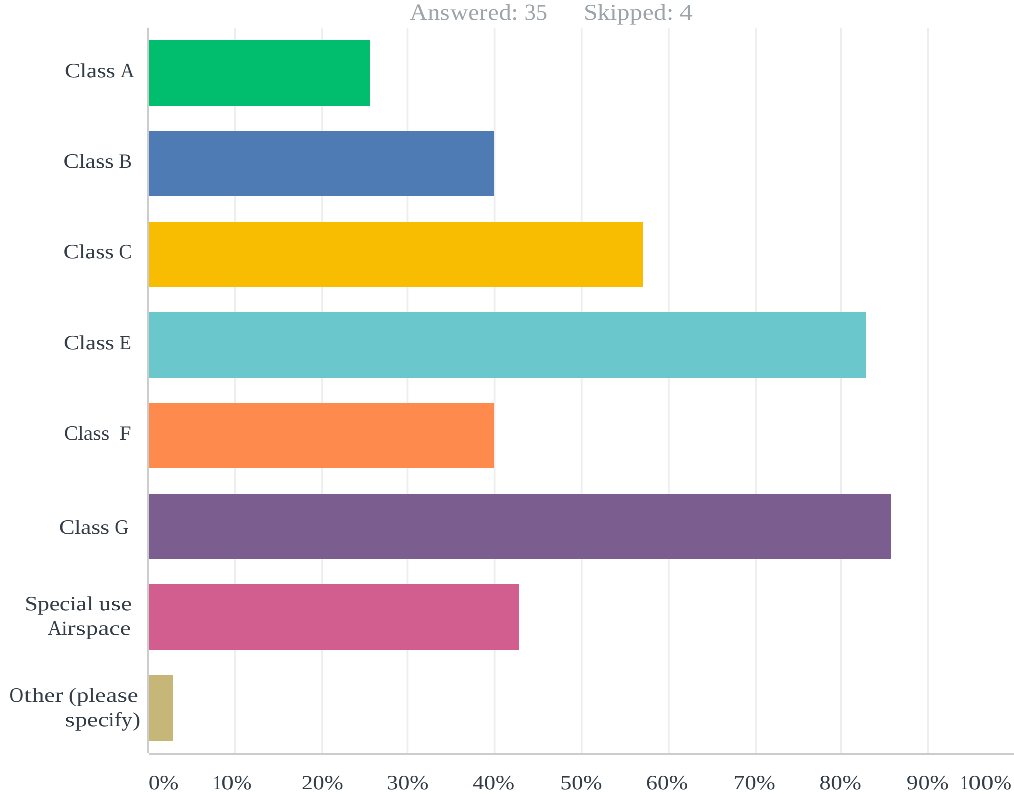
Answered: 36 Skipped: 3



Answer Choices	Responses	
Less than 50 hours	11.11%	4
50 hours to less than 100 hours	8.33%	3
100 hours to less than 200 hours	11.11%	4
200 hours to less than 500 hours	0.00%	0
500 hours to less than 1000 hours	5.56%	2
1000 hours to less than 2000 hours	8.33%	3
2000 hours or more	19.44%	7
I have never been directly involved with manned flight operations	36.11%	13
Total		36

Q10 What class(es) of airspace is your experience in? (select all that apply)

Answered: 35 Skipped: 4

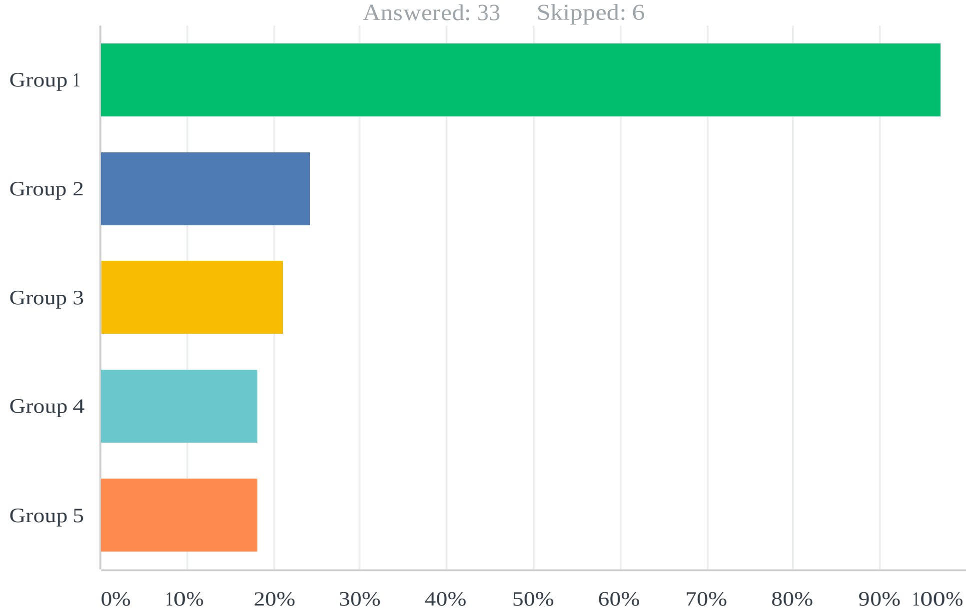


Answer Choices	Responses	
Class A	25.71%	9
Class B	40.00%	14
Class C	57.14%	20
Class E	82.86%	29
Class F	40.00%	14
Class G	85.71%	30
Special use Airspace	42.86%	15
Other (please specify)	2.86%	1
Total Respondents: 35		

#	Other (please specify)
1	Class D and Military Restricted Airspace

Q11 What type(s) of UAS based on the categories described below do you currently or have previously controlled (select all that apply)?

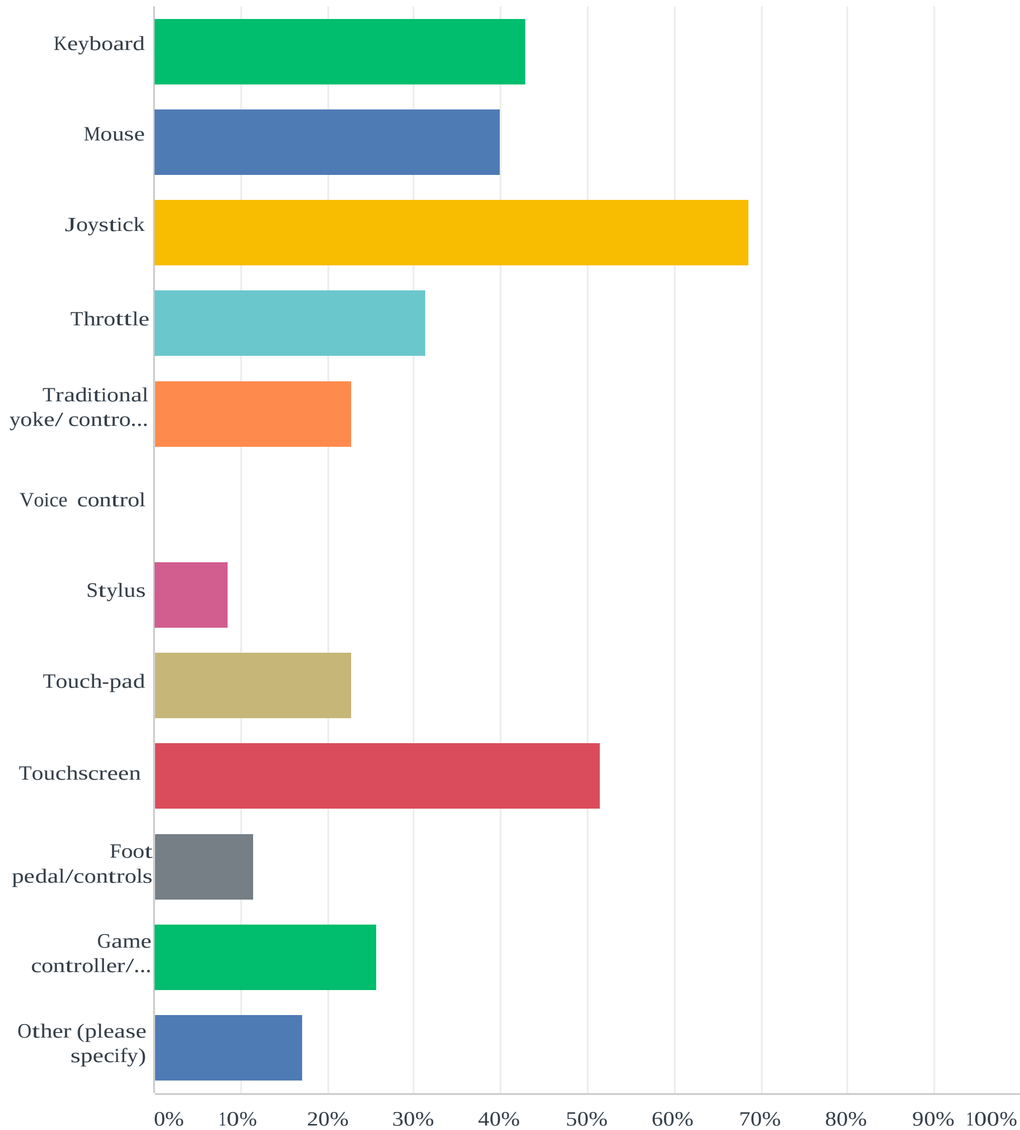
Answered: 33   Skipped: 6



Answer Choices	Responses	
Group 1	96.97%	32
Group 2	24.24%	8
Group 3	21.21%	7
Group 4	18.18%	6
Group 5	18.18%	6
Total Respondents: 33		

Q12 What controls do you use in ground control stations to control UASs? (select all that apply)

Answered: 35 Skipped: 4



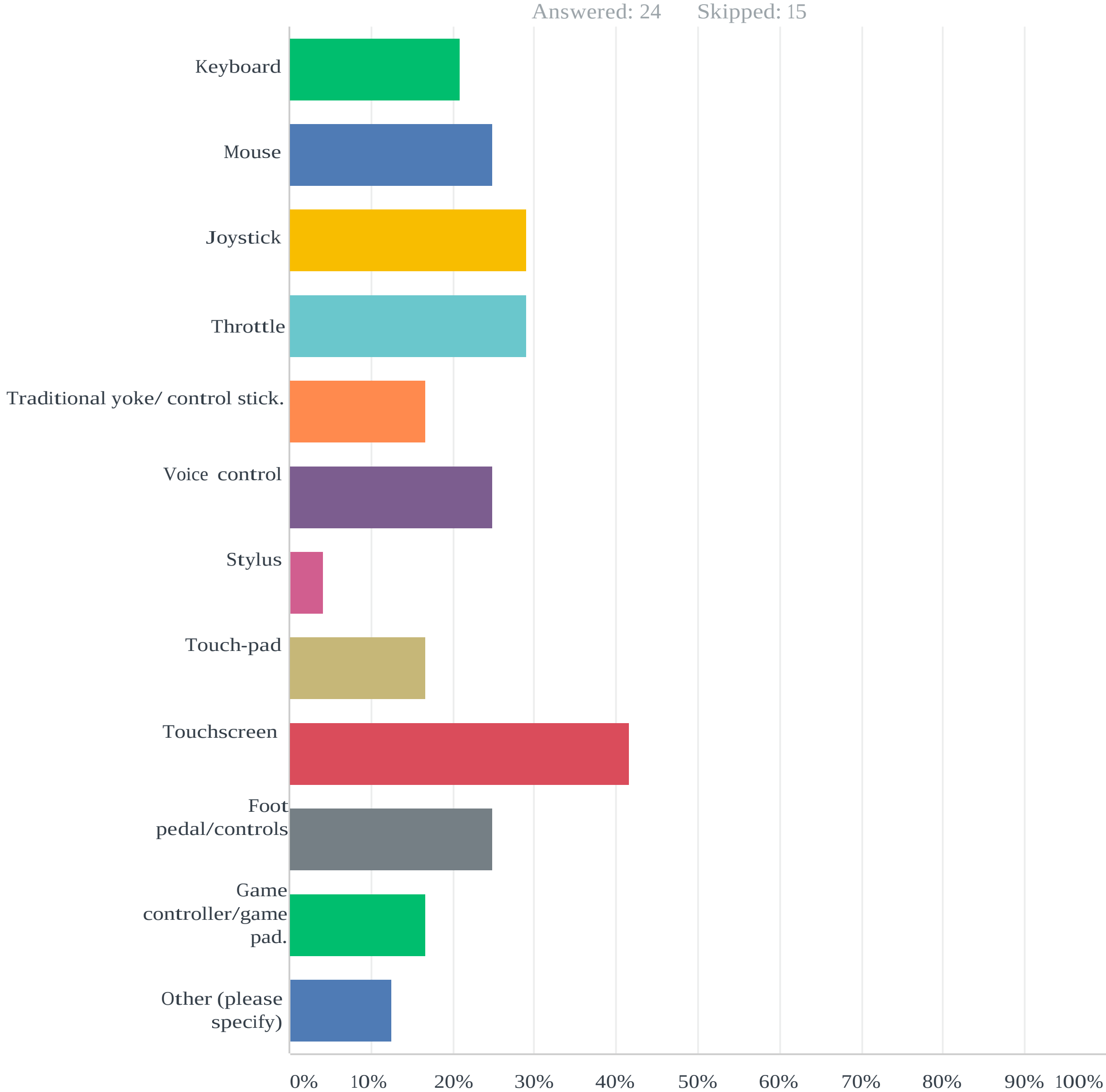
Answer Choices	Responses	
Keyboard	42.86%	15
Mouse	40.00%	14
Joystick	68.57%	24
Throttle	31.43%	11
Traditional yoke/ control stick	22.86%	8
Voice control	0.00%	0
Stylus	8.57%	3
Touch-pad	22.86%	8

Touchscreen	51.43%	18
Foot pedal/controls	11.43%	4
Game controller/ Game pad	25.71%	9
Other (please specify)	17.14%	6
Total Respondents: 35		

#	Other (please specify)
1	Mode 2 RC controller
2	Standard Mode 2 Remote Controller
3	Futaba 9c
4	Transmitter
5	RC type control box (often used on early Groups 1-2)
6	Head tracking

Q13 What controls would you recommend to add to control stations to help make the task easier? (select all that apply)

Answered: 24 Skipped: 15



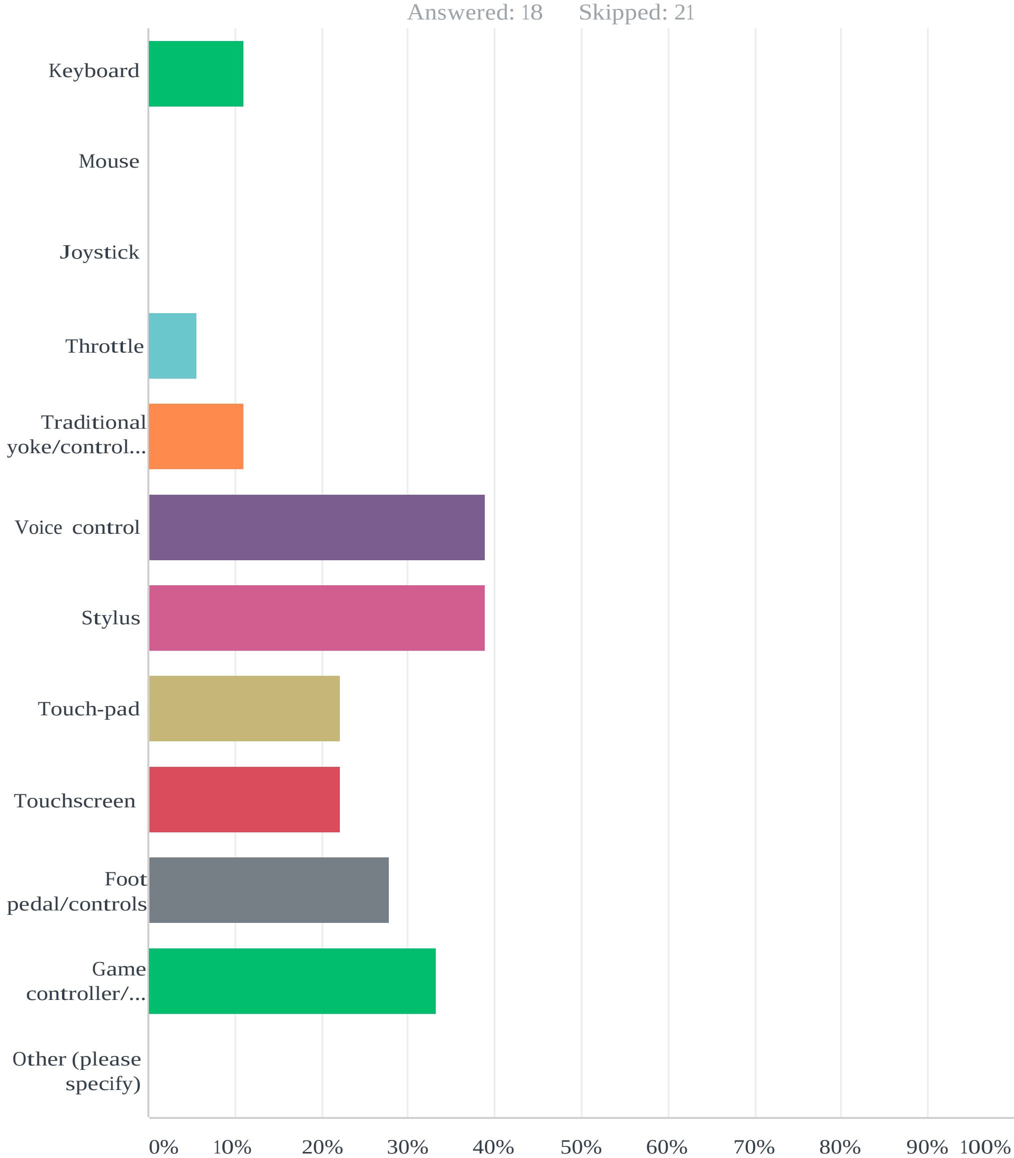
Answer Choices	Responses	
Keyboard	20.83%	5
Mouse	25.00%	6
Joystick	29.17%	7
Throttle	29.17%	7
Traditional yoke/ control stick	16.67%	4
Voice control	25.00%	6
Stylus	4.17%	1
Touch-pad	16.67%	4

Touchscreen	41.67%	10
Foot pedal/controls	25.00%	6
Game controller/ Game pad	16.67%	4
Other (please specify)	12.50%	3
Total Respondents: 24		

#	Other (please specify)
1	Tactile feedback system, AV headset
2	Hall Effect 3 Axis for precision and reliability
3	Head tracking

Q14 What controls would you recommend to remove from stations to help make the task easier? (select all that apply)

Answered: 18 Skipped: 21



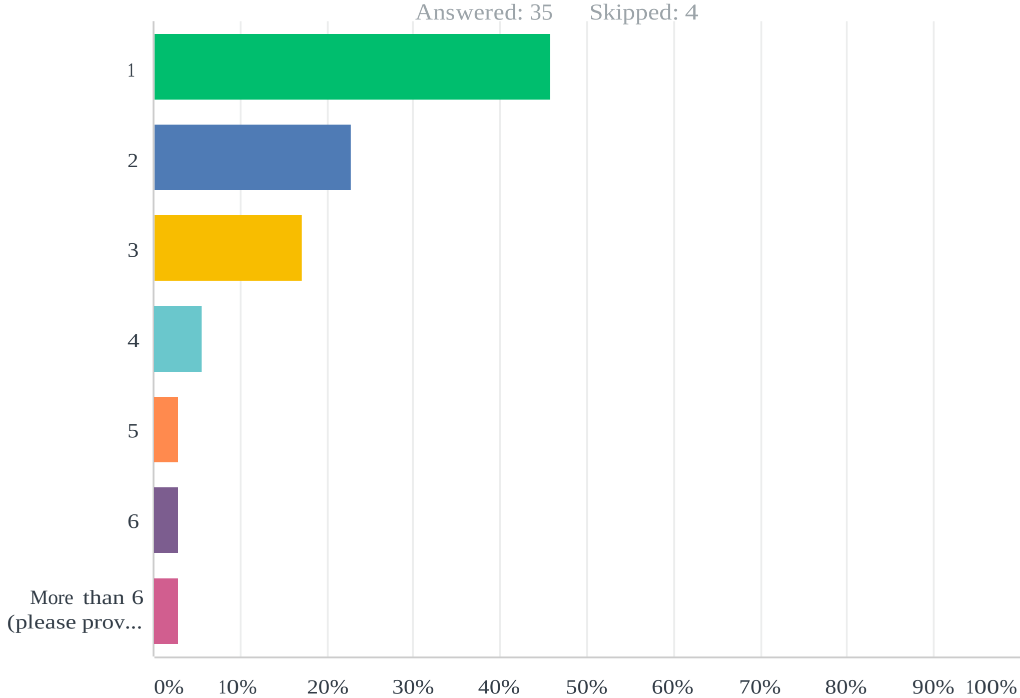
Answer Choices	Responses	
Keyboard	11.11%	2
Mouse	0.00%	0
Joystick	0.00%	0
Throttle	5.56%	1
Traditional yoke/control stick	11.11%	2

Voice control	38.89%	7
Stylus	38.89%	7
Touch-pad	22.22%	4
Touchscreen	22.22%	4
Foot pedal/controls	27.78%	5
Game controller/ Game pad	33.33%	6
Other (please specify)	0.00%	0
Total Respondents: 18		

#	Other (please specify)
	There are no responses.

Q15 How many displays are most commonly available in control stations that you use (have used)?

Answered: 35   Skipped: 4

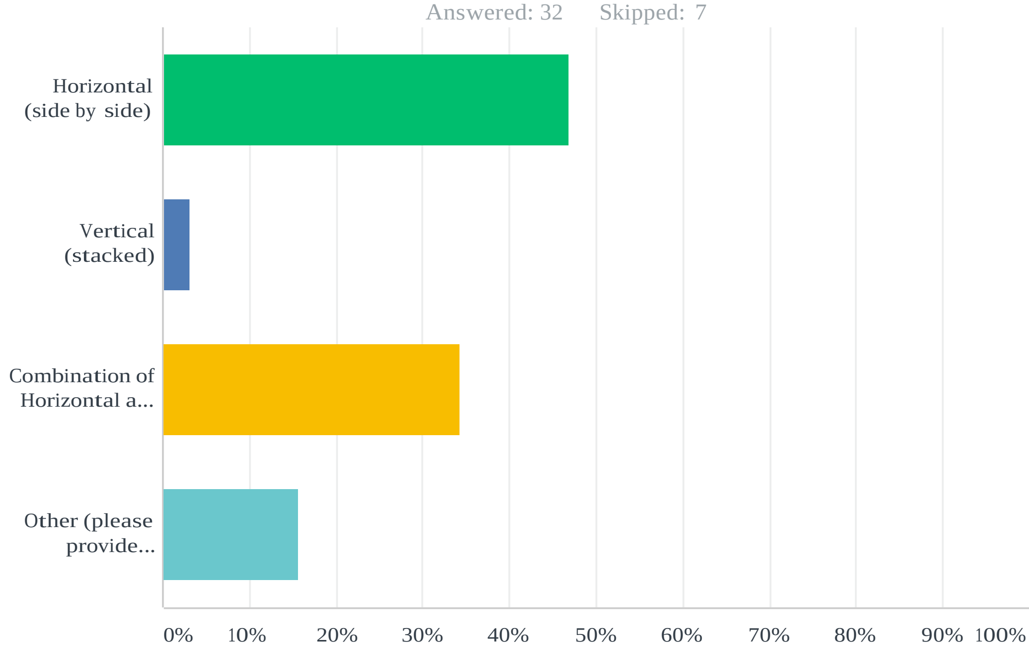


Answer Choices	Responses	
1	45.71%	16
2	22.86%	8
3	17.14%	6
4	5.71%	2
5	2.86%	1
6	2.86%	1
More than 6 (please provide number)	2.86%	1
Total		35

#	More than 6 (please provide number)
1	7

Q16 How are the displays oriented?

Answered: 32 Skipped: 7

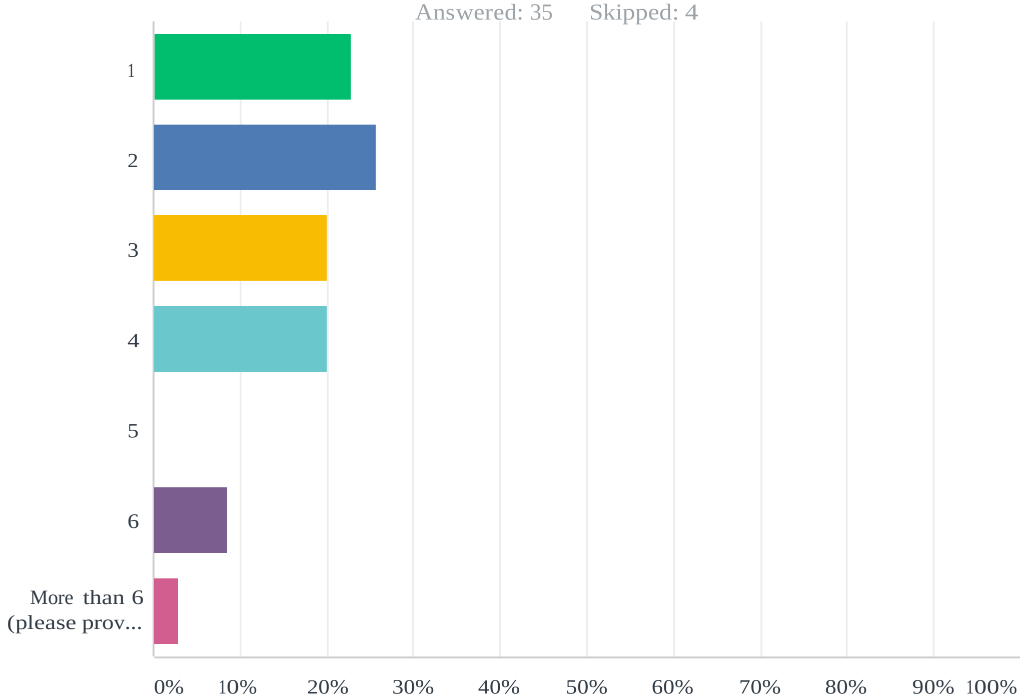


Answer Choices	Responses	
Horizontal (side by side)	46.88%	15
Vertical (stacked)	3.13%	1
Combination of Horizontal and Vertical	34.38%	11
Other (please provide description)	15.63%	5
Total		32

#	Other (please provide description)
1	No standard layout on display - Universal Ground Control System (UGCS) only has 1 screen that supports many "windows"
2	1 display
3	presently using one
4	Various based on location and need, also googles
5	Single display

Q17 How many displays are you comfortable using to control a UAS?

Answered: 35 Skipped: 4

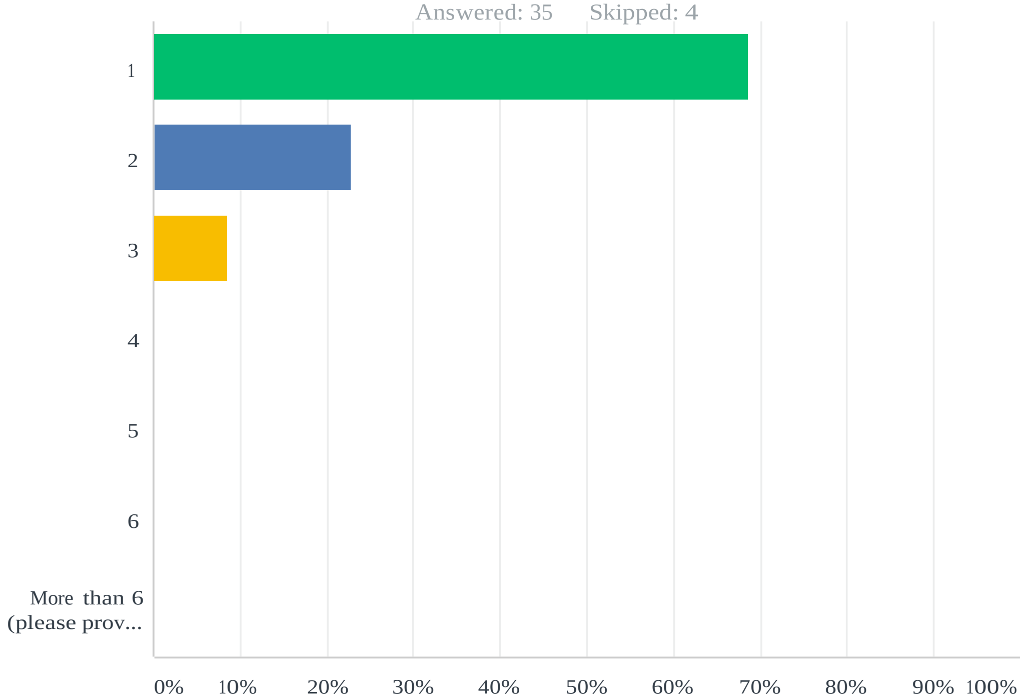


Answer Choices	Responses	
1	22.86%	8
2	25.71%	9
3	20.00%	7
4	20.00%	7
5	0.00%	0
6	8.57%	3
More than 6 (please provide number)	2.86%	1
Total		35

#	More than 6 (please provide number)
1	7

Q18 What is the minimum number of control station displays needed (for flight and performance data) to pilot a UAS?

Answered: 35 Skipped: 4



Answer Choices	Responses	
1	68.57%	24
2	22.86%	8
3	8.57%	3
4	0.00%	0
5	0.00%	0
6	0.00%	0
More than 6 (please provide number)	0.00%	0
Total		35

#	More than 6 (please provide number)
	There are no responses.

Q19 To what extent do you agree with the following statement: My control station mimics the layout of a cockpit.

Answered: 33 Skipped: 6

	Strongly disagree	Disagree	Undecided	Agree	Strongly agree	Total	Weighted Average
(no label)	36.36% 12	39.39% 13	9.09% 3	12.12% 4	3.03% 1	33	0.00

Q20 On average what percentage of time per day do you sit while piloting in a control station?

Answered: 34 Skipped: 5

	Never	Seldom	Sometimes	Often	Almost Always	Total	Weighted Average
(no label)	29.41% 10	29.41% 10	17.65% 6	5.88% 2	17.65% 6	34	0.00

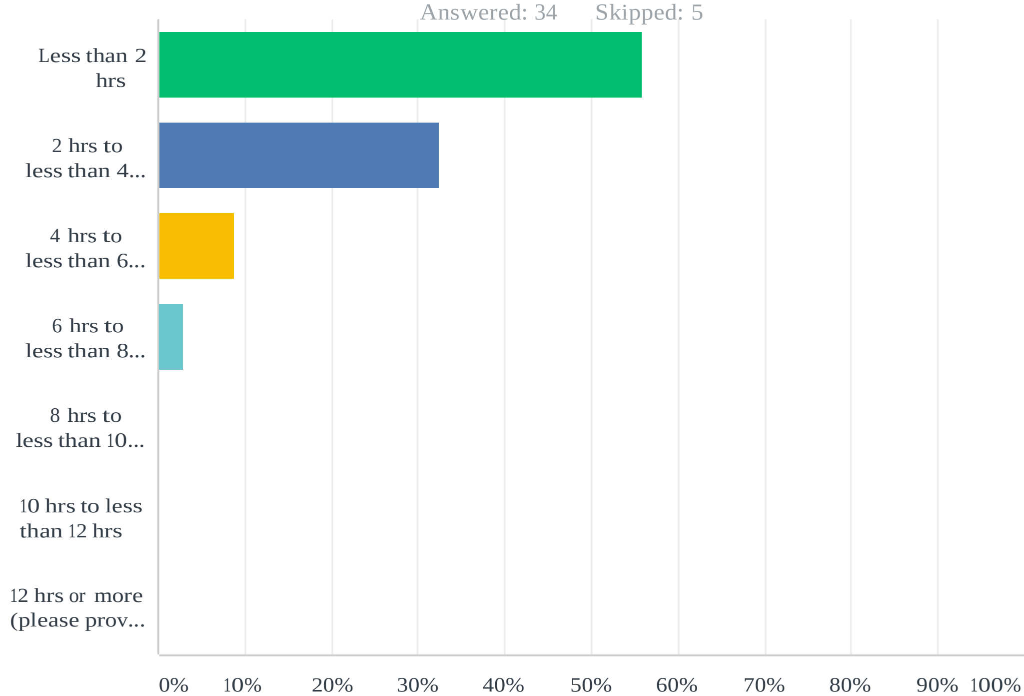
Q21 Using the scale below rate your level of comfort when using UAS control station.

Answered: 34 Skipped: 5

	Very Uncomfortable	Uncomfortable	Neither Uncomfortable nor Comfortable	Comfortable	Very Comfortable	Total	Weighted Average
(no label)	2.94% 1	14.71% 5	14.71% 5	47.06% 16	20.59% 7	34	0.00

Q22 How much time do you spend a day piloting in a control station?

Answered: 34 Skipped: 5

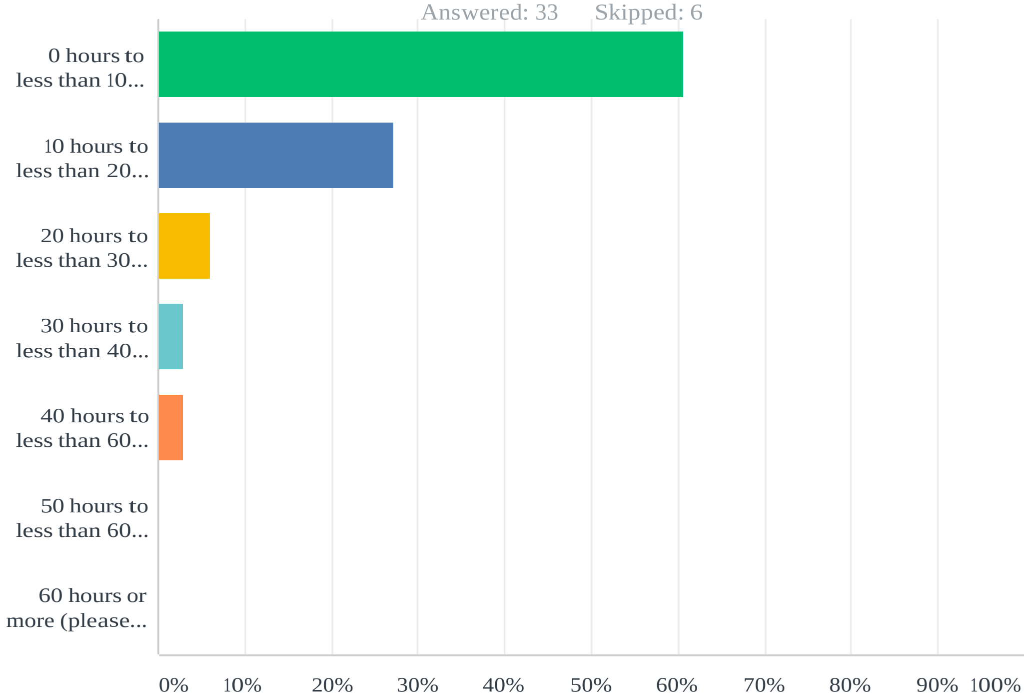


Answer Choices	Responses	
Less than 2 hours	55.88%	19
2 hours to less than 4 hours	32.35%	11
4 hours to less than 6 hours	8.82%	3
6 hours to less than 8 hours	2.94%	1
8 hours to less than 10 hours	0.00%	0
10 hours to less than 12 hours	0.00%	0
12 hours or more (please provide number)	0.00%	0
Total		34

#	12 hours or more (please provide number)
	There are no responses.

Q23 How much time do you spend a week piloting in a control station?

Answered: 33 Skipped: 6

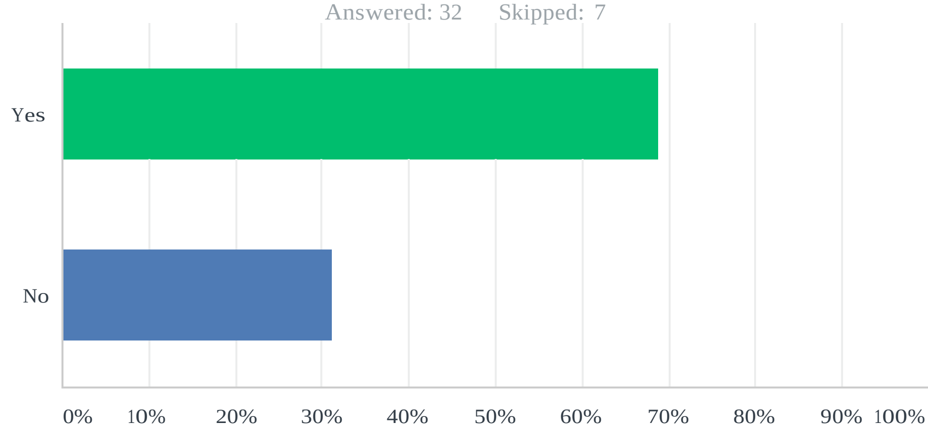


Answer Choices	Responses	
0 hours to less than 10 hours	60.61%	20
10 hours to less than 20 hours	27.27%	9
20 hours to less than 30 hours	6.06%	2
30 hours to less than 40 hours	3.03%	1
40 hours to less than 60 hours	3.03%	1
50 hours to less than 60 hours	0.00%	0
60 hours or more (please provide number)	0.00%	0
Total		33

#	60 hours or more (please provide number)
	There are no responses.

Q24 Are other people frequently in or near the control station while you are piloting UAS in a control station?

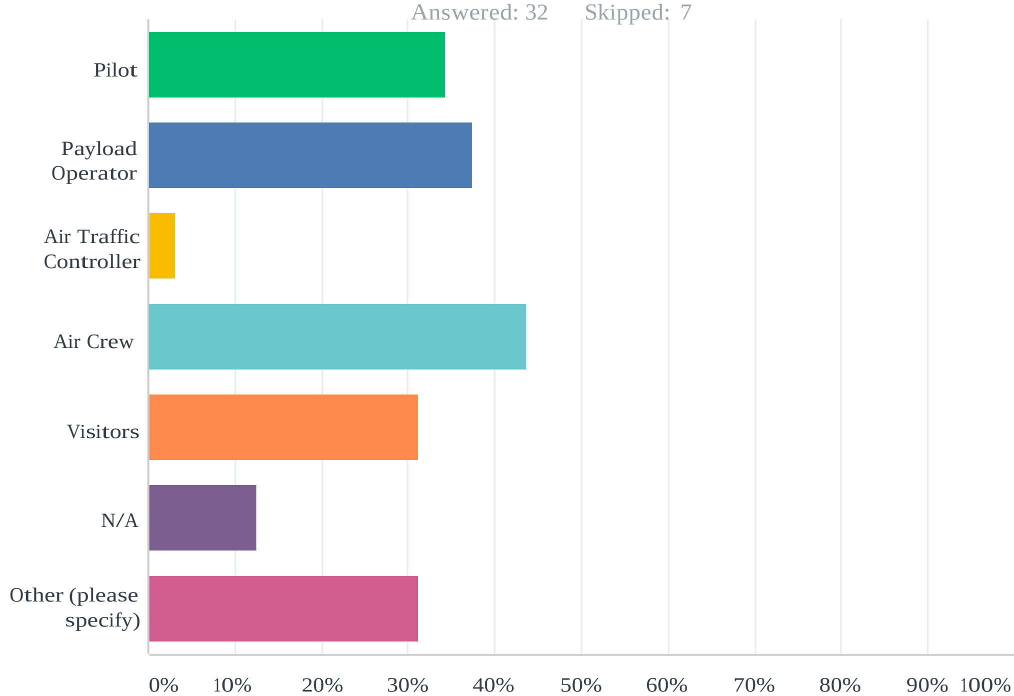
Answered: 32 Skipped: 7



Answer Choices	Responses	
Yes	68.75%	22
No	31.25%	10
Total		32

Q25 If there are other people in or near the control station while you are piloting a UAS, what is their role?

Answered: 32 Skipped: 7

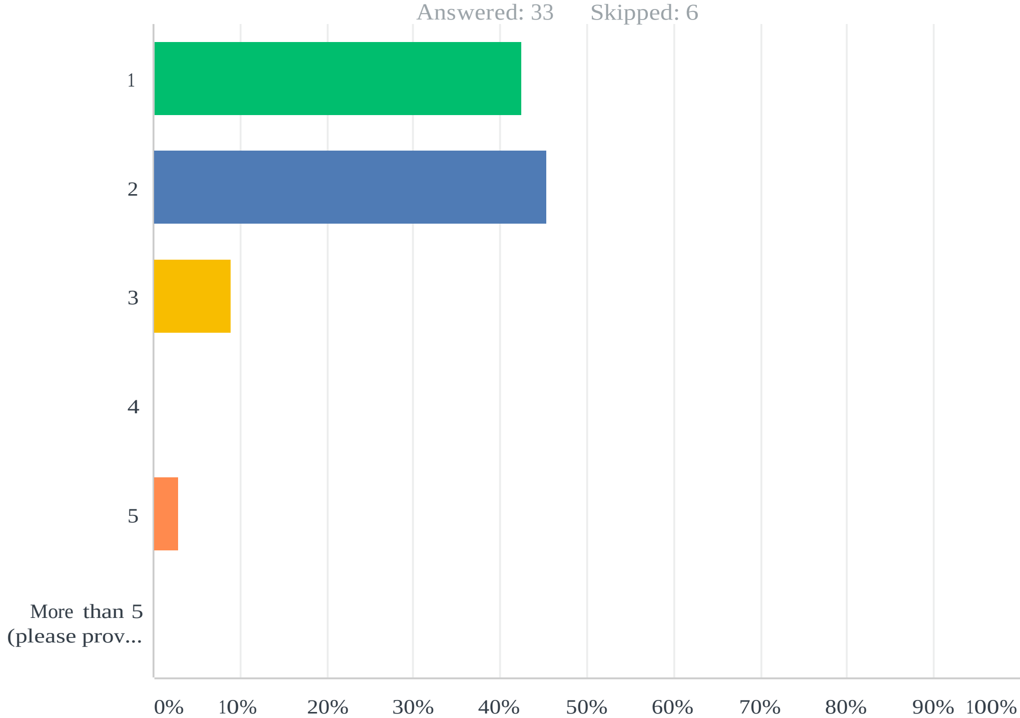


Answer Choices	Responses	
Pilot	34.38%	11
Payload Operator	37.50%	12
Air Traffic Controller	3.13%	1
Air Crew	43.75%	14
Visitors	31.25%	10
N/A	12.50%	4
Other (please specify)	31.25%	10
Total Respondents: 32		

#	Other (please specify)
1	scientific team members, support engineers
2	Observer
3	Intelligence personnel
4	Spotter
5	Driver and/or visual observer
6	Control Station Maintainers (Groups 3, 4, 5), when needed.
7	visual observer
8	Visual Observer
9	Visual Observer
10	Visual Observer

Q26 How many people are usually working in the control station at any given time?

Answered: 33 Skipped: 6

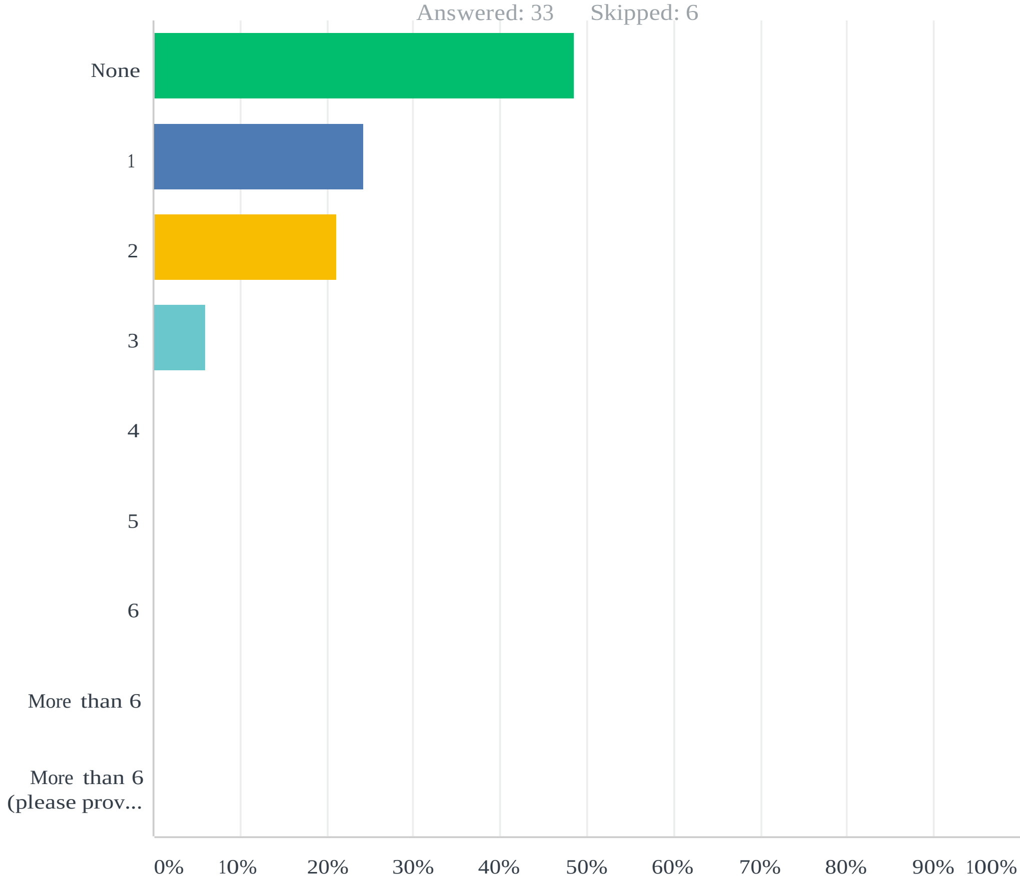


Answer Choices	Responses	
1	42.42%	14
2	45.45%	15
3	9.09%	3
4	0.00%	0
5	3.03%	1
More than 5 (please provide number)	0.00%	0
Total		33

#	More than 5 (please provide number)
	There are no responses.

Q27 How many monitors are shared by multiple people? (e.g. common navigation screen)

Answered: 33 Skipped: 6

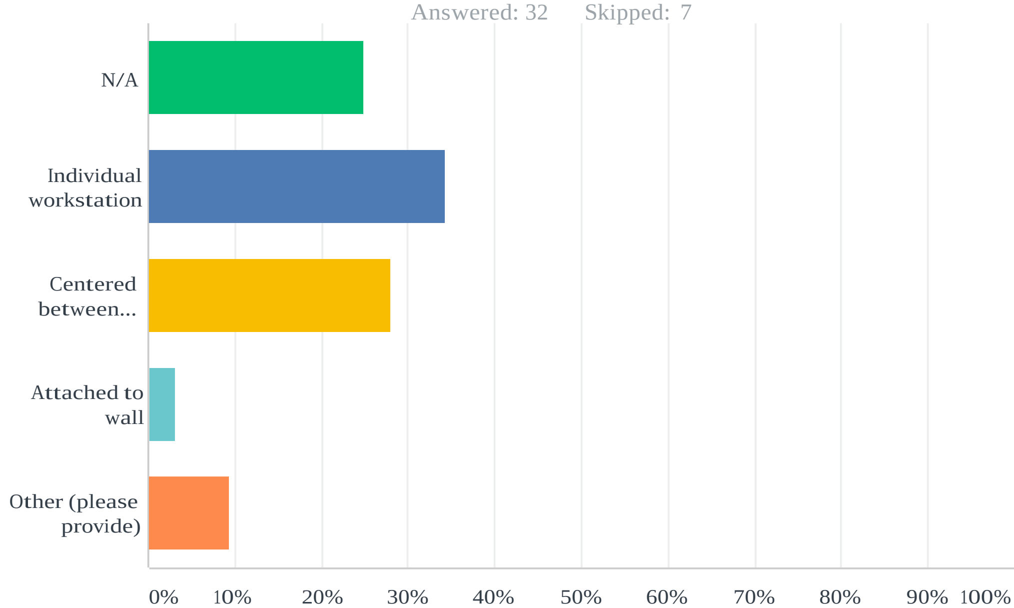


Answer Choices	Responses	
None	48.48%	16
1	24.24%	8
2	21.21%	7
3	6.06%	2
4	0.00%	0
5	0.00%	0
6	0.00%	0
More than 6	0.00%	0
More than 6 (please provide number)	0.00%	0
Total		33

#	More than 6 (please provide number)
	There are no responses.

Q28 Where are the most commonly shared monitors positioned?

Answered: 32 Skipped: 7

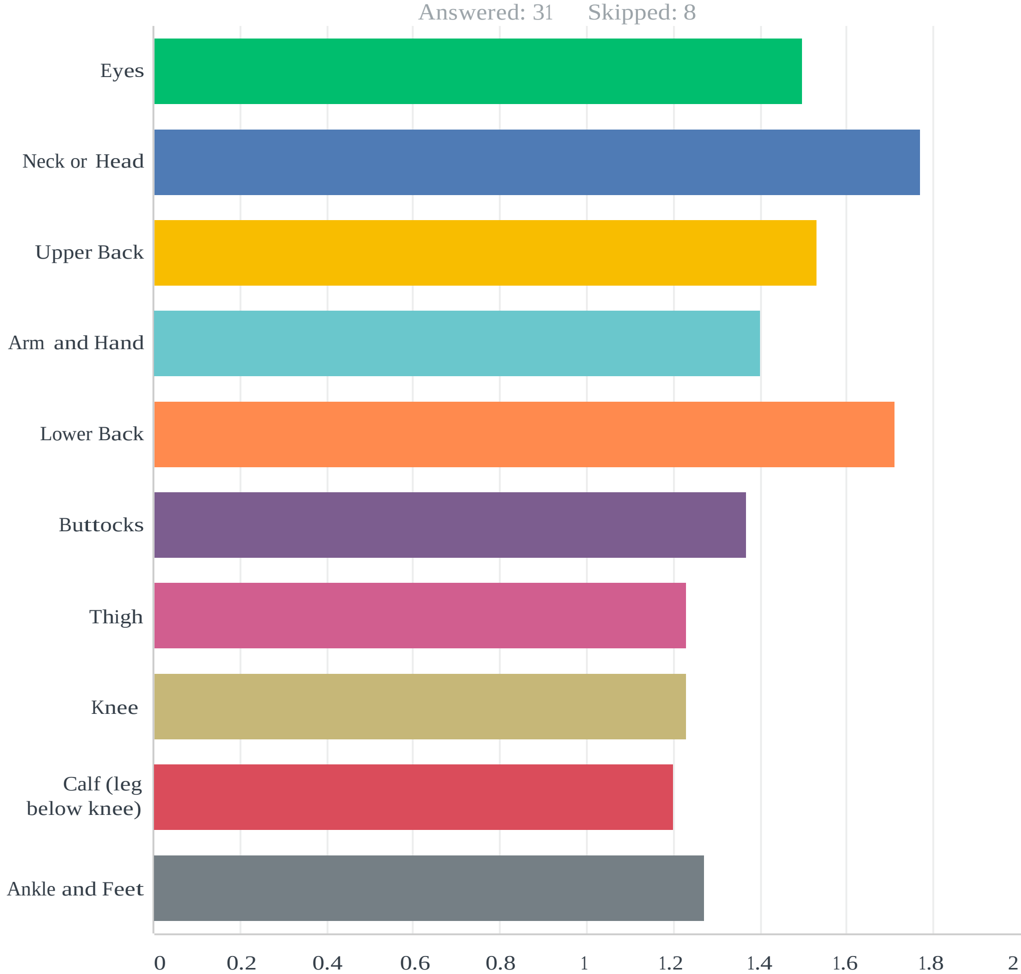


Answer Choices	Responses	
N/A	25.00%	8
Individual workstation	34.38%	11
Centered between crew-members	28.13%	9
Attached to wall	3.13%	1
Other (please provide)	9.38%	3
Total		32

#	Other (please provide)
1	set aside from control station
2	Head mounted goggles
3	Attached to control surface

Q29 Do you experience any discomfort or fatigue while piloting from your workstation? If so, please mark the discomfort map below. The human body is split into sections and discomfort levels can be expressed for each section by selecting a number representative of the level of discomfort. Greater number values are associated with more discomfort.

Answered: 31 Skipped: 8

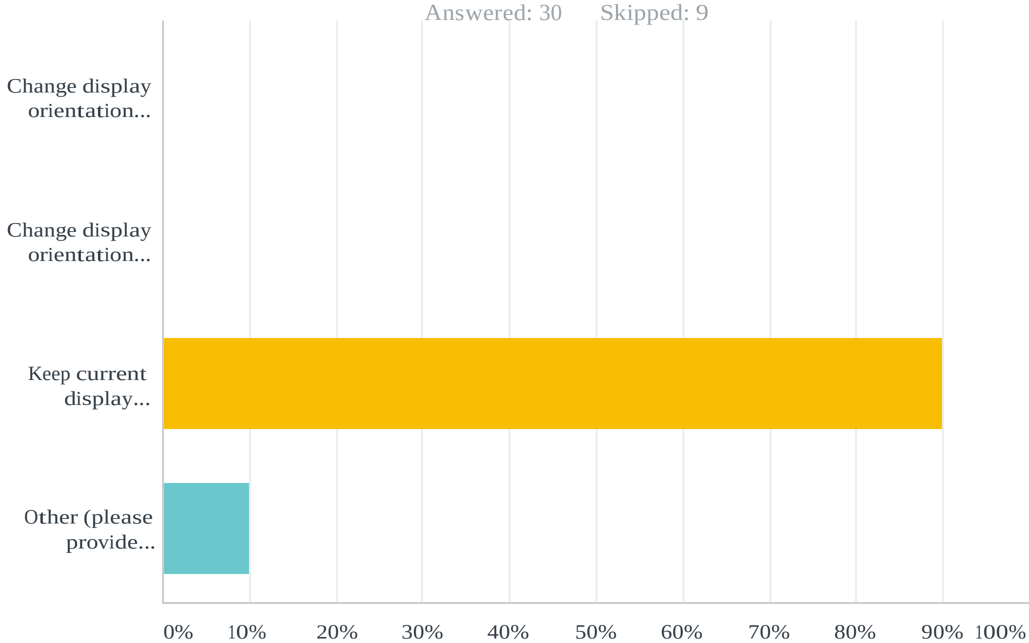


	1 - No Discomfort	2 - Slight Discomfort	3 - Moderate Discomfort	4 - Severe Discomfort	5 - Extreme Discomfort	Total	Weighted Average
Eyes	60.00% 18	30.00% 9	10.00% 3	0.00% 0	0.00% 0	30	1.50
Neck or Head	46.67% 14	30.00% 9	23.33% 7	0.00% 0	0.00% 0	30	1.77
Upper Back	63.33% 19	20.00% 6	16.67% 5	0.00% 0	0.00% 0	30	1.53
Arm and Hand	66.67% 20	26.67% 8	6.67% 2	0.00% 0	0.00% 0	30	1.40
Lower Back	51.61% 16	29.03% 9	16.13% 5	3.23% 1	0.00% 0	31	1.71

Buttocks	70.00% 21	23.33% 7	6.67% 2	0.00% 0	0.00% 0	30	1.37
Thigh	80.00% 24	16.67% 5	3.33% 1	0.00% 0	0.00% 0	30	1.23
Knee	83.33% 25	10.00% 3	6.67% 2	0.00% 0	0.00% 0	30	1.23
Calf (leg below knee)	83.33% 25	13.33% 4	3.33% 1	0.00% 0	0.00% 0	30	1.20
Ankle and Feet	80.00% 24	13.33% 4	6.67% 2	0.00% 0	0.00% 0	30	1.27

Q30 If you could change the display orientation of the work station, how would you change it?

Answered: 30 Skipped: 9

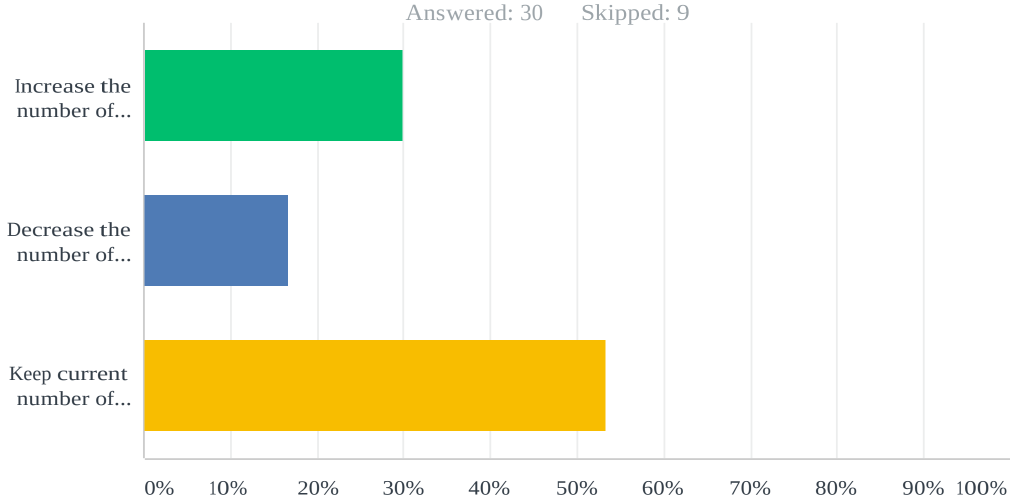


Answer Choices	Responses	
Change display orientation from horizontal (side by side) to vertical (stacked)	0.00%	0
Change display orientation from vertical (stacked) to horizontal (side by side)	0.00%	0
Keep current display orientation	90.00%	27
Other (please provide description)	10.00%	3
Total		30

#	Other (please provide description)
1	As close to a manned aviation glass cockpit as possible
2	Increase from 1 screen to multiple for more display "room"
3	Depends on the situation. I prefer a vertical, with the vision system at eye level, and the moving map displayed below. I also prefer HUD-style information

Q31 If you could change the number of displays of your workstation, how would you change it?

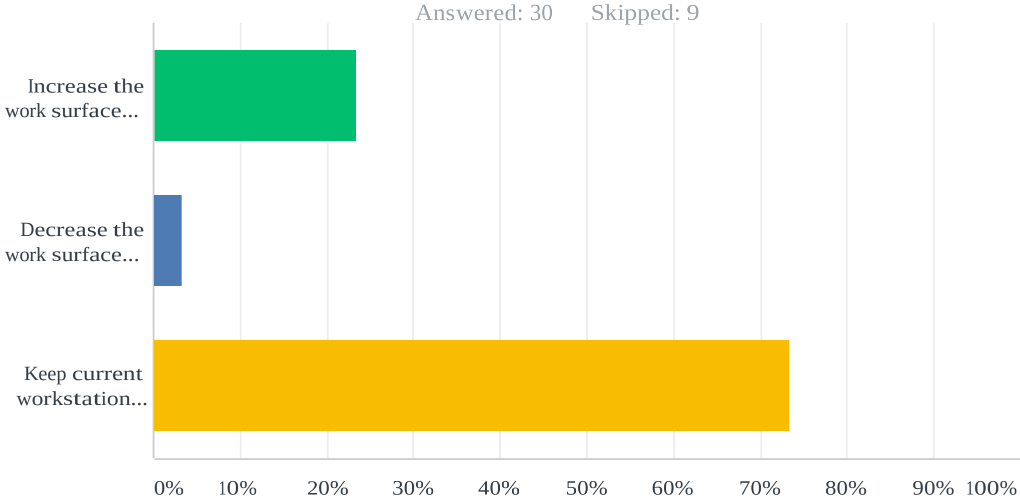
Answered: 30 Skipped: 9



Answer Choices	Responses	
Increase the number of displays	30.00%	9
Decrease the number of displays	16.67%	5
Keep current number of displays	53.33%	16
Total		30

Q32 If you could change the work surface height of your workstation, how would you change it?

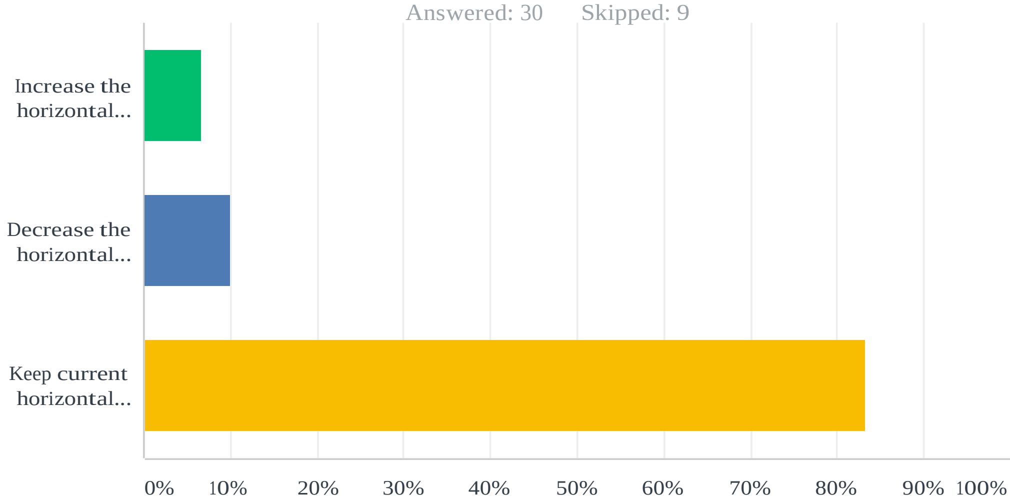
Answered: 30 Skipped: 9



Answer Choices	Responses	
Increase the work surface height	23.33%	7
Decrease the work surface height	3.33%	1
Keep current workstation height	73.33%	22
Total		30

Q33 If you could change the horizontal reach distance to manipulate controls of your workstation, how would you change it?

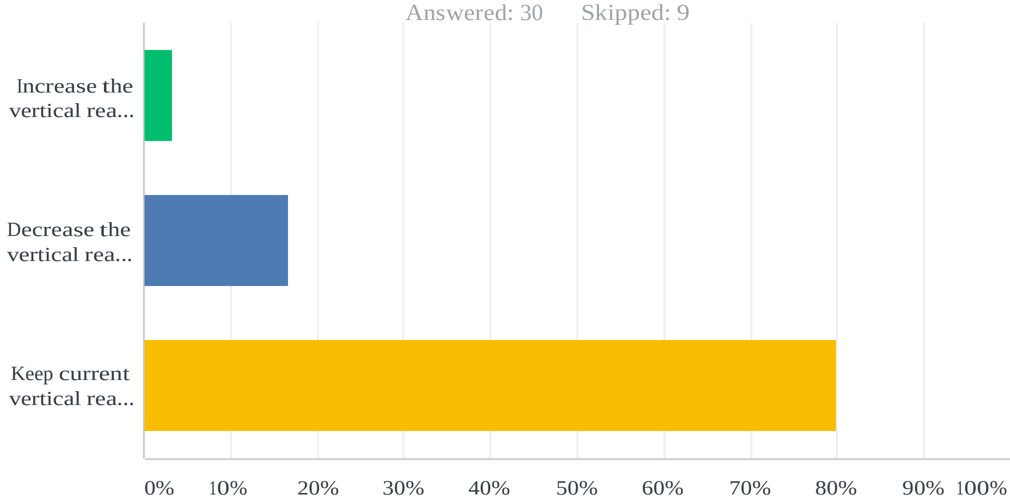
Answered: 30 Skipped: 9



Answer Choices	Responses	
Increase the horizontal reach distance to manipulate controls	6.67%	2
Decrease the horizontal reach distance to manipulate controls	10.00%	3
Keep current horizontal reach distance	83.33%	25
Total		30

Q34 If you could change the vertical reach distance to manipulate controls of your workstation, how would you change it?

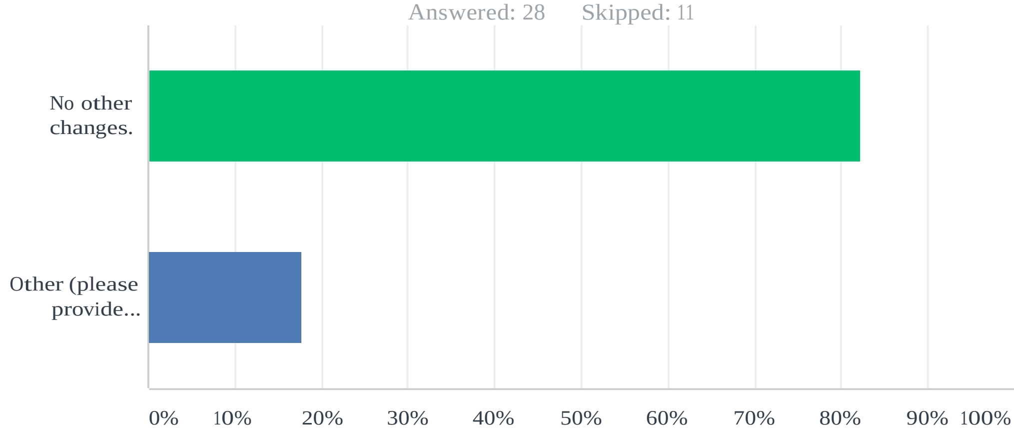
Answered: 30 Skipped: 9



Answer Choices	Responses	
Increase the vertical reach distance to manipulate controls	3.33%	1
Decrease the vertical reach distance to manipulate controls	16.67%	5
Keep current vertical reach distance	80.00%	24
Total		30

Q35 If you could change anything else about the physical layout of your workstation, that was not covered by questions 30-34, what would it be?

Answered: 28   Skipped: 11

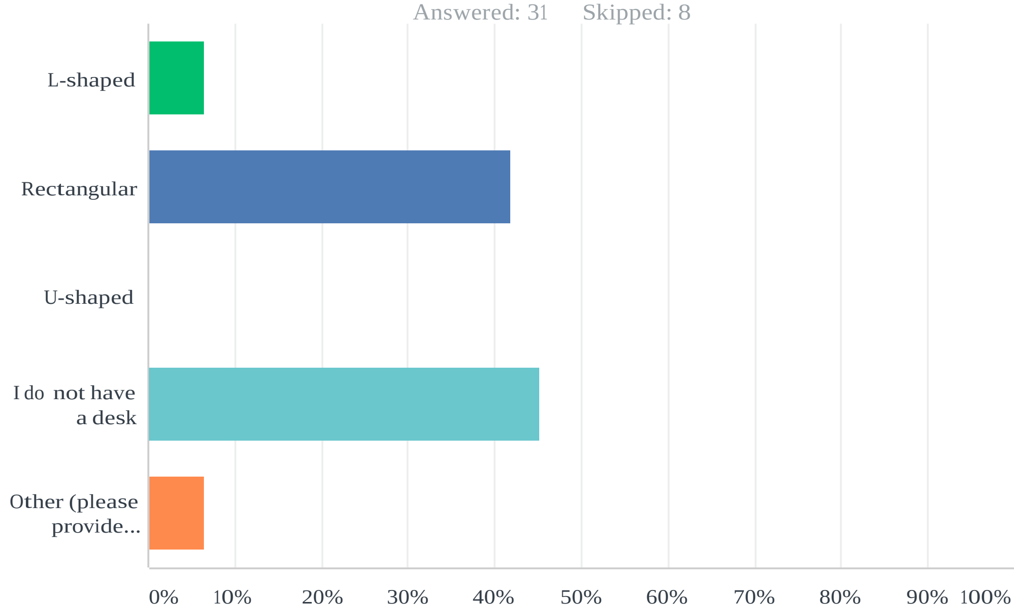


Answer Choices	Responses	
No other changes.	82.14%	23
Other (please provide description)	17.86%	5
Total		28

#	Other (please provide description)
1	Reduce glare on monitors. dissipate unit heat better
2	Add touch to screens vice using mouse for selection where make sense
3	Better sun shade
4	You did not describe HOTAS-style controllers. I believe these are much more intuitive than the traditional joysticks, throttle or rudder controls. I have flown with game controllers, but I don't feel they are the right size for the right amount of control during teleoperations. Of course, none of that matters when flying by waypoint.
5	The Vert/Horz combination of screens provides the most screen surface around a centered point, limiting eye travel or head movement, which is good. A single, large screen covering the same surface area may also meet those parameters without any screen cross over issues.

Q36 What does your work surface look like?

Answered: 31 Skipped: 8



Answer Choices	Responses	
L-shaped	6.45%	2
Rectangular	41.94%	13
U-shaped	0.00%	0
I do not have a desk	45.16%	14
Other (please provide description)	6.45%	2
Total		31

#	Other (please provide description)
1	Mostly a laptop and small table with the mode 2 RC.
2	Rectangular desk or collapsible card table

Q37 Do you agree that your current work surface is the best design for your operations?

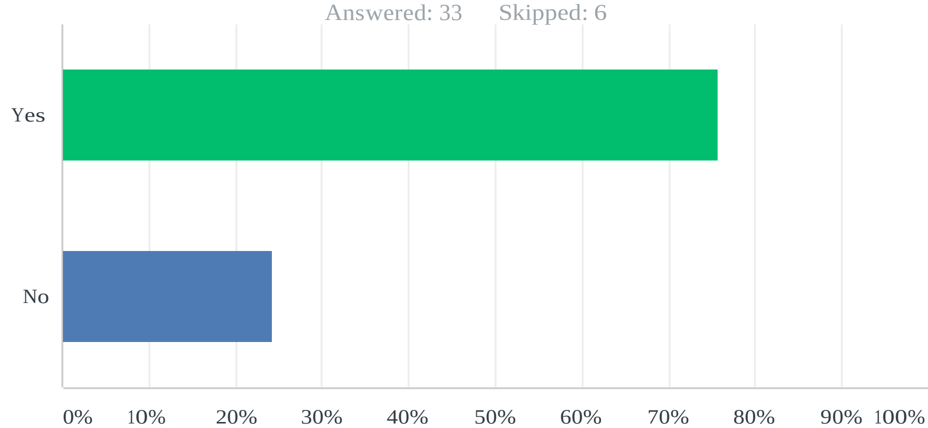
Answered: 31 Skipped: 8

	Strongly Disagree	Disagree	Neither Disagree nor Agree	Agree	Strongly Agree	Total	Weighted Average
(no label)	9.68% 3	22.58% 7	32.26% 10	35.48% 11	0.00% 0	31	0.00

#	Why or why not?
1	UASs are set up like RC's not aircraft with the forethought of working in the national airspace
2	the units are too modular and are frequently at risk of damage or loss in transport/setup
3	u shape would be more efficient and effective
4	Have not seen other configurations.
5	Would be nice to have side- panels for less important switches moving toward the rear
6	The screens, keyboard and mouse controls cover the majority of the desk limiting space for the operators to lay out any support documents that may be required for the flight not covered on the system
7	Easier for me to work with.
8	Flights are done in the field - but if BVLOS is approved I would answer differently.
9	Ease of access
10	My system is flexible and mobile, as it should be
11	Limited space for taking any required notes.

Q38 Do you or someone you know control UASs in a mobile environment?

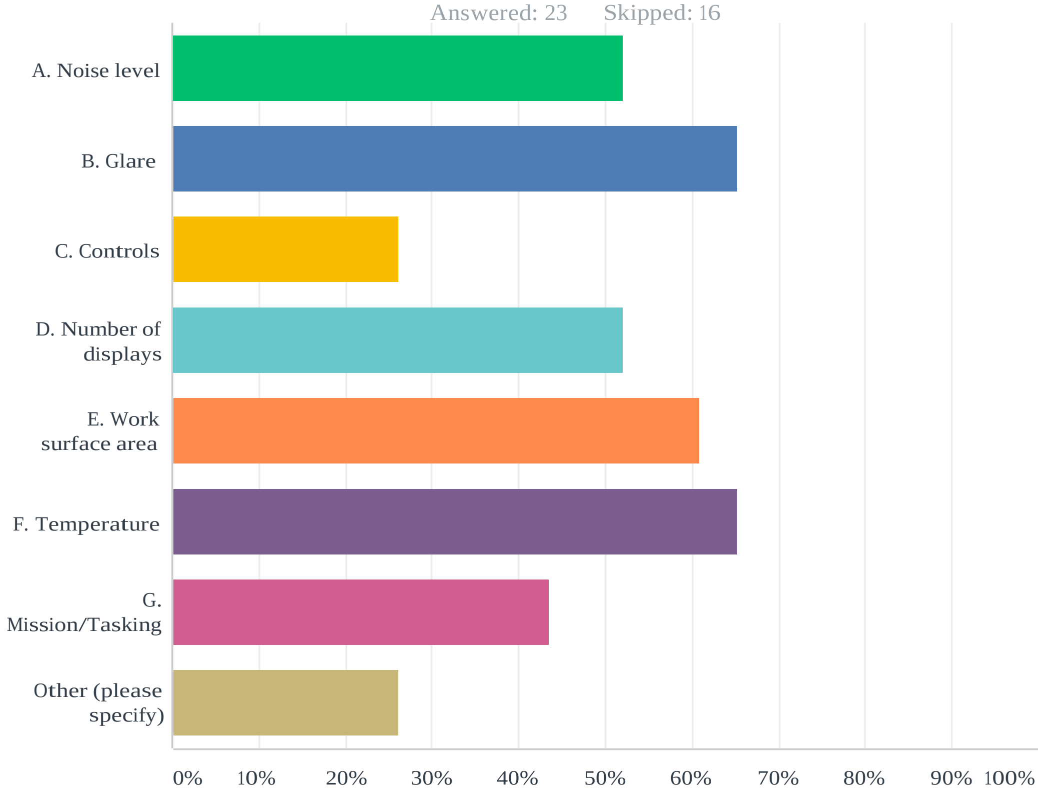
Answered: 33 Skipped: 6



Answer Choices	Responses	
Yes	75.76%	25
No	24.24%	8
Total		33

Q39 What is different between the mobile and fixed ground control stations? (select all that apply)

Answered: 23 Skipped: 16

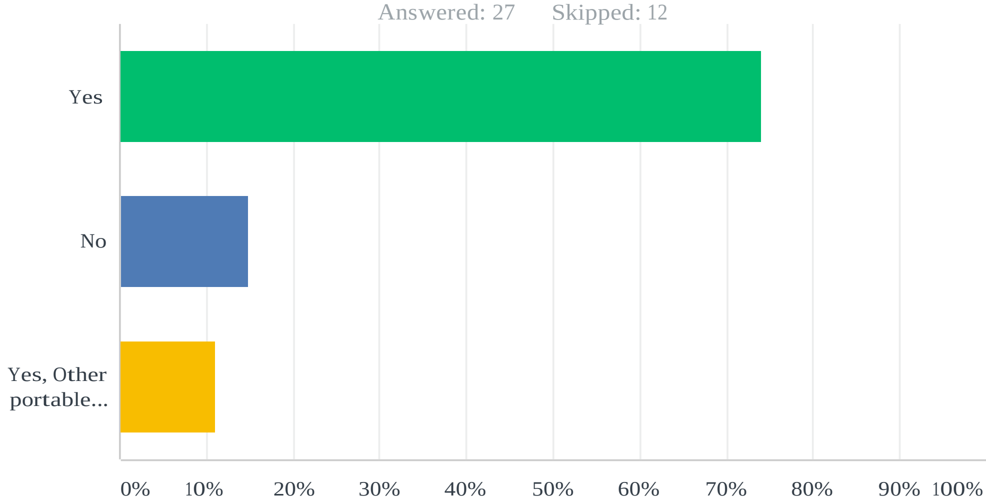


Answer Choices	Responses	
A. Noise level	52.17%	12
B. Glare	65.22%	15
C. Controls	26.09%	6
D. Number of displays	52.17%	12
E. Work surface area	60.87%	14
F. Temperature	65.22%	15
G. Mission/Tasking	43.48%	10
Other (please specify)	26.09%	6
Total Respondents: 23		

#	Other (please specify)
1	length of time aloft
2	Always have flown in mobile ground station
3	Shipboard systems also had to deal with corrosion to external equipment (Launch & recover devices, antenna)
4	Mobility
5	Terrain in the field
6	All of the above

Q40 Do you use a backpack or other portable solution to transport UAS specific items when mobile and controlling a UAS?

Answered: 27 Skipped: 12

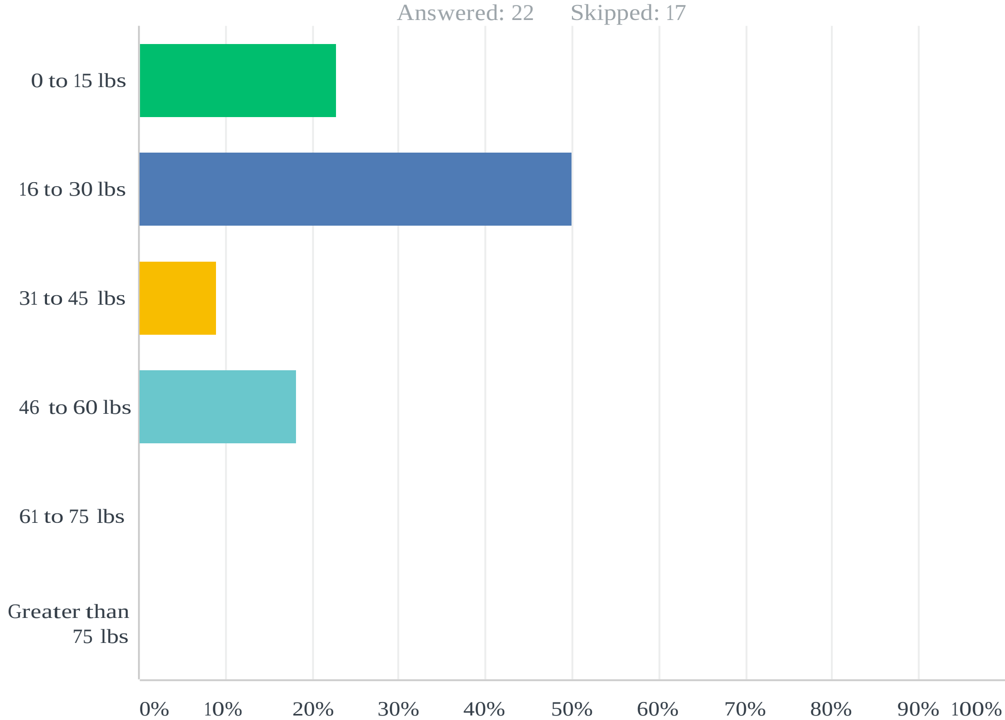


Answer Choices	Responses	
Yes	74.07%	20
No	14.81%	4
Yes, Other portable solution (please specify)	11.11%	3
Total		27

#	Yes, Other portable solution (please specify)
1	Pelican travel case(s)
2	I have used a Gator 4-wheel vehicle and have worked a control station mounted onboard a US warship. I have not used a backpack system.
3	Rolling cart

Q41 How heavy is the backpack or other portable solution when loaded with UAS specific items?

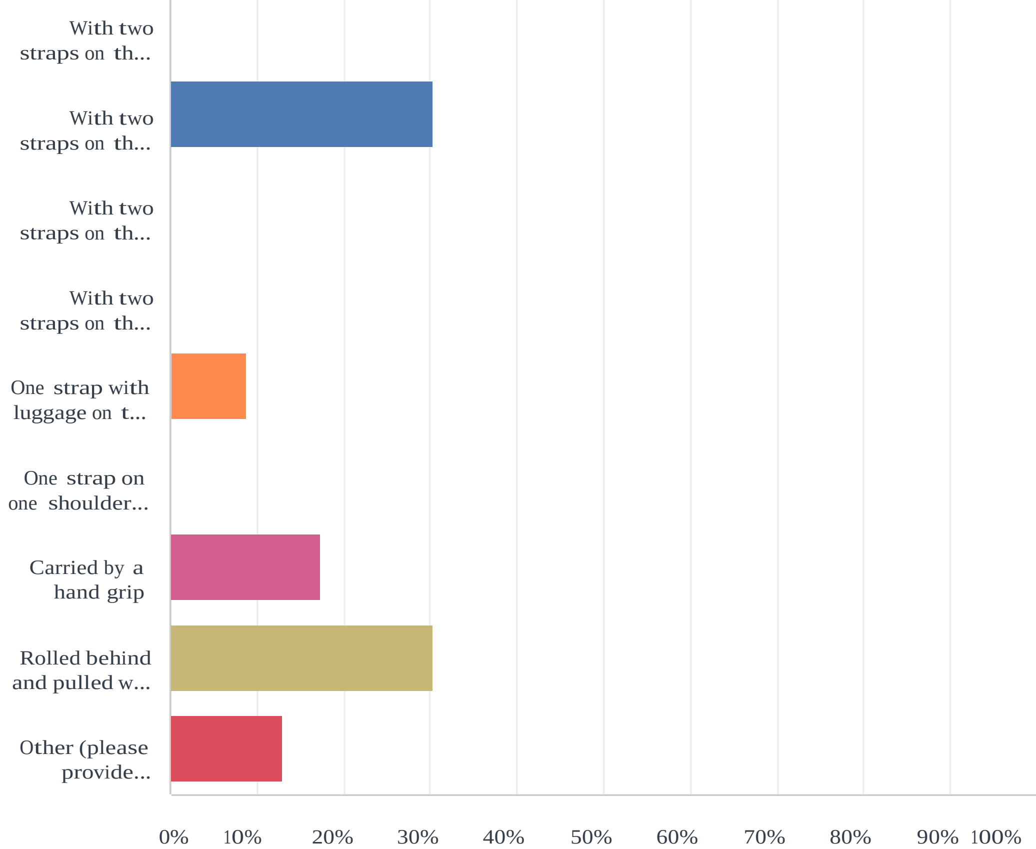
Answered: 22 Skipped: 17



Answer Choices	Responses	
0 to 15 lbs	22.73%	5
16 to 30 lbs	50.00%	11
31 to 45 lbs	9.09%	2
46 to 60 lbs	18.18%	4
61 to 75 lbs	0.00%	0
Greater than 75 lbs	0.00%	0
Total		22

Q42 How is the backpack or other portable solution worn or carried?

Answered: 23 Skipped: 16



Answer Choices	Responses	
With two straps on the shoulders - Pack on front	0.00%	0
With two straps on the shoulders - Pack on back	30.43%	7
With two straps on the shoulders - Pack on front and back	0.00%	0
With two straps on the shoulders - Vest	0.00%	0
One strap with luggage on the same side of the body	8.70%	2
One strap on one shoulder and the luggage on the opposite side of the body	0.00%	0
Carried by a hand grip	17.39%	4
Rolled behind and pulled with a hand grip	30.43%	7
Other (please provide description)	13.04%	3
Total		23

#	Other (please provide description)
1	Carried by two people with hand grip on each side.
2	Mounted onto a 4-wheel drive vehicle and a USS warship
3	Use of lanyard around neck

Q43 If you would be interested in participating in an interview to provide more detailed descriptions on control station design, please provide an email for us to contact you.

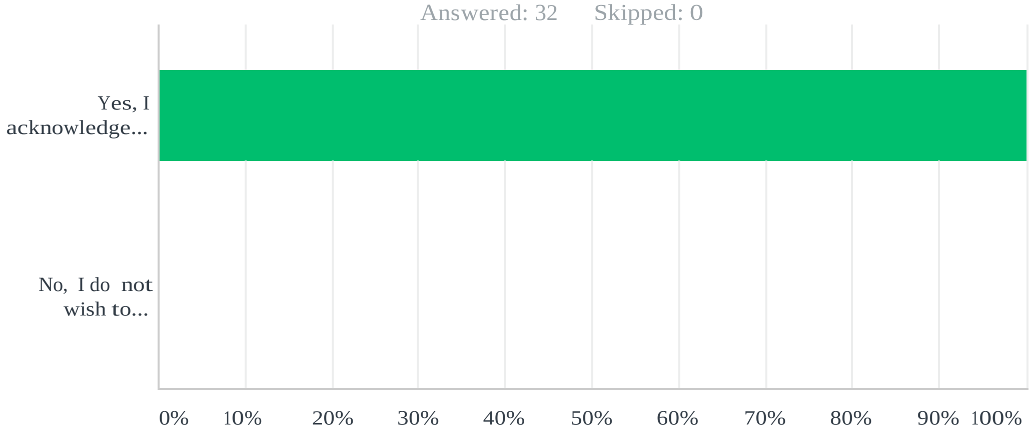
Answered: 18 Skipped: 21

Answer Choices	Responses
Email:	100.00% 18

10.2 SURVEY DATA: GROUPS 1 AND 2

Q1 Would you like to proceed with the survey?

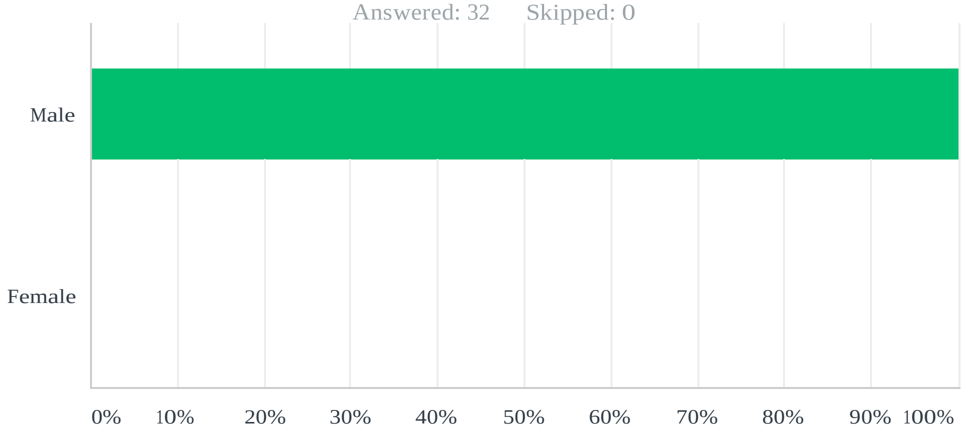
Answered: 32 Skipped: 0



Answer Choices	Responses	
Yes, I acknowledge that I have read the above information and would like to take the survey	100.00%	32
No, I do not wish to participate at this time	0.00%	0
TOTAL		32

Q2 Gender:

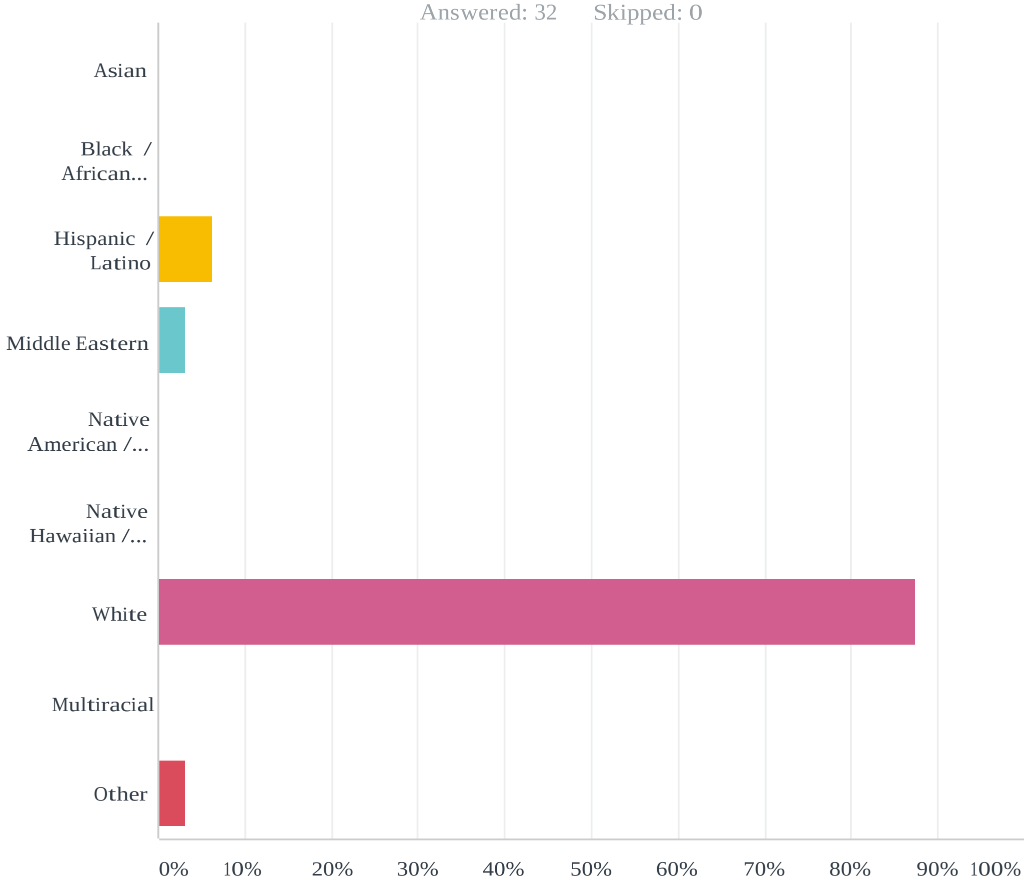
Answered: 32 Skipped: 0



Answer Choices	Responses	
Male	100.00%	32
Female	0.00%	0
TOTAL		32

Q3 Ethnicity:

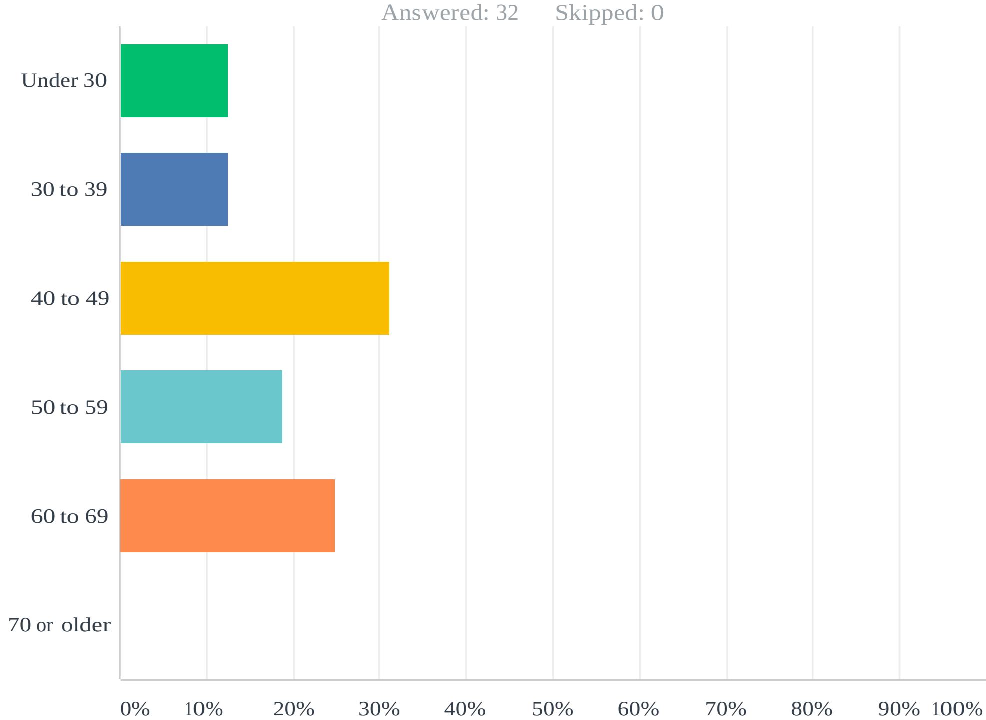
Answered: 32 Skipped: 0



Answer Choices	Responses	
Asian	0.00%	0
Black / African American	0.00%	0
Hispanic / Latino	6.25%	2
Middle Eastern	3.13%	1
Native American / Alaska Native	0.00%	0
Native Hawaiian / Other Pacific Islander	0.00%	0
White	87.50%	28
Multiracial	0.00%	0
Other	3.13%	1
TOTAL		32

Q4 Age:

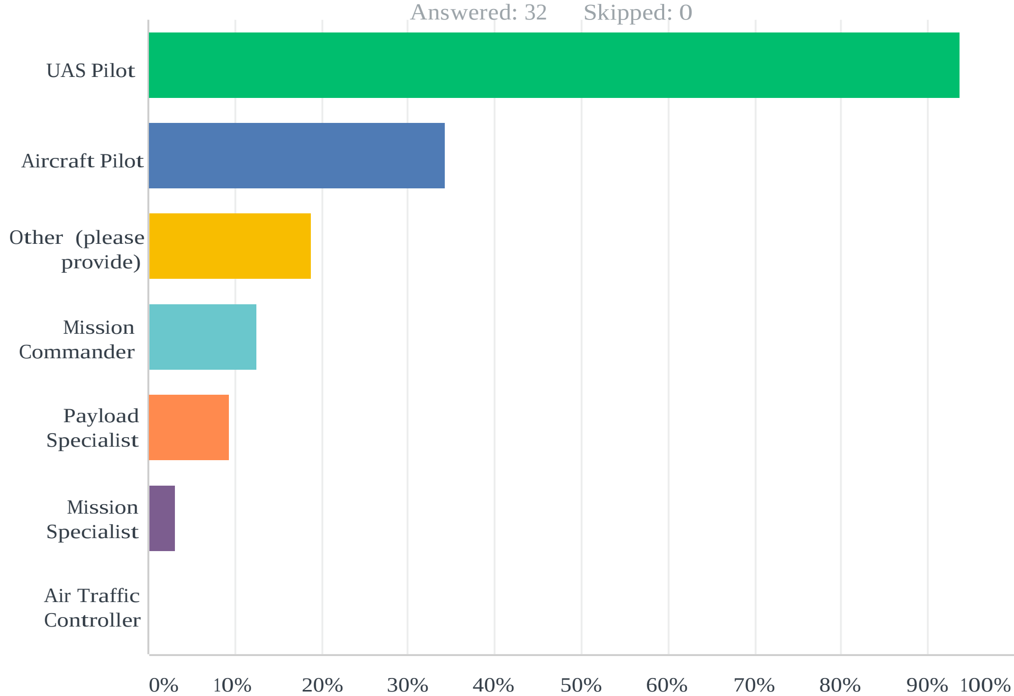
Answered: 32 Skipped: 0



Answer Choices	Responses	
Under 30	12.50%	4
30 to 39	12.50%	4
40 to 49	31.25%	10
50 to 59	18.75%	6
60 to 69	25.00%	8
70 or older	0.00%	0
TOTAL		32

Q5 I am a (select all that apply):

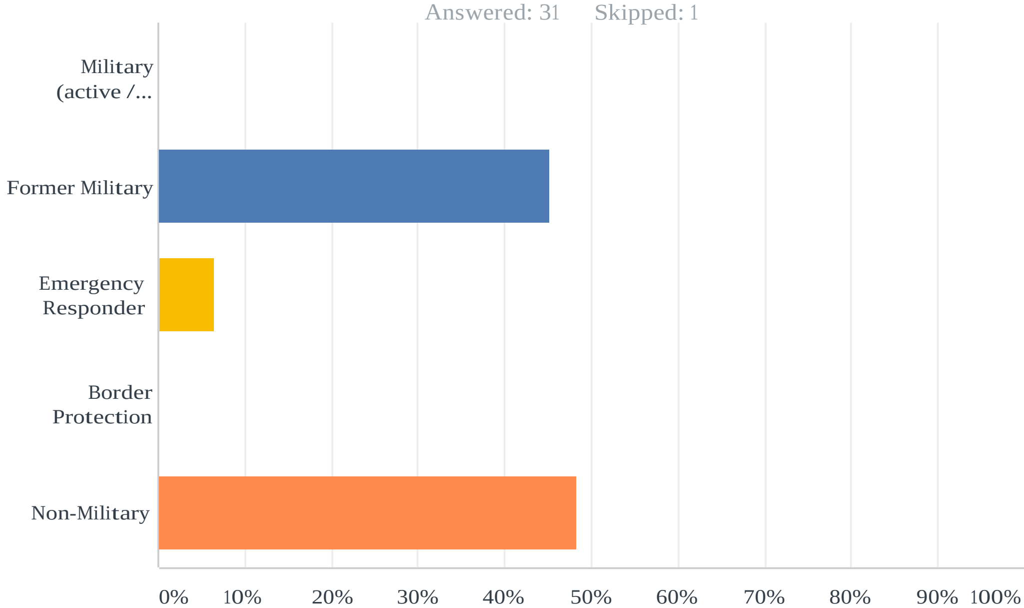
Answered: 32 Skipped: 0



Answer Choices	Responses	
UAS Pilot	93.75%	30
Aircraft Pilot	34.38%	11
Other (please provide)	18.75%	6
Mission Commander	12.50%	4
Payload Specialist	9.38%	3
Mission Specialist	3.13%	1
Air Traffic Controller	0.00%	0
Total Respondents: 32		

Q6 I am currently:

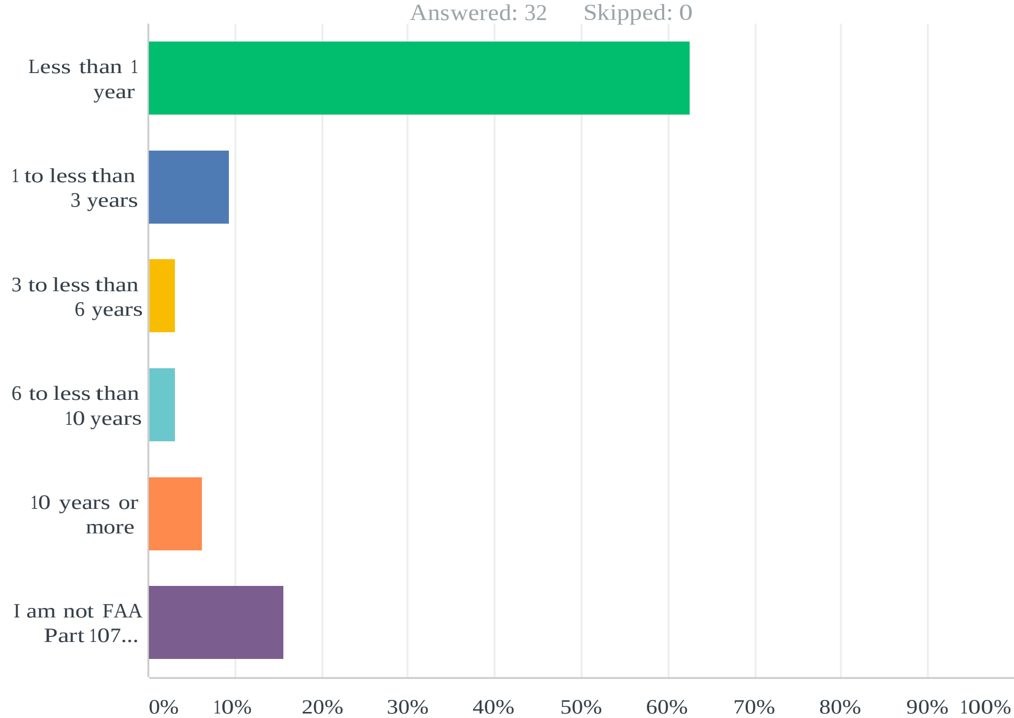
Answered: 31 Skipped: 1



Answer Choices	Responses	
Military (active / reserves)	0.00%	0
Former Military	45.16%	14
Emergency Responder	6.45%	2
Border Protection	0.00%	0
Non-Military	48.39%	15
TOTAL		31

Q7 I have held a FAA Part 107 certification or DOD equivalent to fly Unmanned Aircraft Systems [UAS] and drones for:

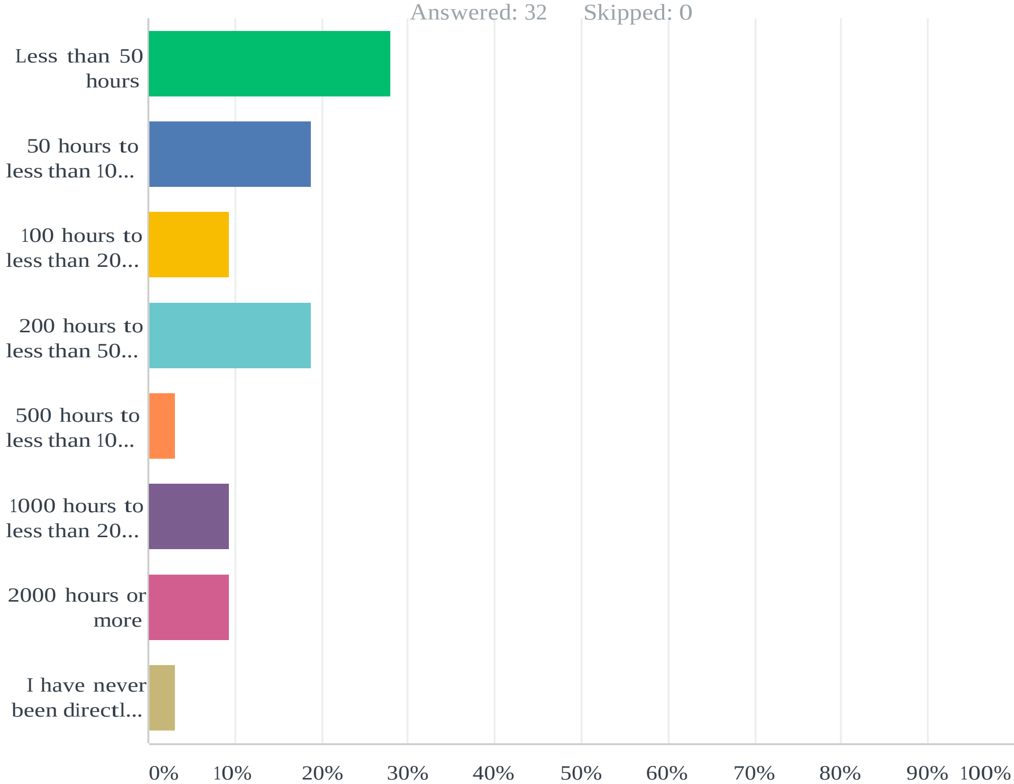
Answered: 32 Skipped: 0



Answer Choices	Responses	
Less than 1 year	62.50%	20
1 to less than 3 years	9.38%	3
3 to less than 6 years	3.13%	1
6 to less than 10 years	3.13%	1
10 years or more	6.25%	2
I am not FAA Part 107 certified	15.63%	5
TOTAL		32

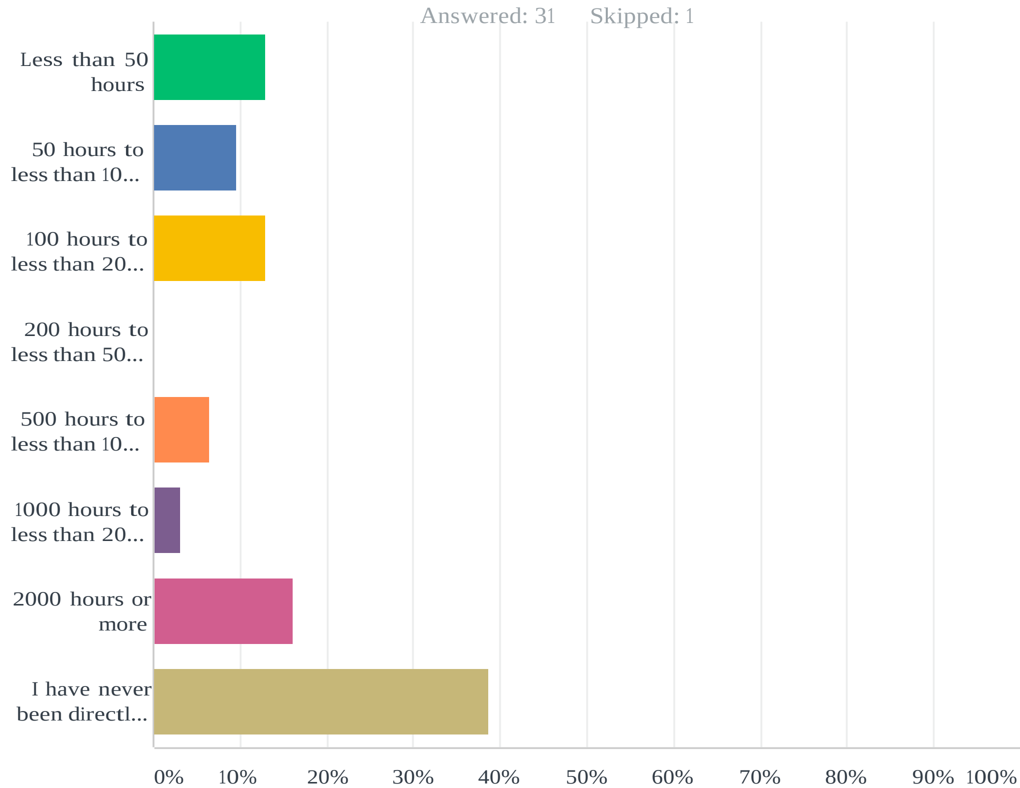
Q8 I have flown/controlled unmanned flight operations for:

Answered: 32 Skipped: 0



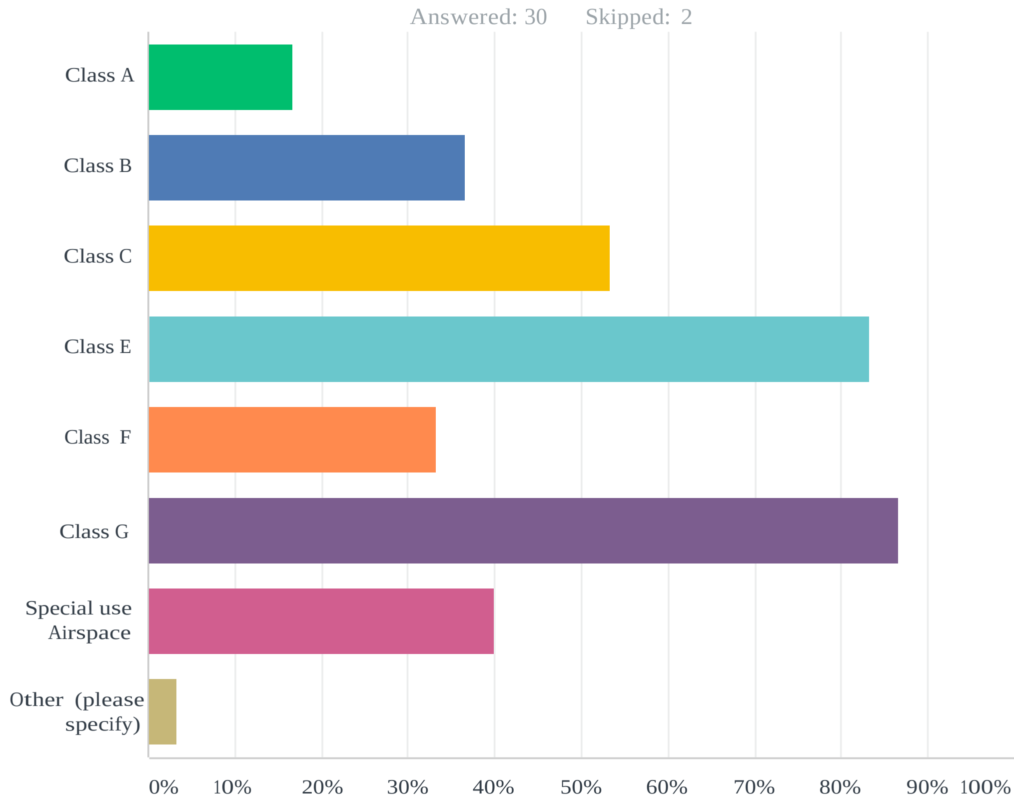
Answer Choices	Responses	
Less than 50 hours	28.13%	9
50 hours to less than 100 hours	18.75%	6
100 hours to less than 200 hours	9.38%	3
200 hours to less than 500 hours	18.75%	6
500 hours to less than 1000 hours	3.13%	1
1000 hours to less than 2000 hours	9.38%	3
2000 hours or more	9.38%	3
I have never been directly involved with unmanned flight operations	3.13%	1
TOTAL		32

Q9 I have flown/controlled manned flight operations for:



Answer Choices	Responses	
Less than 50 hours	12.90%	4
50 hours to less than 100 hours	9.68%	3
100 hours to less than 200 hours	12.90%	4
200 hours to less than 500 hours	0.00%	0
500 hours to less than 1000 hours	6.45%	2
1000 hours to less than 2000 hours	3.23%	1
2000 hours or more	16.13%	5
I have never been directly involved with manned flight operations	38.71%	12
TOTAL		31

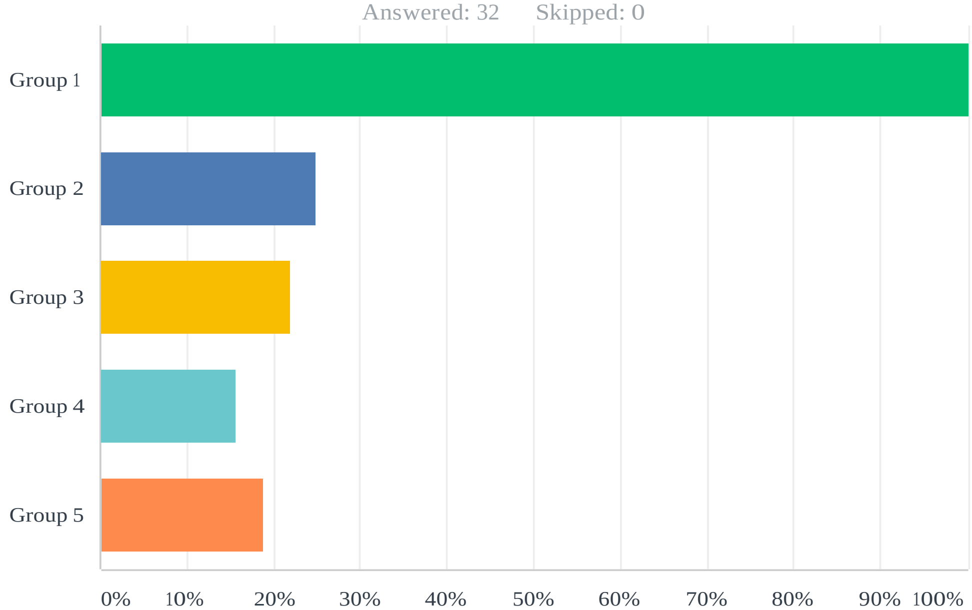
Q10 What classes of airspace is your experience in? (select all that apply)



Answer Choices	Responses	
Class A	16.67%	5
Class B	36.67%	11
Class C	53.33%	16
Class E	83.33%	25
Class F	33.33%	10
Class G	86.67%	26
Special use Airspace	40.00%	12
Other (please specify)	3.33%	1
Total Respondents: 30		

Q11 What type(s) of UAS based on the categories described below do you currently or have previously controlled (select all that apply)?

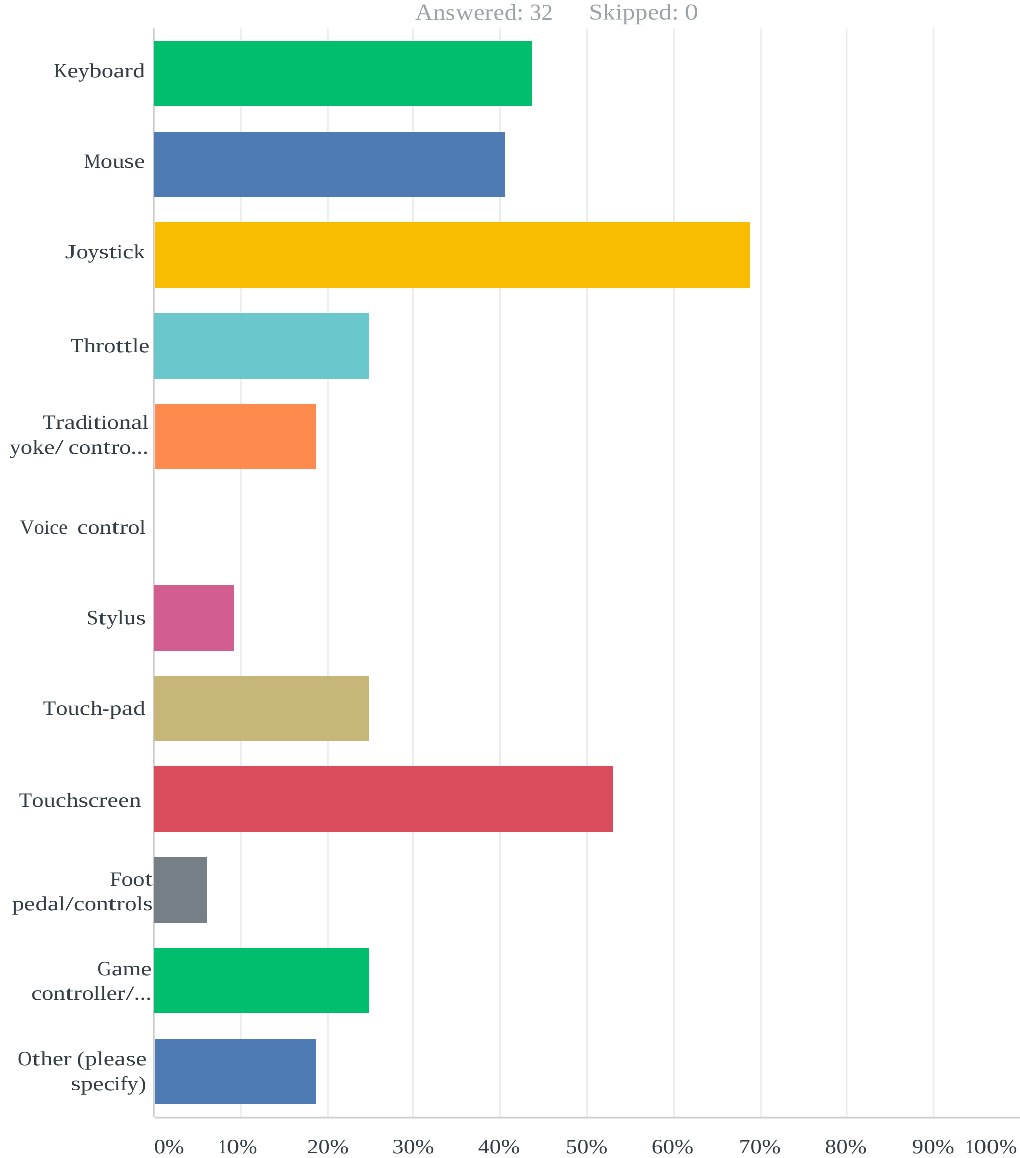
Answered: 32 Skipped: 0



Answer Choices	Responses	
Group 1	100.00%	32
Group 2	25.00%	8
Group 3	21.88%	7
Group 4	15.63%	5
Group 5	18.75%	6
Total Respondents: 32		

Q12 What controls do you use in ground control stations to control UASs? (select all that apply)

Answered: 32 Skipped: 0

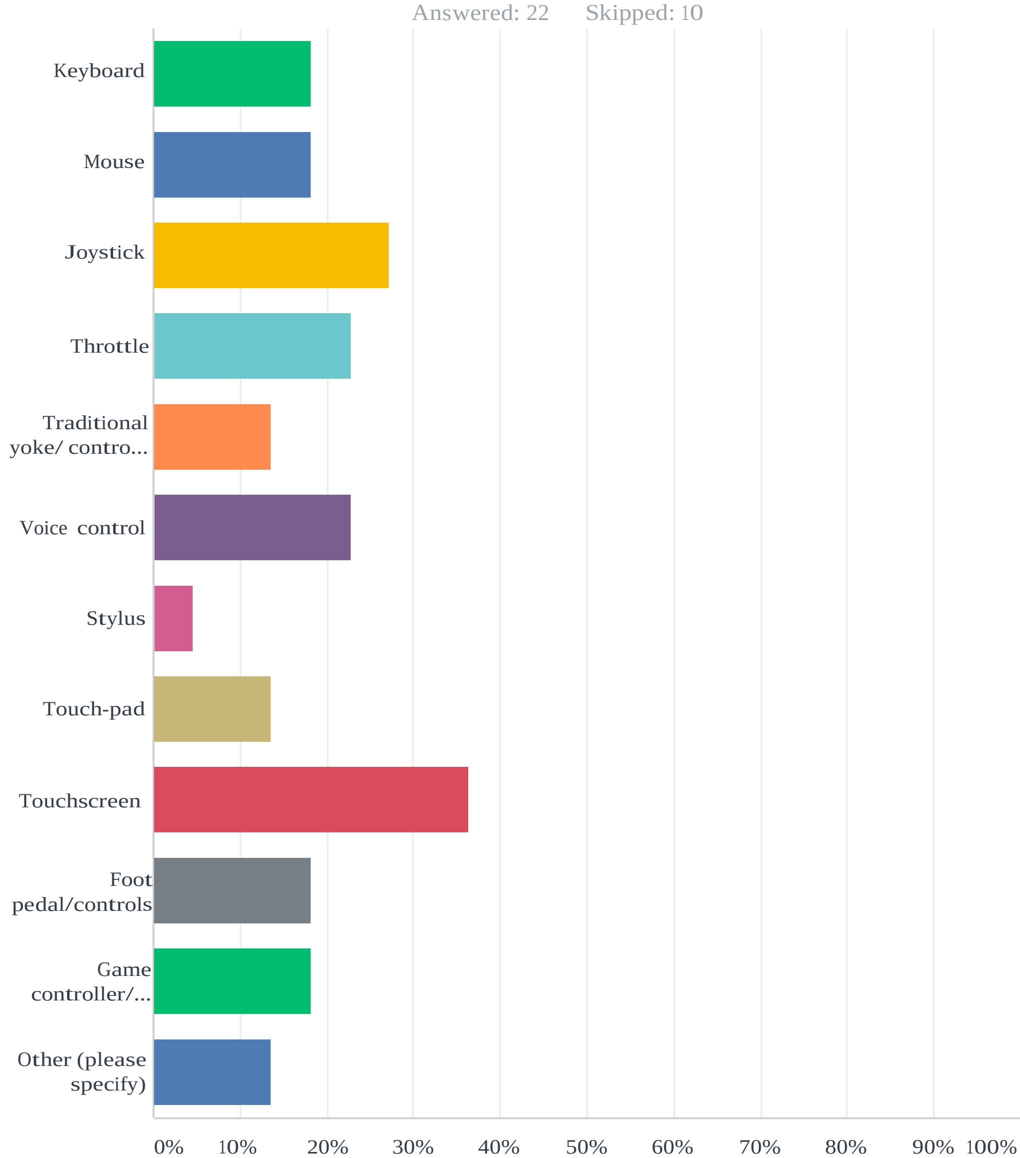


Answer Choices	Responses	
Keyboard	43.75%	14
Mouse	40.63%	13
Joystick	68.75%	22
Throttle	25.00%	8
Traditional yoke/ control stick	18.75%	6
Voice control	0.00%	0
Stylus	9.38%	3
Touch-pad	25.00%	8

Touchscreen	53.13%	17
Foot pedal/controls	6.25%	2
Game controller/ Game pad	25.00%	8
Other (please specify)	18.75%	6
Total Respondents: 32		

Q13 What controls would you recommend to add to control stations to help make the task easier? (select all that apply)

Answered: 22 Skipped: 10

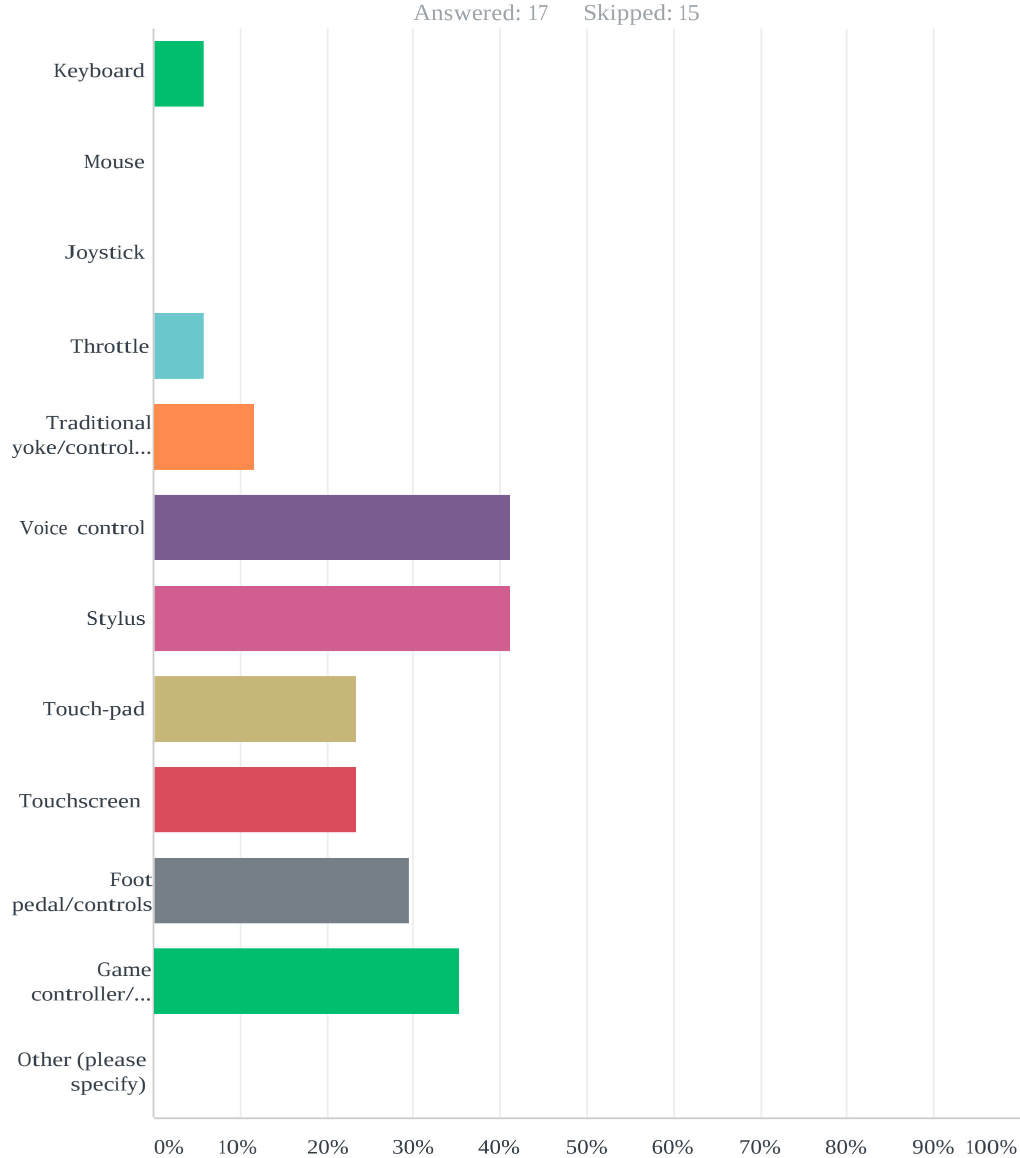


Answer Choices	Responses	
Keyboard	18.18%	4
Mouse	18.18%	4
Joystick	27.27%	6
Throttle	22.73%	5
Traditional yoke/ control stick	13.64%	3
Voice control	22.73%	5
Stylus	4.55%	1
Touch-pad	13.64%	3

Touchscreen	36.36%	8
Foot pedal/controls	18.18%	4
Game controller/ Game pad	18.18%	4
Other (please specify)	13.64%	3
Total Respondents: 22		

Q14 What controls would you recommend to remove from stations to help make the task easier? (select all that apply)

Answered: 17 Skipped: 15

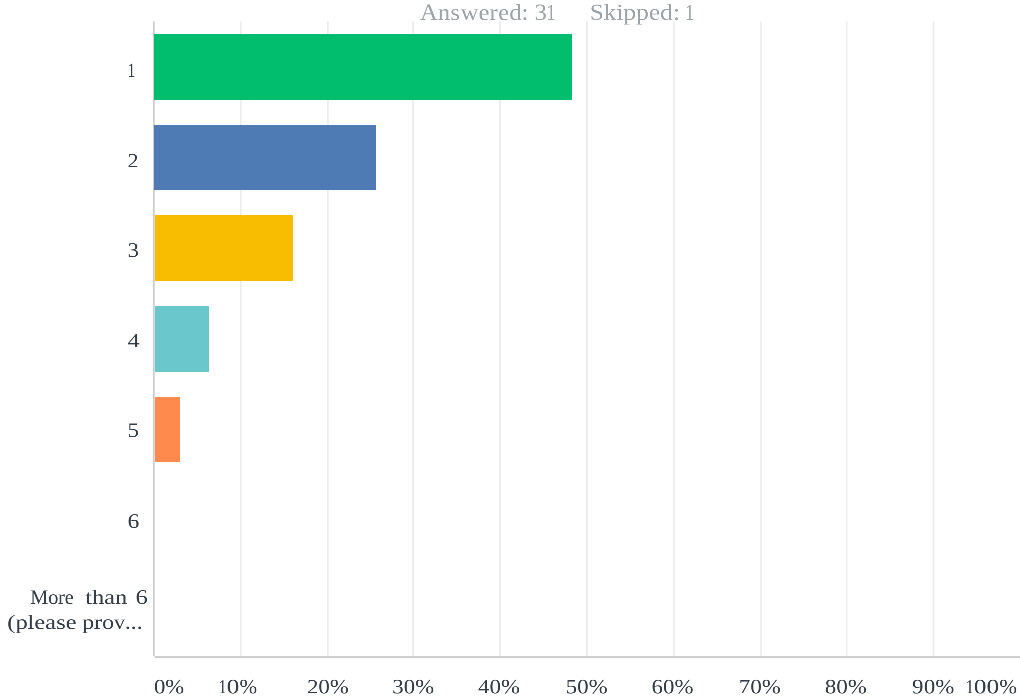


Answer Choices	Responses	
Keyboard	5.88%	1
Mouse	0.00%	0
Joystick	0.00%	0
Throttle	5.88%	1
Traditional yoke/control stick	11.76%	2
Voice control	41.18%	7
Stylus	41.18%	7
Touch-pad	23.53%	4

Touchscreen	23.53%	4
Foot pedal/controls	29.41%	5
Game controller/ Game pad	35.29%	6
Other (please specify)	0.00%	0
Total Respondents: 17		

Q15 How many displays are most commonly available in control stations that you use (have used)?

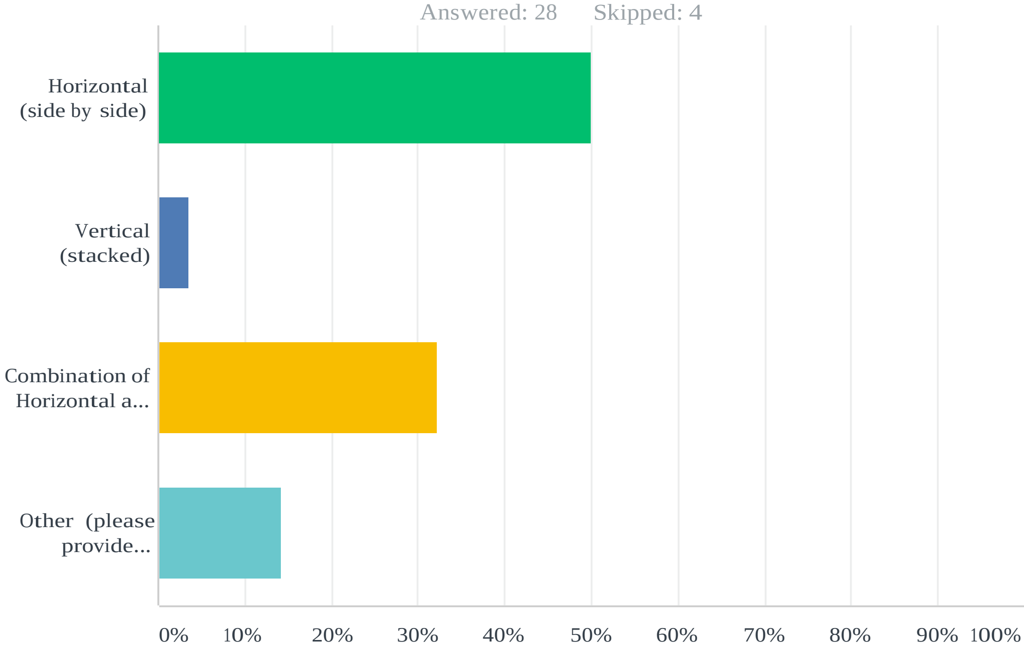
Answered: 31 Skipped: 1



Answer Choices	Responses	
1	48.39%	15
2	25.81%	8
3	16.13%	5
4	6.45%	2
5	3.23%	1
6	0.00%	0
More than 6 (please provide number)	0.00%	0
TOTAL		31

Q16 How are the displays oriented?

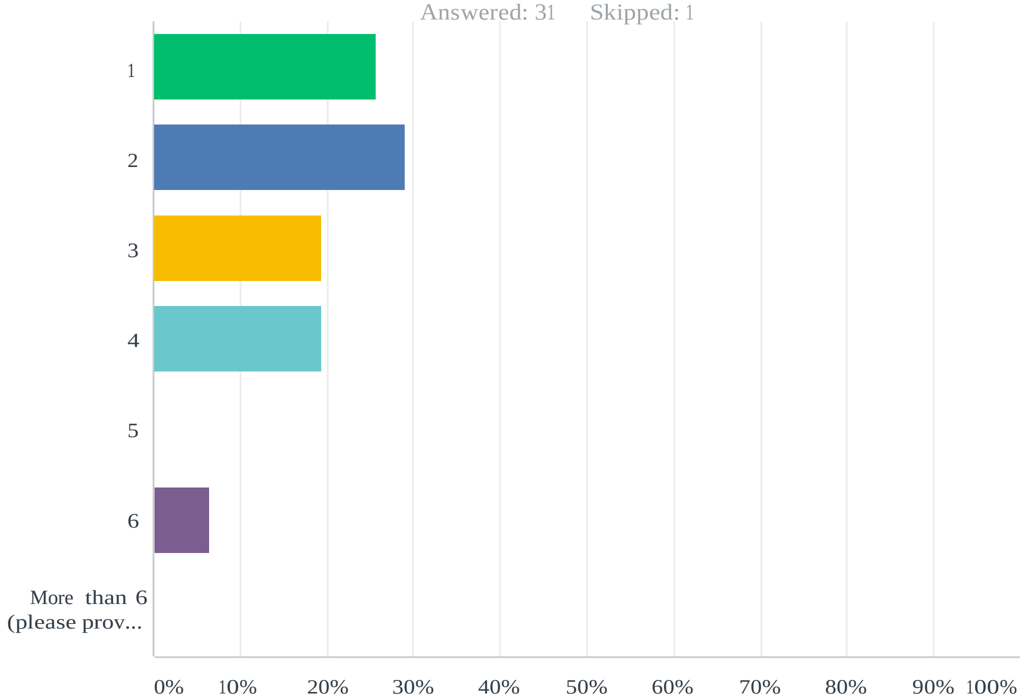
Answered: 28 Skipped: 4



Answer Choices	Responses	
Horizontal (side by side)	50.00%	14
Vertical (stacked)	3.57%	1
Combination of Horizontal and Vertical	32.14%	9
Other (please provide description)	14.29%	4
TOTAL		28

Q17 How many displays are you comfortable using to control a UAS?

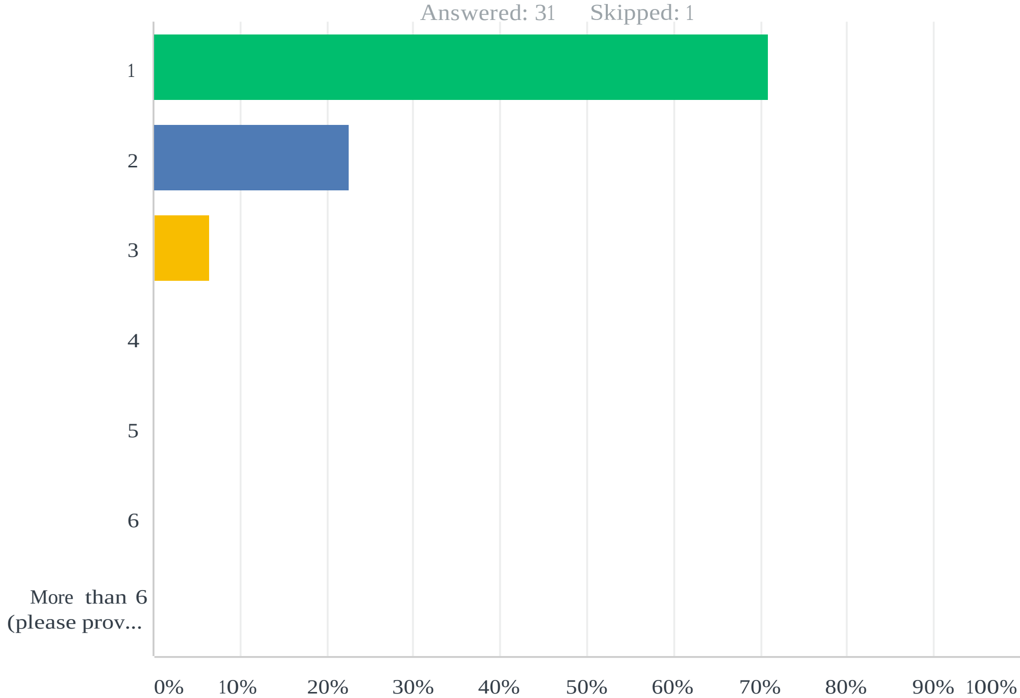
Answered: 31 Skipped: 1



Answer Choices	Responses	
1	25.81%	8
2	29.03%	9
3	19.35%	6
4	19.35%	6
5	0.00%	0
6	6.45%	2
More than 6 (please provide number)	0.00%	0
TOTAL		31

Q18 What is the minimum number of control station displays needed (for flight and performance data) to pilot a UAS?

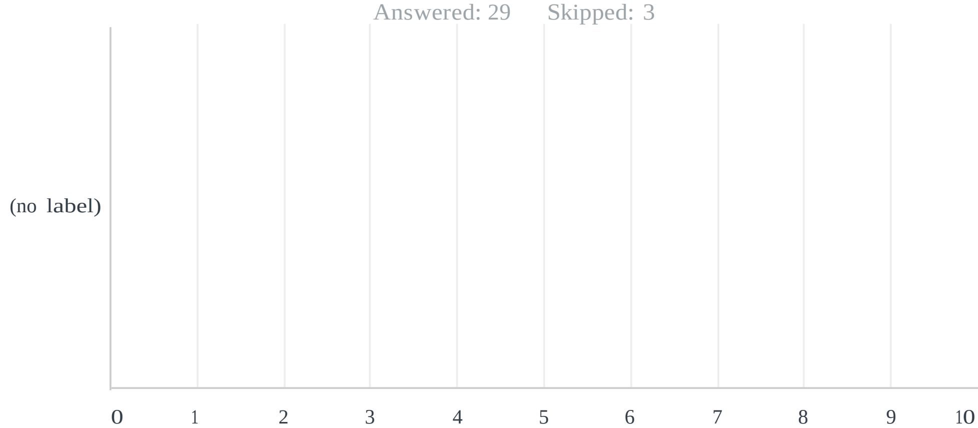
Answered: 31 Skipped: 1



Answer Choices	Responses	
1	70.97%	22
2	22.58%	7
3	6.45%	2
4	0.00%	0
5	0.00%	0
6	0.00%	0
More than 6 (please provide number)	0.00%	0
TOTAL		31

Q19 To what extent do you agree with the following statement:My control station mimics the layout of a cockpit.

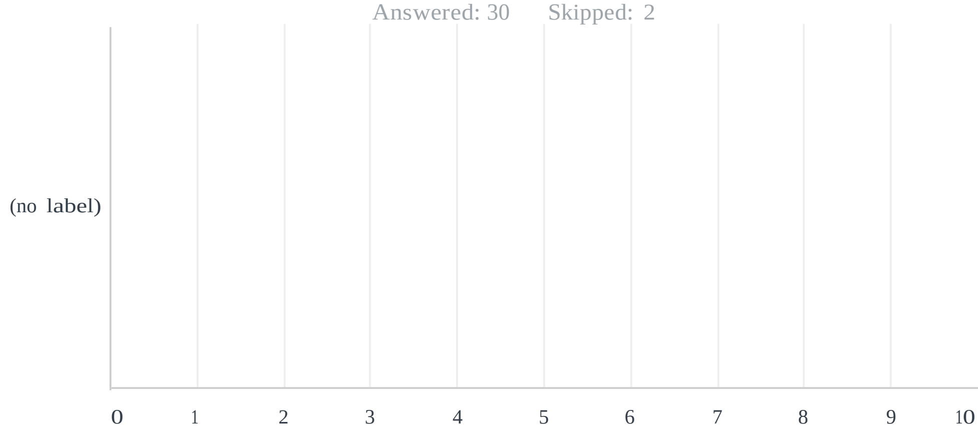
Answered: 29 Skipped: 3



	Strongly disagree	Disagree	Undecided	Agree	Strongly agree	Total	Weighted Average
(no label)	37.93% 11	37.93% 11	10.34% 3	10.34% 3	3.45% 1	29	0.00

Q20 On average what percentage of time per day do you sit while piloting in a control station?

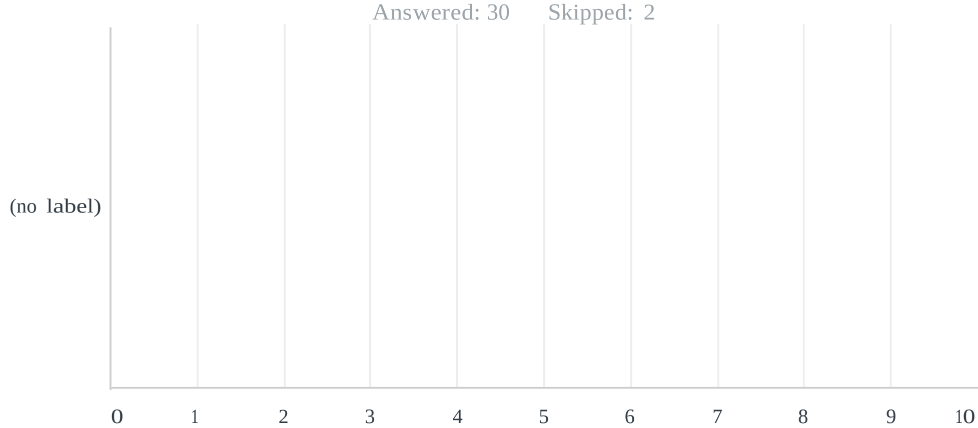
Answered: 30 Skipped: 2



	Never	Seldom	Sometimes	Often	Almost Always	Total	Weighted Average
(no label)	30.00% 9	30.00% 9	20.00% 6	6.67% 2	13.33% 4	30	0.00

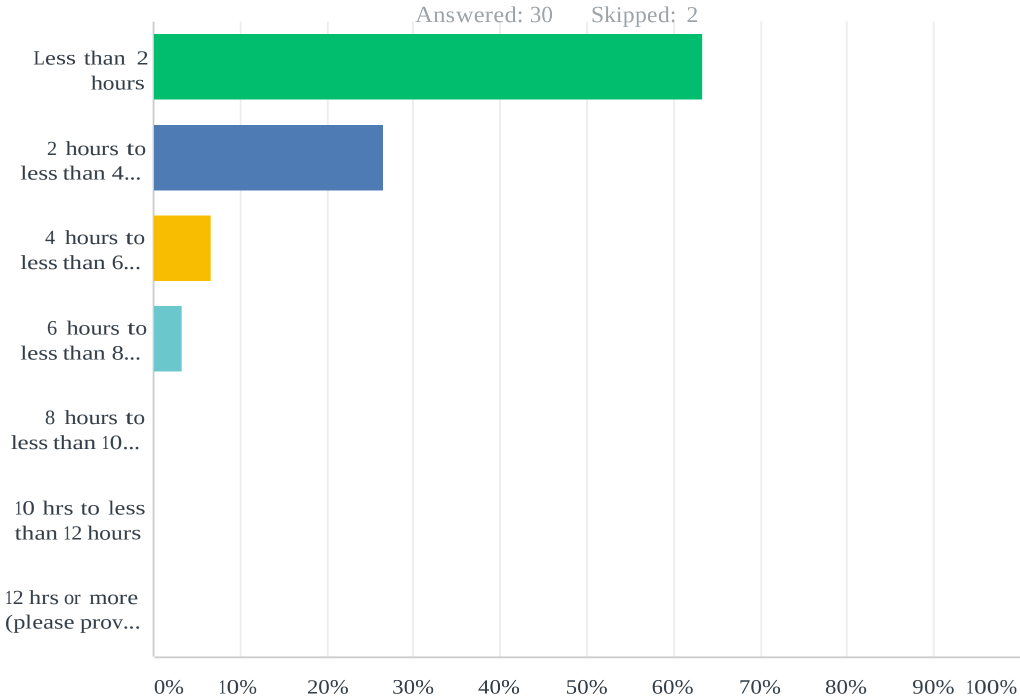
Q21 Using the scale below rate your level of comfort when using UAS control station.

Answered: 30 Skipped: 2



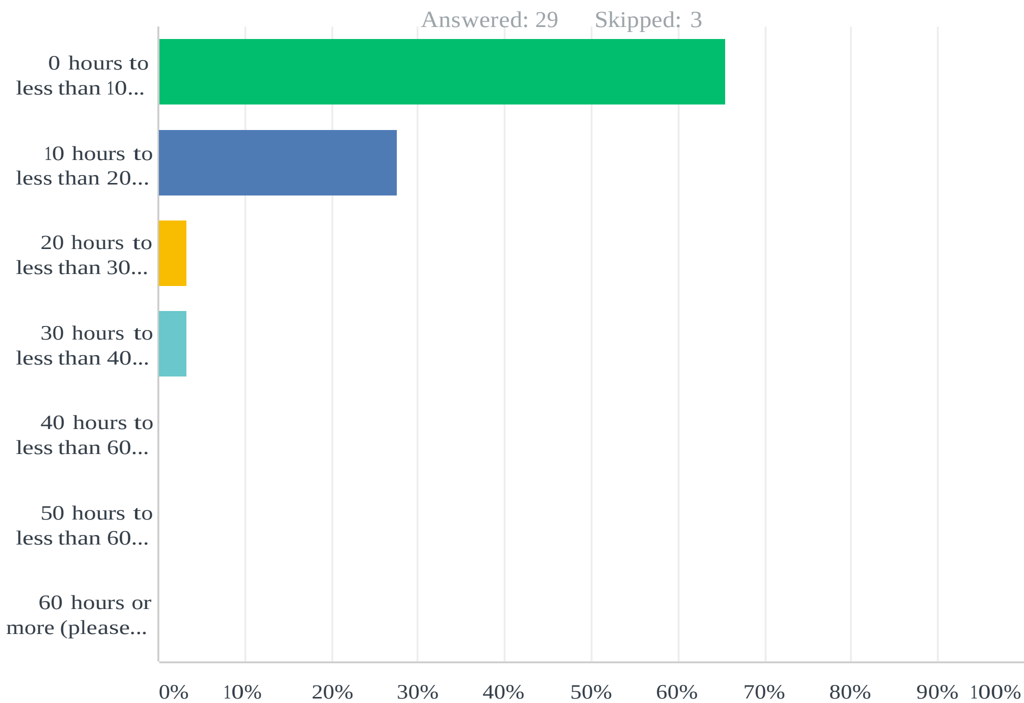
	Very Uncomfortable	Uncomfortable	Neither Uncomfortable nor Comfortable	Comfortable	Very Comfortable	Total	Weighted Average
(no label)	3.33% 1	10.00% 3	16.67% 5	50.00% 15	20.00% 6	30	0.00

Q22 How much time do you spend a day piloting in a control station?



Answer Choices	Responses	
Less than 2 hours	63.33%	19
2 hours to less than 4 hours	26.67%	8
4 hours to less than 6 hours	6.67%	2
6 hours to less than 8 hours	3.33%	1
8 hours to less than 10 hours	0.00%	0
10 hrs to less than 12 hours	0.00%	0
12 hrs or more (please provide number)	0.00%	0
TOTAL		30

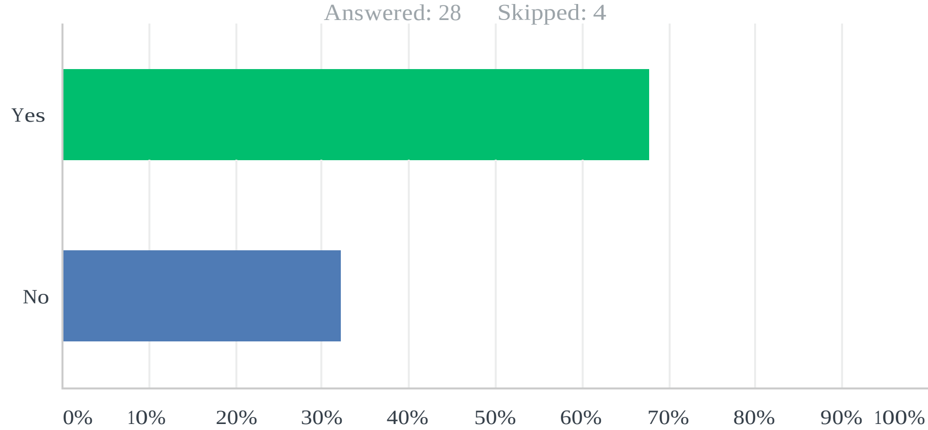
Q23 How much time do you spend a week piloting in a control station?



Answer Choices	Responses	
0 hours to less than 10 hours	65.52%	19
10 hours to less than 20 hours	27.59%	8
20 hours to less than 30 hours	3.45%	1
30 hours to less than 40 hours	3.45%	1
40 hours to less than 60 hours	0.00%	0
50 hours to less than 60 hours	0.00%	0
60 hours or more (please provide number)	0.00%	0
TOTAL		29

Q24 Are other people frequently in or near the control station while you are piloting UAS in a control station?

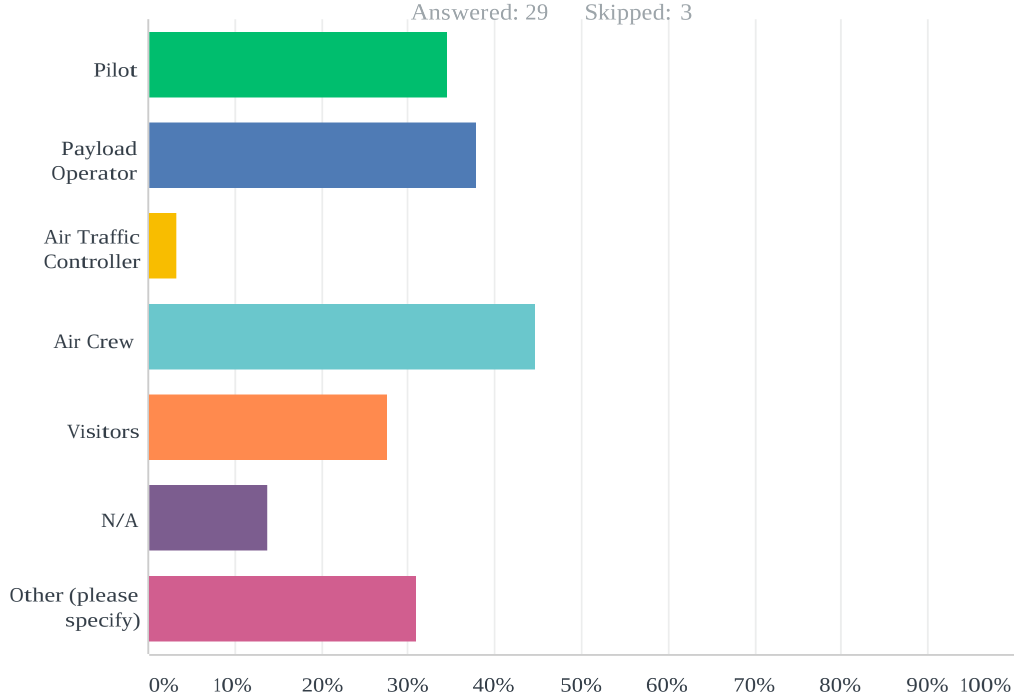
Answered: 28 Skipped: 4



Answer Choices	Responses	
Yes	67.86%	19
No	32.14%	9
TOTAL		28

Q25 If there are other people in or near the control station while you are piloting a UAS, what is their role?

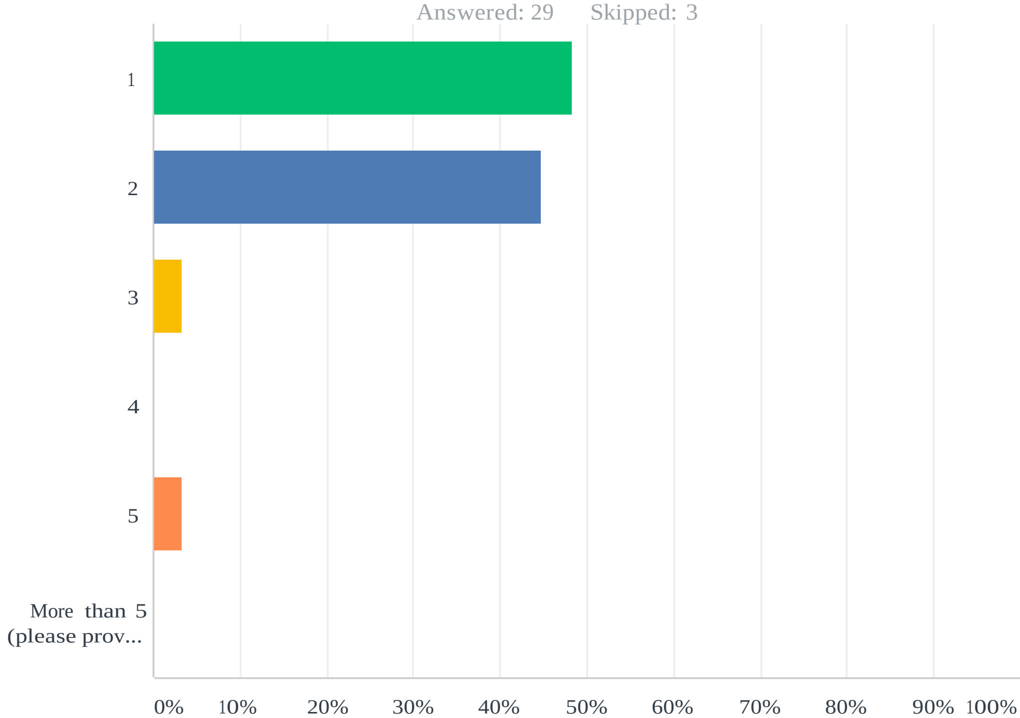
Answered: 29 Skipped: 3



Answer Choices	Responses	
Pilot	34.48%	10
Payload Operator	37.93%	11
Air Traffic Controller	3.45%	1
Air Crew	44.83%	13
Visitors	27.59%	8
N/A	13.79%	4
Other (please specify)	31.03%	9
Total Respondents: 29		

Q26 How many people are usually working in the control station at any given time?

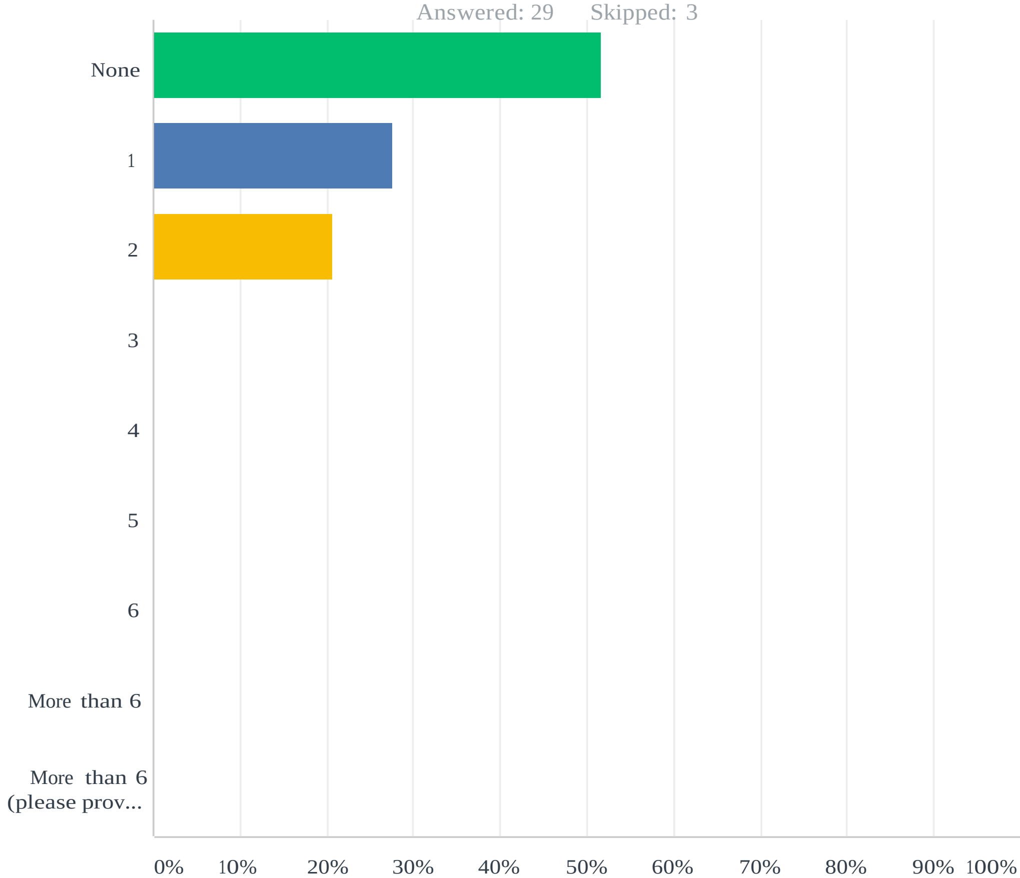
Answered: 29 Skipped: 3



Answer Choices	Responses	
1	48.28%	14
2	44.83%	13
3	3.45%	1
4	0.00%	0
5	3.45%	1
More than 5 (please provide number)	0.00%	0
TOTAL		29

Q27 How many monitors are shared by multiple people? (e.g. common navigation screen)

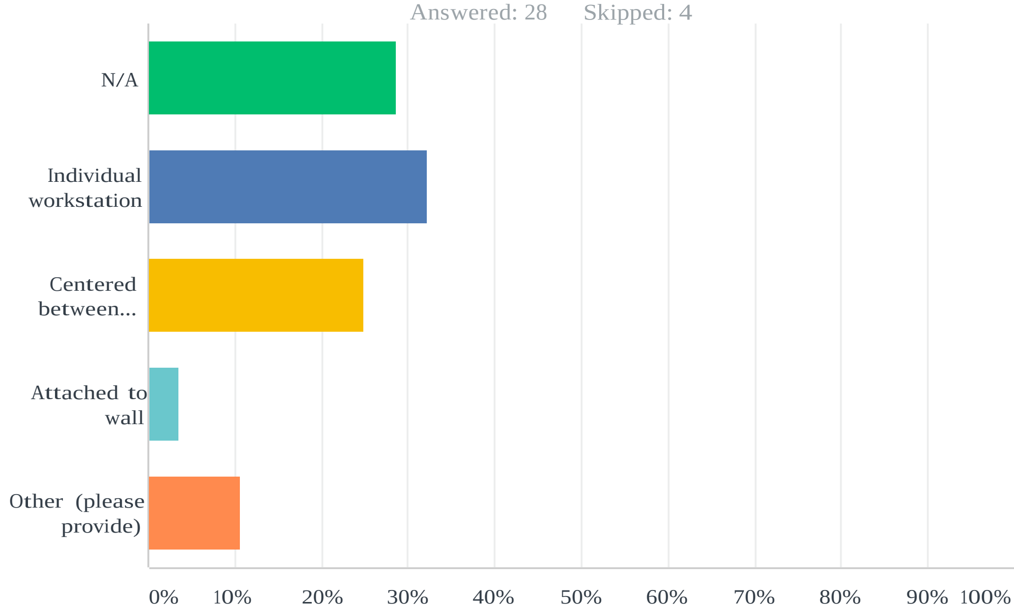
Answered: 29 Skipped: 3



Answer Choices	Responses	
None	51.72%	15
1	27.59%	8
2	20.69%	6
3	0.00%	0
4	0.00%	0
5	0.00%	0
6	0.00%	0
More than 6	0.00%	0
More than 6 (please provide number)	0.00%	0
TOTAL		29

Q28 Where are the most commonly shared monitors positioned?

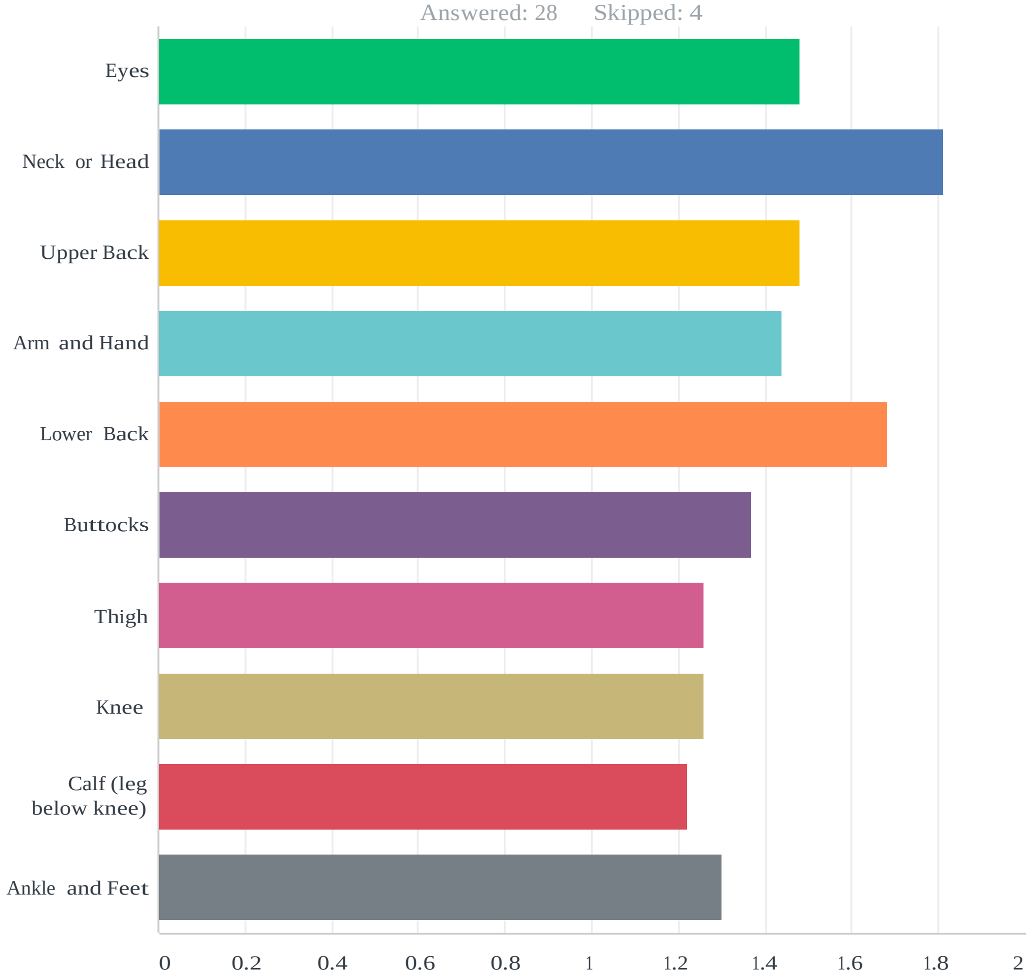
Answered: 28 Skipped: 4



Answer Choices	Responses	
N/A	28.57%	8
Individual workstation	32.14%	9
Centered between crew-members	25.00%	7
Attached to wall	3.57%	1
Other (please provide)	10.71%	3
TOTAL		28

Q29 Do you experience any discomfort or fatigue while piloting from your workstation? If so, please mark the discomfort map below. The human body is split into sections and discomfort levels can be expressed for each section by selecting a number representative of the level of discomfort. Greater number values are associated with more discomfort.

Answered: 28 Skipped: 4

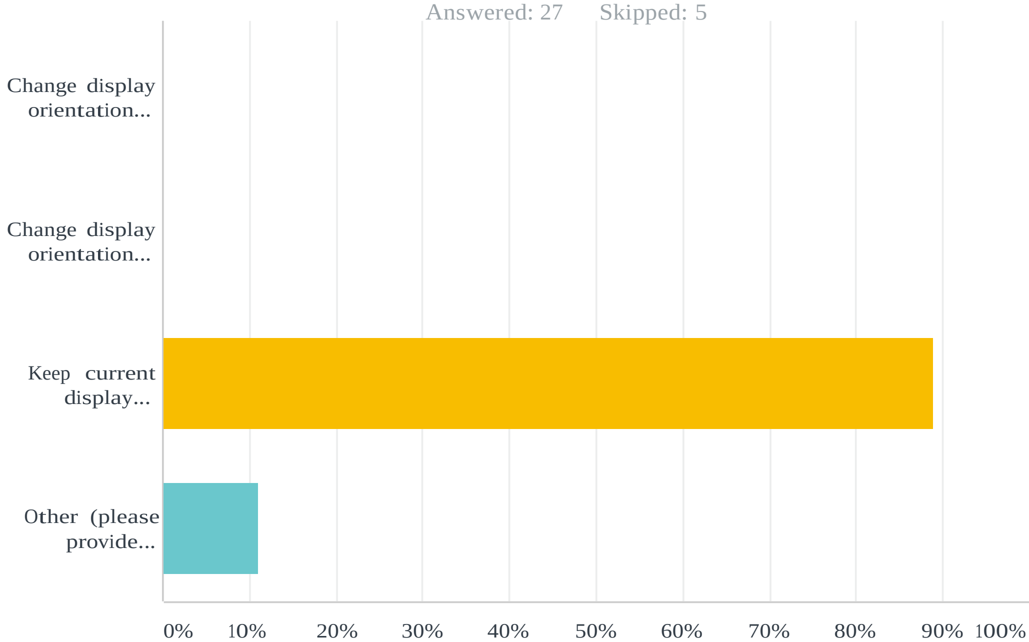


	1 - No Discomfort	2 - Slight Discomfort	3 - Moderate Discomfort	4 - Severe Discomfort	5 - Extreme Discomfort	Total	Weighted Average
Eyes	59.26% 16	33.33% 9	7.41% 2	0.00% 0	0.00% 0	27	1.48
Neck or Head	44.44% 12	29.63% 8	25.93% 7	0.00% 0	0.00% 0	27	1.81
Upper Back	66.67% 18	18.52% 5	14.81% 4	0.00% 0	0.00% 0	27	1.48
Arm and Hand	62.96% 17	29.63% 8	7.41% 2	0.00% 0	0.00% 0	27	1.44
Lower Back	53.57% 15	28.57% 8	14.29% 4	3.57% 1	0.00% 0	28	1.68

Buttocks	70.37% 19	22.22% 6	7.41% 2	0.00% 0	0.00% 0	27	1.37
Thigh	77.78% 21	18.52% 5	3.70% 1	0.00% 0	0.00% 0	27	1.26
Knee	81.48% 22	11.11% 3	7.41% 2	0.00% 0	0.00% 0	27	1.26
Calf (leg below knee)	81.48% 22	14.81% 4	3.70% 1	0.00% 0	0.00% 0	27	1.22
Ankle and Feet	77.78% 21	14.81% 4	7.41% 2	0.00% 0	0.00% 0	27	1.30

Q30 If you could change the display orientation of the work station, how would you change it?

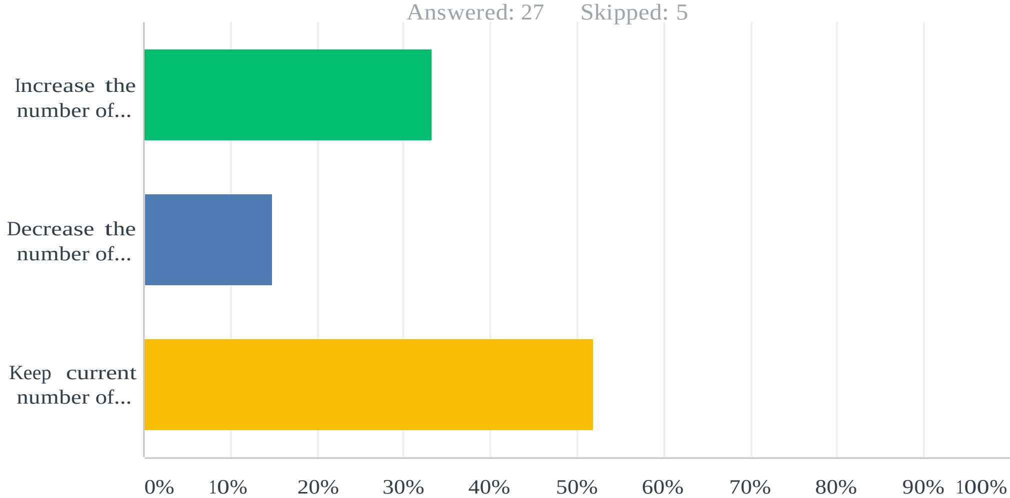
Answered: 27 Skipped: 5



Answer Choices	Responses	
Change display orientation from horizontal (side by side) to vertical (stacked)	0.00%	0
Change display orientation from vertical (stacked) to horizontal (side by side)	0.00%	0
Keep current display orientation	88.89%	24
Other (please provide description)	11.11%	3
TOTAL		27

Q31 If you could change the number of displays of your workstation, how would you change it?

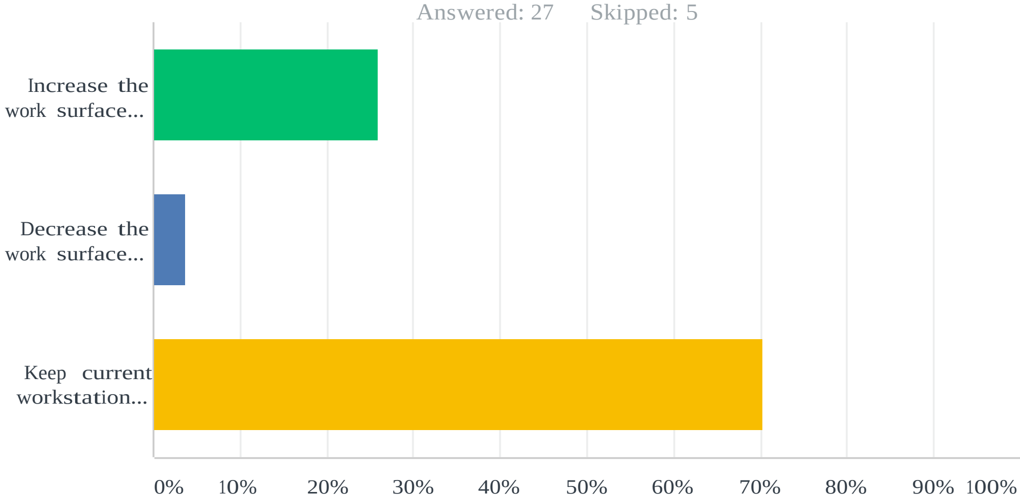
Answered: 27 Skipped: 5



Answer Choices	Responses	
Increase the number of displays	33.33%	9
Decrease the number of displays	14.81%	4
Keep current number of displays	51.85%	14
TOTAL		27

Q32 If you could change the work surface height of your workstation, how would you change it?

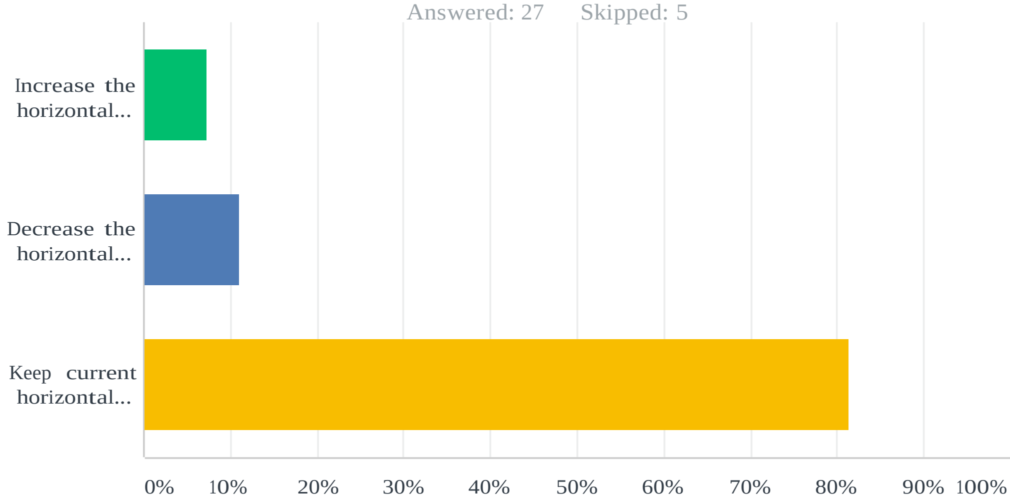
Answered: 27 Skipped: 5



Answer Choices	Responses	
Increase the work surface height	25.93%	7
Decrease the work surface height	3.70%	1
Keep current workstation height	70.37%	19
TOTAL		27

Q33 If you could change the horizontal reach distance to manipulate controls of your workstation, how would you change it?

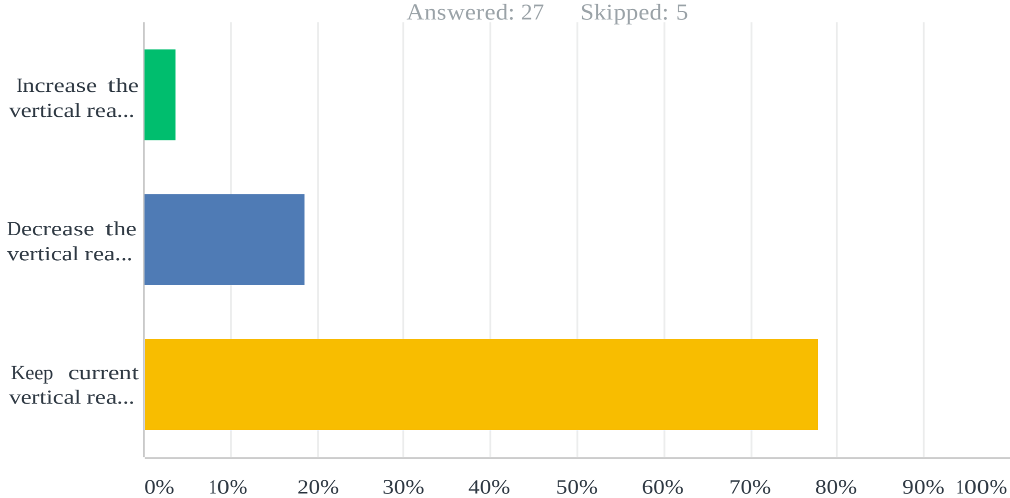
Answered: 27 Skipped: 5



Answer Choices	Responses	
Increase the horizontal reach distance to manipulate controls	7.41%	2
Decrease the horizontal reach distance to manipulate controls	11.11%	3
Keep current horizontal reach distance	81.48%	22
TOTAL		27

Q34 If you could change the vertical reach distance to manipulate controls of your workstation, how would you change it?

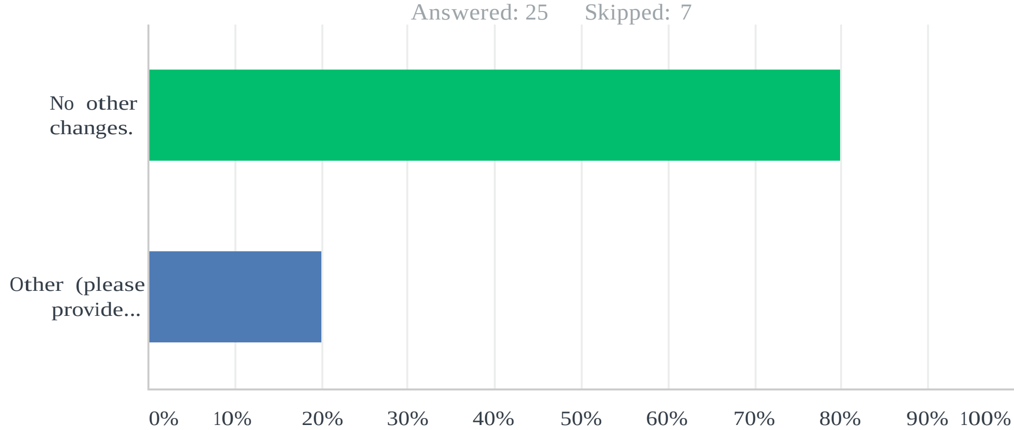
Answered: 27 Skipped: 5



Answer Choices	Responses	
Increase the vertical reach distance to manipulate controls	3.70%	1
Decrease the vertical reach distance to manipulate controls	18.52%	5
Keep current vertical reach distance	77.78%	21
TOTAL		27

Q35 If you could change anything else about the physical layout of your workstation, that was not covered by questions 30-34, what would it be?

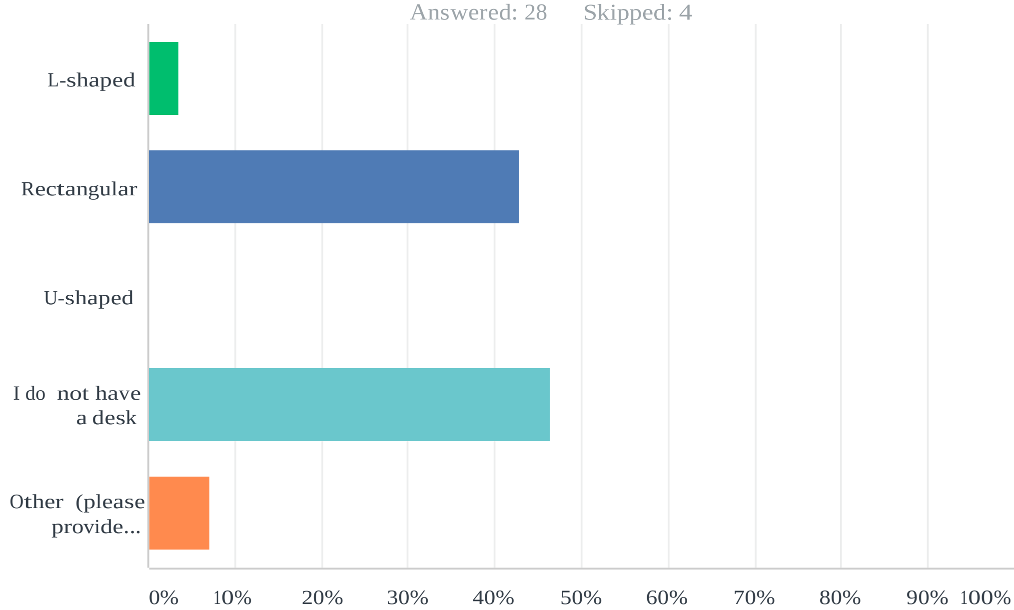
Answered: 25 Skipped: 7



Answer Choices	Responses	
No other changes.	80.00%	20
Other (please provide description)	20.00%	5
TOTAL		25

Q36 What does your work surface look like?

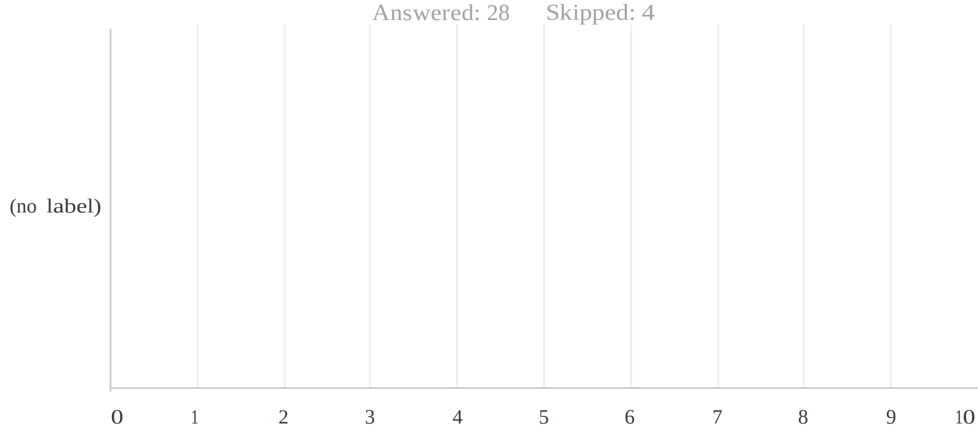
Answered: 28 Skipped: 4



Answer Choices	Responses	
L-shaped	3.57%	1
Rectangular	42.86%	12
U-shaped	0.00%	0
I do not have a desk	46.43%	13
Other (please provide description)	7.14%	2
TOTAL		28

Q37 Do you agree that your current work surface is the best design for your operations?

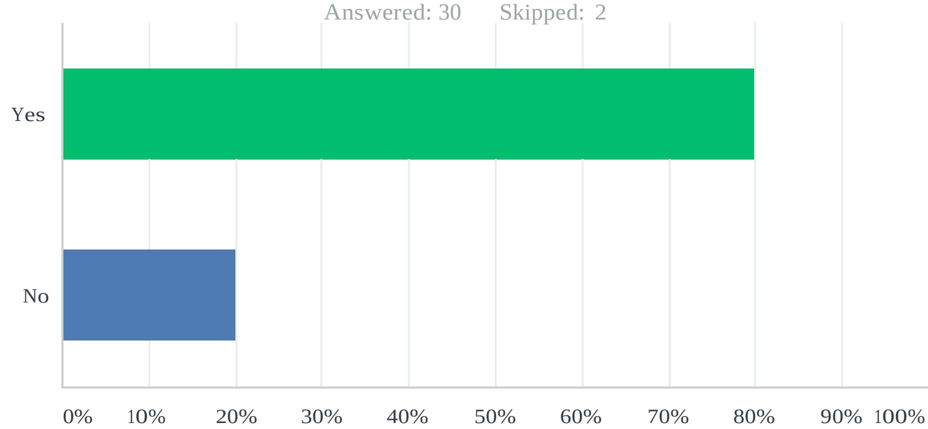
Answered: 28 Skipped: 4



	Strongly Disagree	Disagree	Neither Disagree nor Agree	Agree	Strongly Agree	Total	Weighted Average
(no label)	10.71% 3	17.86% 5	35.71% 10	35.71% 10	0.00% 0	28	0.00

Q38 Do you or someone you know control UASs in a mobile environment?

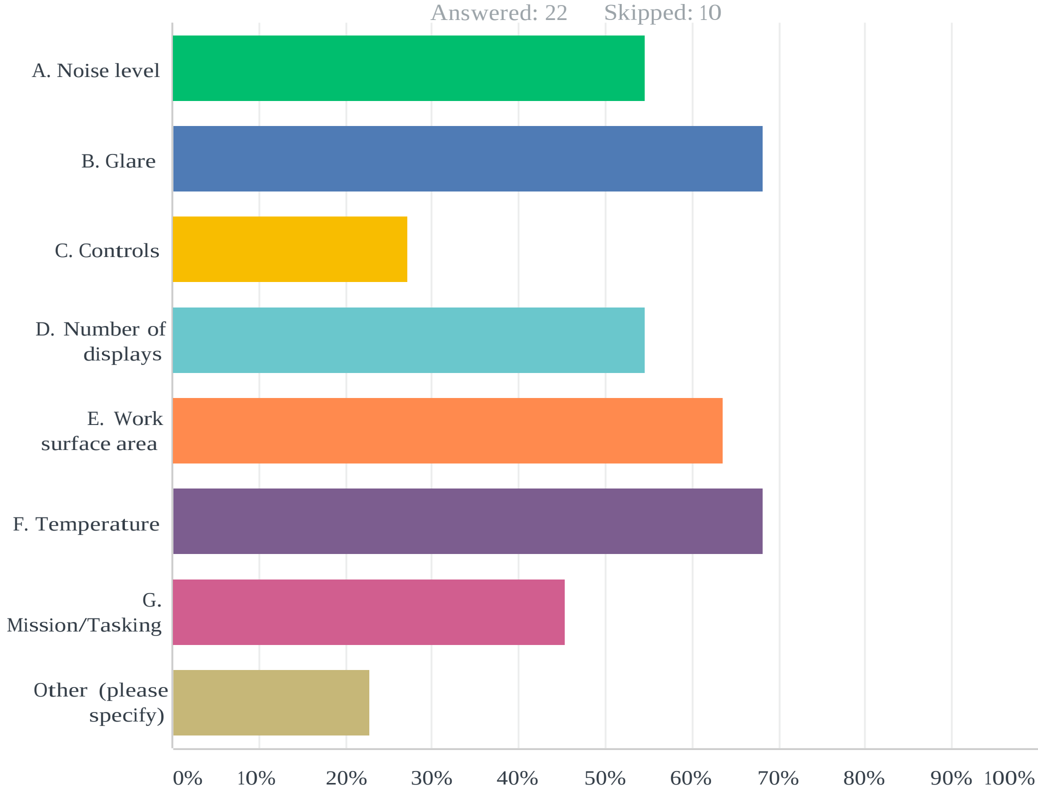
Answered: 30 Skipped: 2



Answer Choices	Responses	
Yes	80.00%	24
No	20.00%	6
TOTAL		30

Q39 What is different between the mobile and fixed ground control stations? (select all that apply)

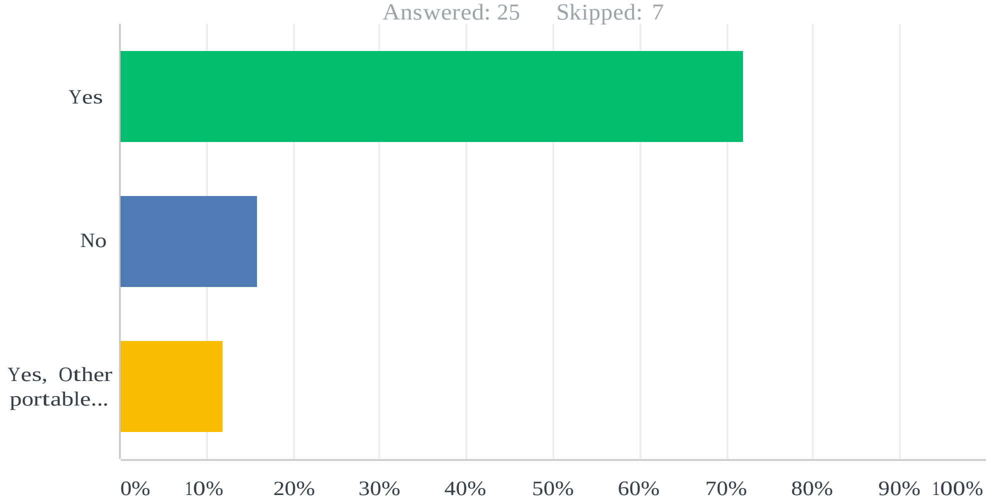
Answered: 22 Skipped: 10



Answer Choices	Responses	
A. Noise level	54.55%	12
B. Glare	68.18%	15
C. Controls	27.27%	6
D. Number of displays	54.55%	12
E. Work surface area	63.64%	14
F. Temperature	68.18%	15
G. Mission/Tasking	45.45%	10
Other (please specify)	22.73%	5
Total Respondents: 22		

Q40 Do you use a backpack or other portable solution to transport UAS specific items when mobile and controlling a UAS?

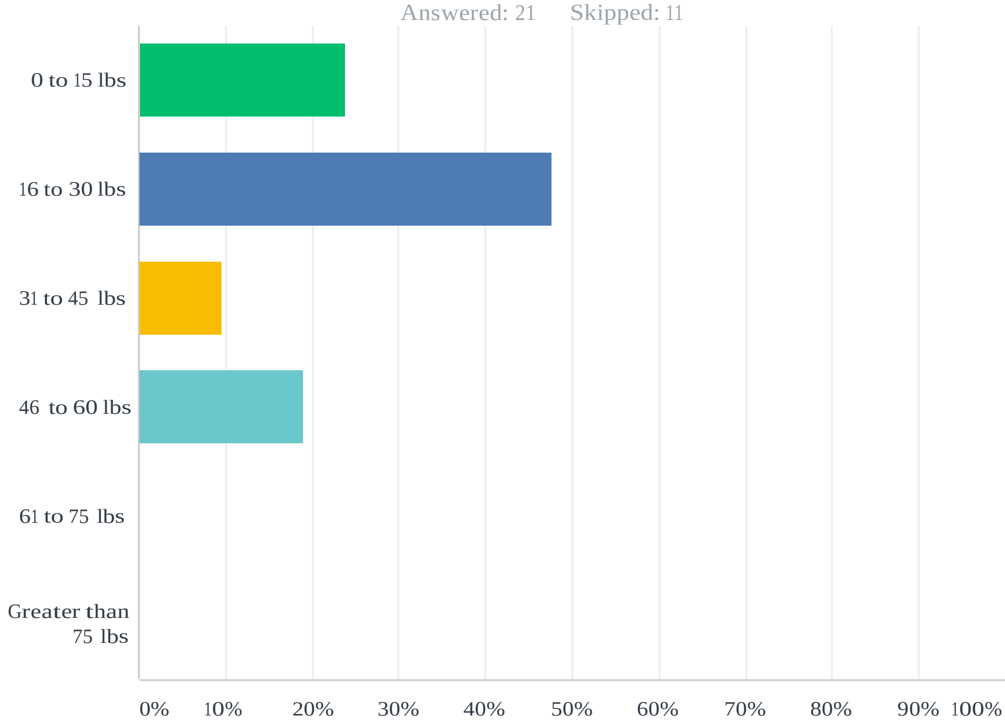
Answered: 25 Skipped: 7



Answer Choices	Responses	
Yes	72.00%	18
No	16.00%	4
Yes, Other portable solution (please specify)	12.00%	3
TOTAL		25

Q41 How heavy is the backpack or other portable solution when loaded with UAS specific items?

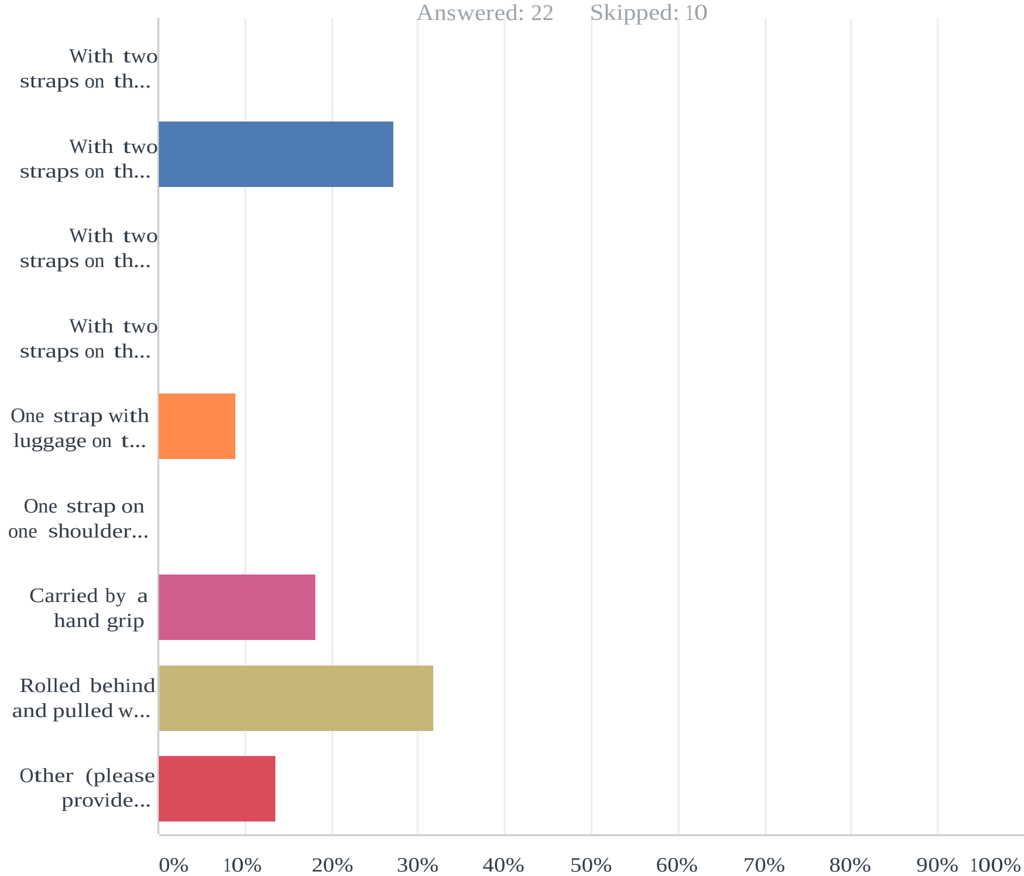
Answered: 21 Skipped: 11



Answer Choices	Responses	
0 to 15 lbs	23.81%	5
16 to 30 lbs	47.62%	10
31 to 45 lbs	9.52%	2
46 to 60 lbs	19.05%	4
61 to 75 lbs	0.00%	0
Greater than 75 lbs	0.00%	0
TOTAL		21

Q42 How is the backpack or other portable solution worn or carried?

Answered: 22 Skipped: 10



Answer Choices	Responses	
With two straps on the shoulders - Pack on front	0.00%	0
With two straps on the shoulders - Pack on back	27.27%	6
With two straps on the shoulders - Pack on front and back	0.00%	0
With two straps on the shoulders - Vest	0.00%	0
One strap with luggage on the same side of the body	9.09%	2
One strap on one shoulder and the luggage on the opposite side of the body	0.00%	0
Carried by a hand grip	18.18%	4
Rolled behind and pulled with a hand grip	31.82%	7
Other (please provide description)	13.64%	3
TOTAL		22

Q43 If you would be interested in participating in an interview to provide more detailed descriptions on control station design, please provide an email for us to contact you.

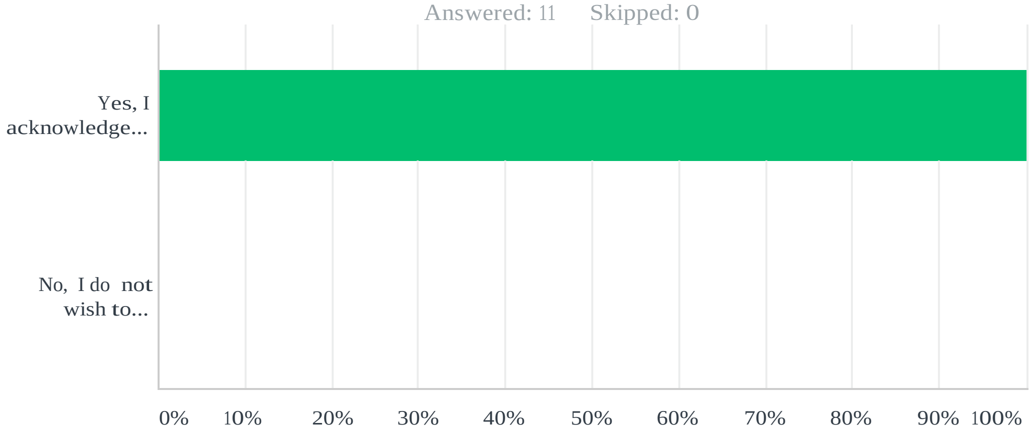
Answered: 15 Skipped: 17

Answer Choices	Responses	
Email:	100.00%	15

10.3 SURVEY DATA: GROUPS 3, 4, AND 5

Q1 Would you like to proceed with the survey?

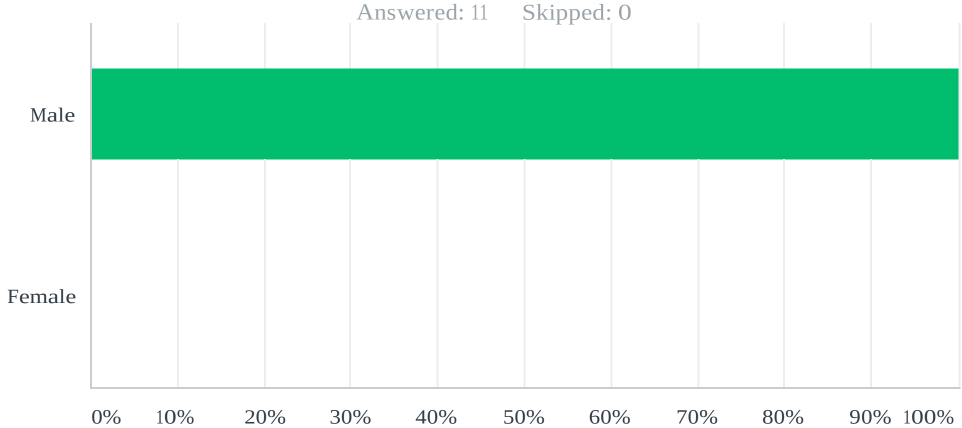
Answered: 11 Skipped: 0



Answer Choices	Responses	
Yes, I acknowledge that I have read the above information and would like to take the survey	100.00%	11
No, I do not wish to participate at this time	0.00%	0
TOTAL		11

Q2 Gender:

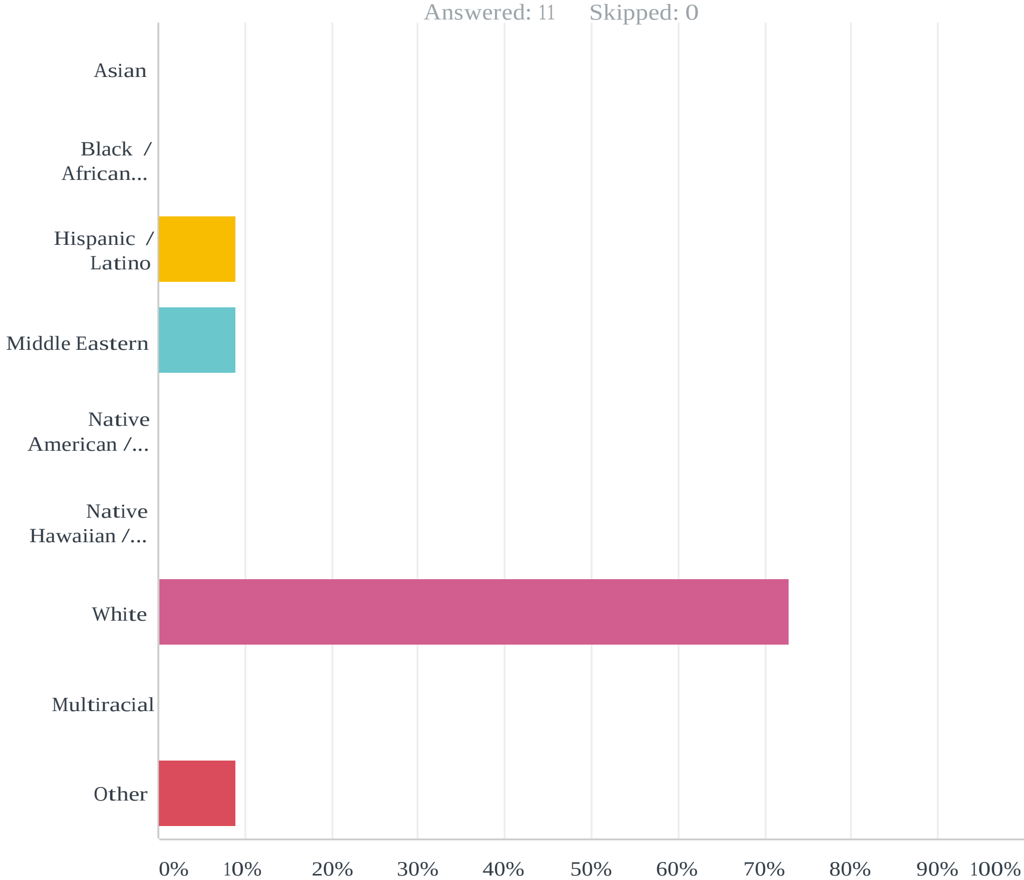
Answered: 11 Skipped: 0



Answer Choices	Responses	
Male	100.00%	11
Female	0.00%	0
TOTAL		11

Q3 Ethnicity:

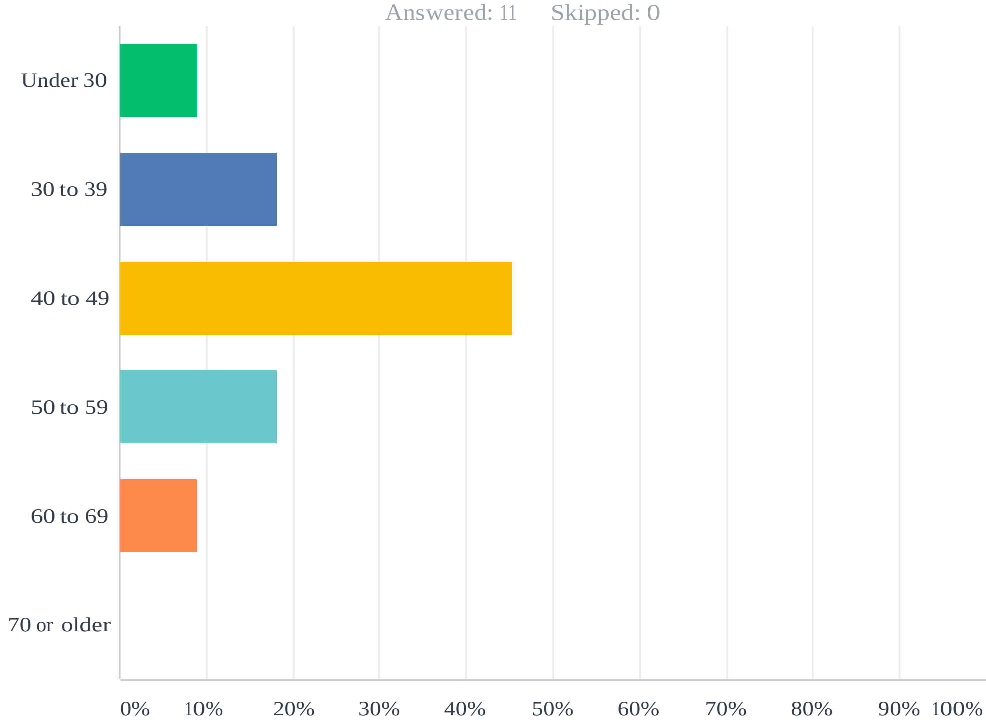
Answered: 11 Skipped: 0



Answer Choices	Responses	
Asian	0.00%	0
Black / African American	0.00%	0
Hispanic / Latino	9.09%	1
Middle Eastern	9.09%	1
Native American / Alaska Native	0.00%	0
Native Hawaiian / Other Pacific Islander	0.00%	0
White	72.73%	8
Multiracial	0.00%	0
Other	9.09%	1
TOTAL		11

Q4 Age:

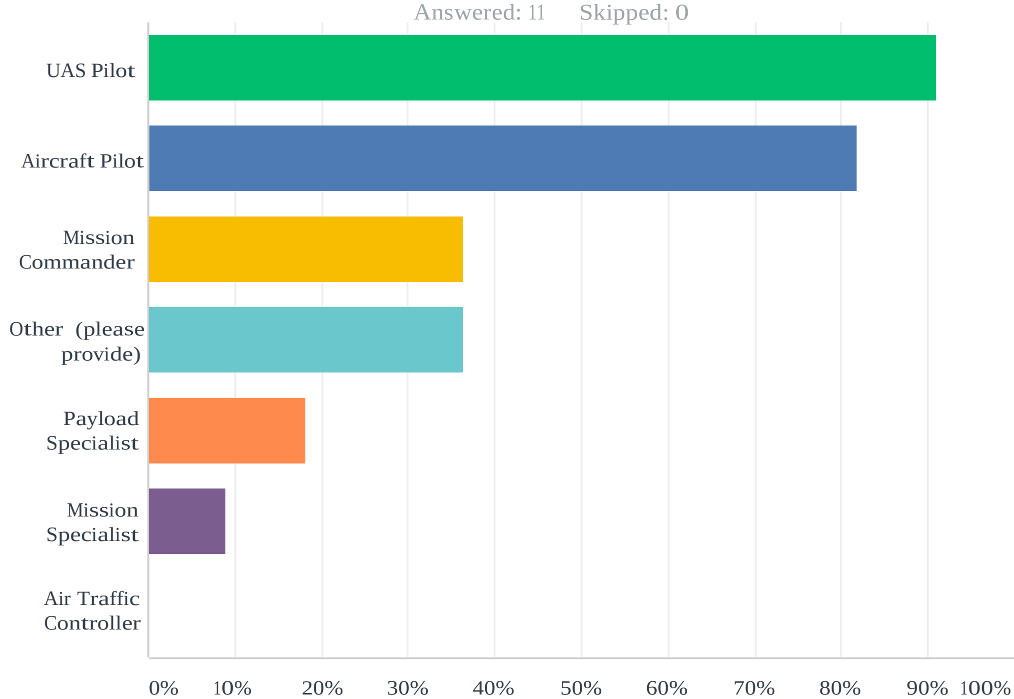
Answered: 11 Skipped: 0



Answer Choices	Responses	
Under 30	9.09%	1
30 to 39	18.18%	2
40 to 49	45.45%	5
50 to 59	18.18%	2
60 to 69	9.09%	1
70 or older	0.00%	0
TOTAL		11

Q5 I am a (select all that apply):

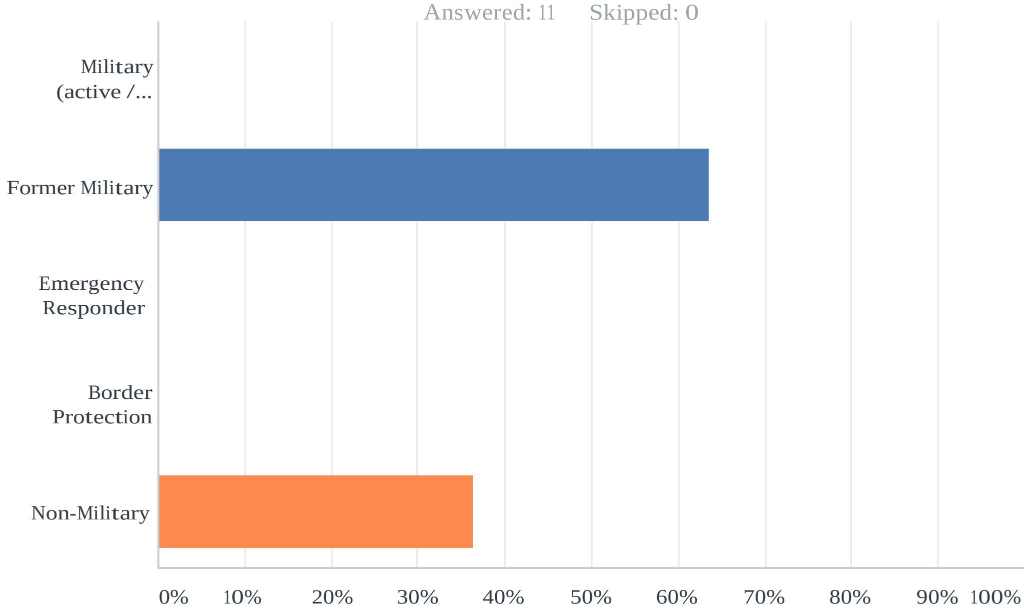
Answered: 11 Skipped: 0



Answer Choices	Responses	
UAS Pilot	90.91%	10
Aircraft Pilot	81.82%	9
Mission Commander	36.36%	4
Other (please provide)	36.36%	4
Payload Specialist	18.18%	2
Mission Specialist	9.09%	1
Air Traffic Controller	0.00%	0
Total Respondents: 11		

Q6 I am currently:

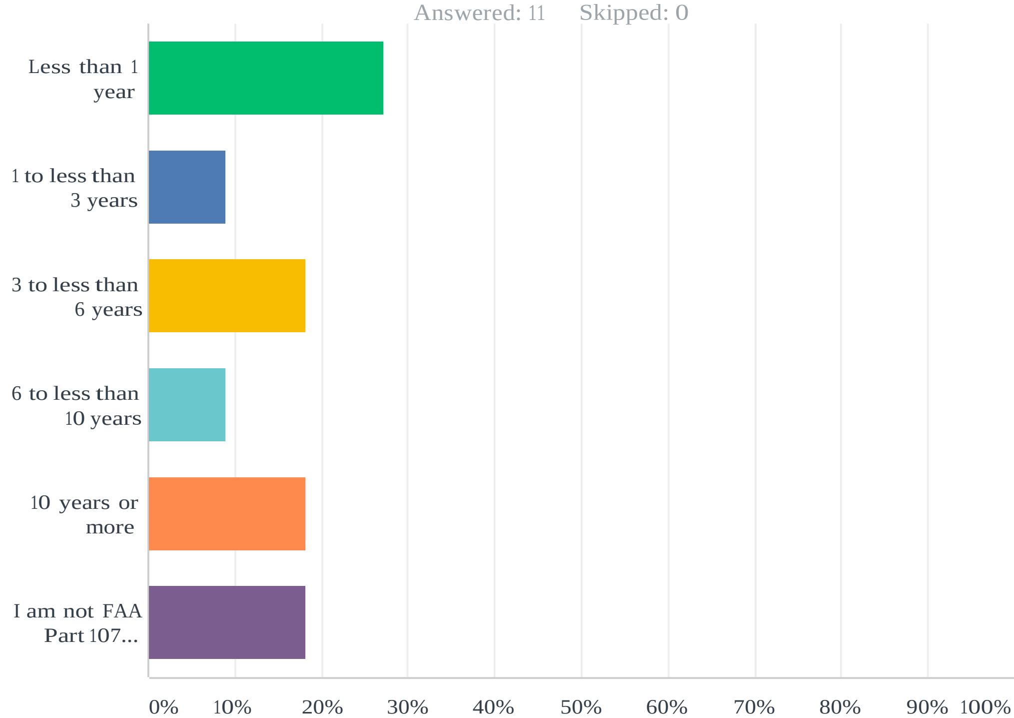
Answered: 11 Skipped: 0



Answer Choices	Responses	
Military (active / reserves)	0.00%	0
Former Military	63.64%	7
Emergency Responder	0.00%	0
Border Protection	0.00%	0
Non-Military	36.36%	4
TOTAL		11

Q7 I have held a FAA Part 107 certification or DOD equivalent to fly Unmanned Aircraft Systems [UAS] and drones for:

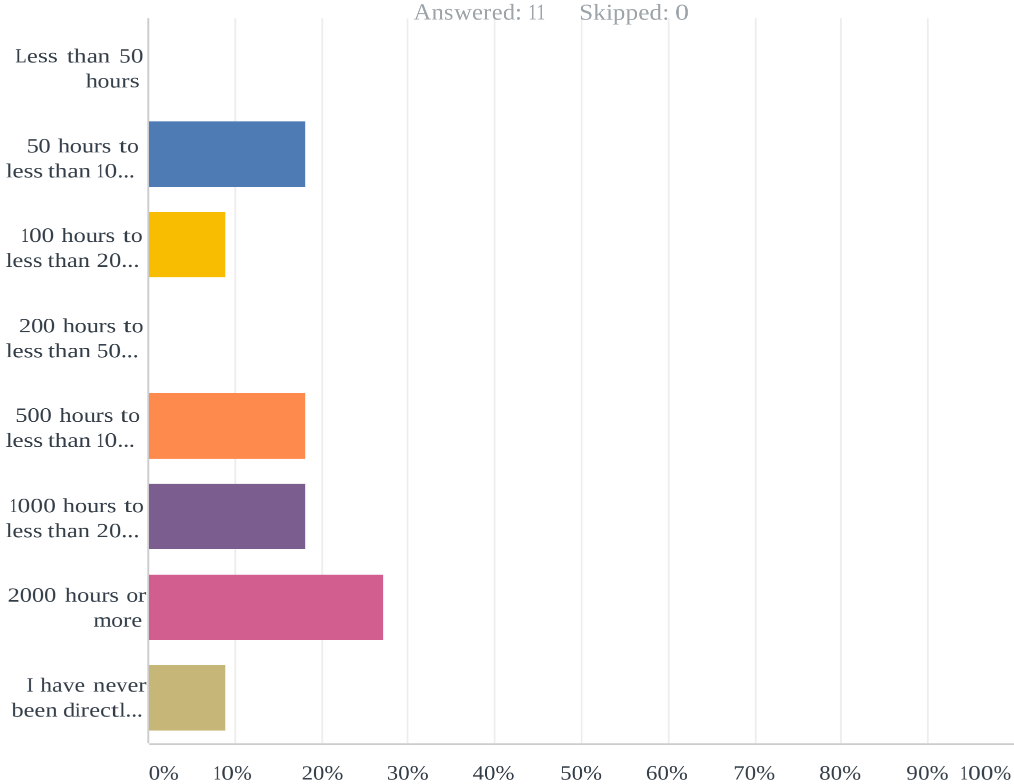
Answered: 11 Skipped: 0



Answer Choices	Responses	
Less than 1 year	27.27%	3
1 to less than 3 years	9.09%	1
3 to less than 6 years	18.18%	2
6 to less than 10 years	9.09%	1
10 years or more	18.18%	2
I am not FAA Part 107 certified	18.18%	2
TOTAL		11

Q8 I have flown/controlled unmanned flight operations for:

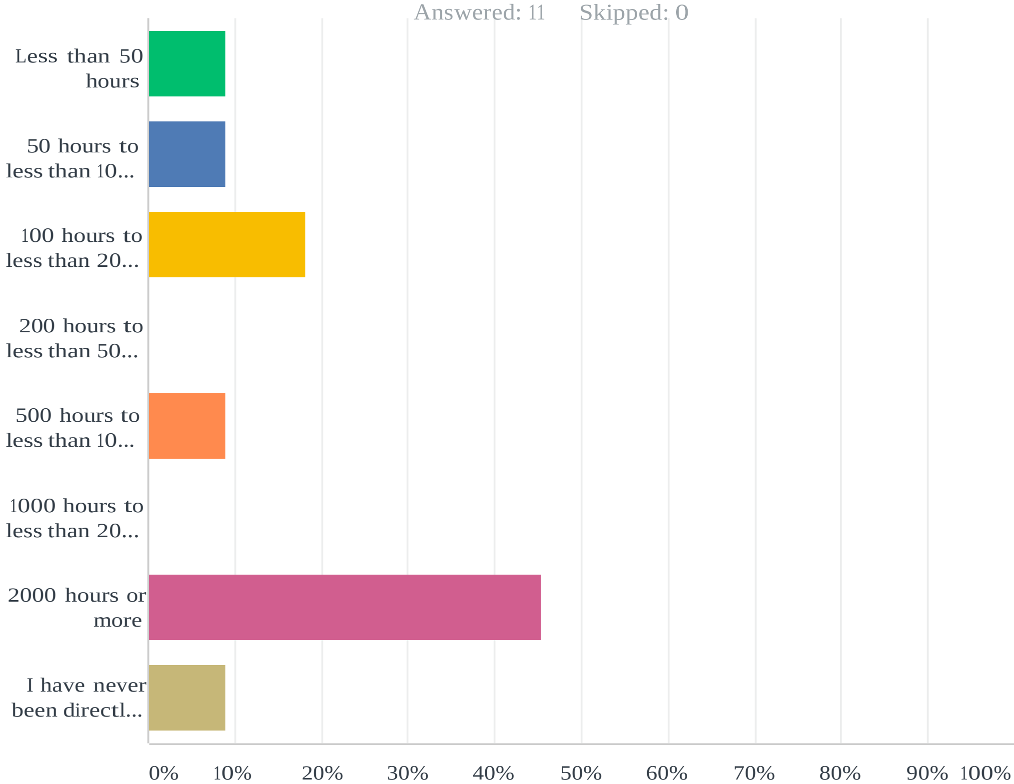
Answered: 11 Skipped: 0



Answer Choices	Responses	
Less than 50 hours	0.00%	0
50 hours to less than 100 hours	18.18%	2
100 hours to less than 200 hours	9.09%	1
200 hours to less than 500 hours	0.00%	0
500 hours to less than 1000 hours	18.18%	2
1000 hours to less than 2000 hours	18.18%	2
2000 hours or more	27.27%	3
I have never been directly involved with unmanned flight operations	9.09%	1
TOTAL		11

Q9 I have flown/controlled manned flight operations for:

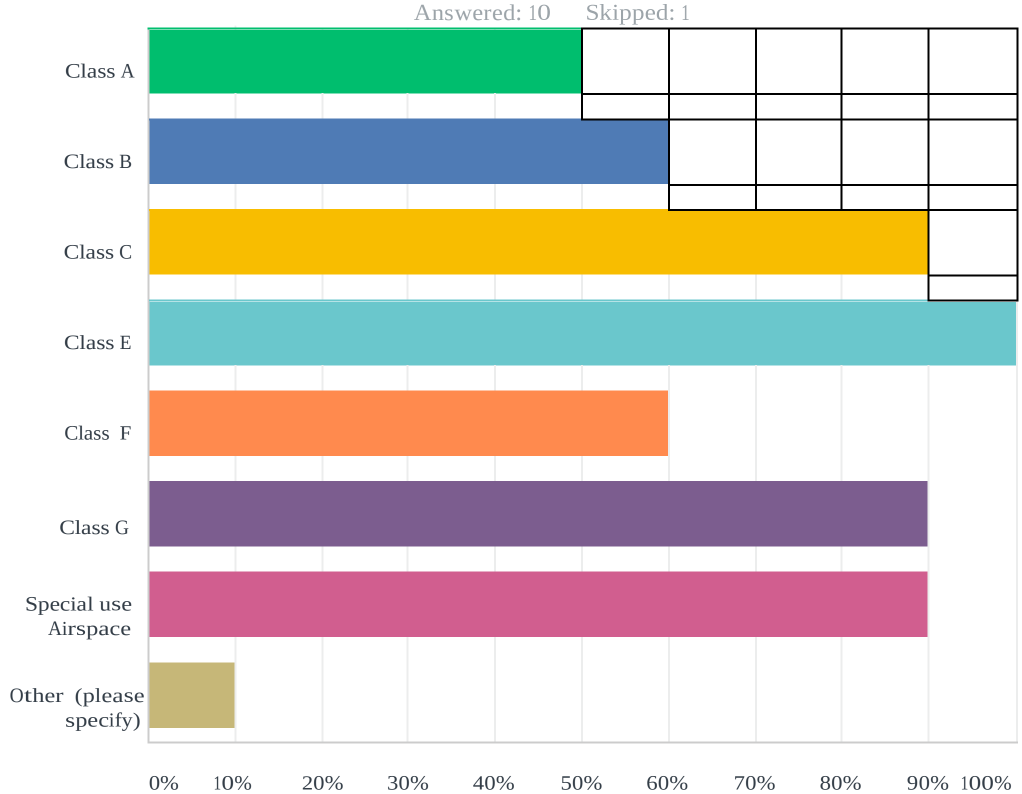
Answered: 11 Skipped: 0



Answer Choices	Responses	
Less than 50 hours	9.09%	1
50 hours to less than 100 hours	9.09%	1
100 hours to less than 200 hours	18.18%	2
200 hours to less than 500 hours	0.00%	0
500 hours to less than 1000 hours	9.09%	1
1000 hours to less than 2000 hours	0.00%	0
2000 hours or more	45.45%	5
I have never been directly involved with manned flight operations	9.09%	1
TOTAL		11

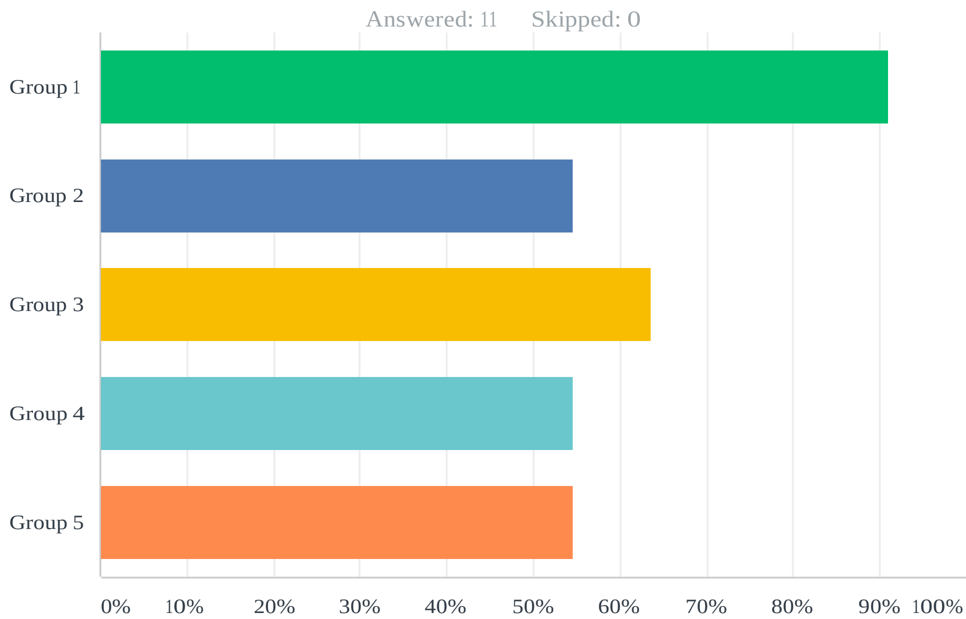
Q10 What classes of airspace is your experience in? (select all that apply)

Answered: 10   Skipped: 1



Answer Choices	Responses	
Class A	50.00%	5
Class B	60.00%	6
Class C	90.00%	9
Class E	100.00%	10
Class F	60.00%	6
Class G	90.00%	9
Special use Airspace	90.00%	9
Other (please specify)	10.00%	1
Total Respondents: 10		

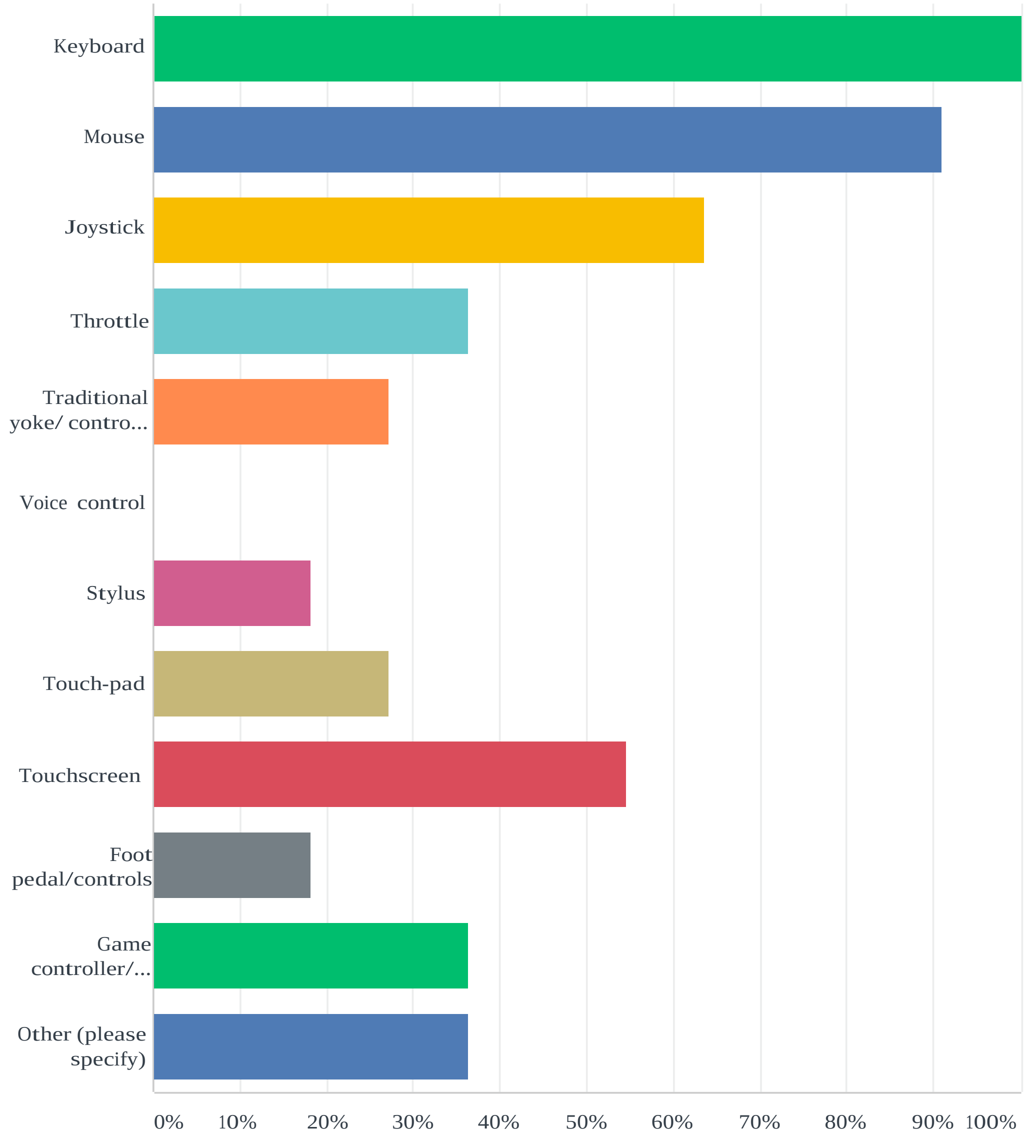
Q11 What type(s) of UAS based on the categories described below do you currently or have previously controlled (select all that apply)?



Answer Choices	Responses	
Group 1	90.91%	10
Group 2	54.55%	6
Group 3	63.64%	7
Group 4	54.55%	6
Group 5	54.55%	6
Total Respondents: 11		

Q12 What controls do you use in ground control stations to control UASs? (select all that apply)

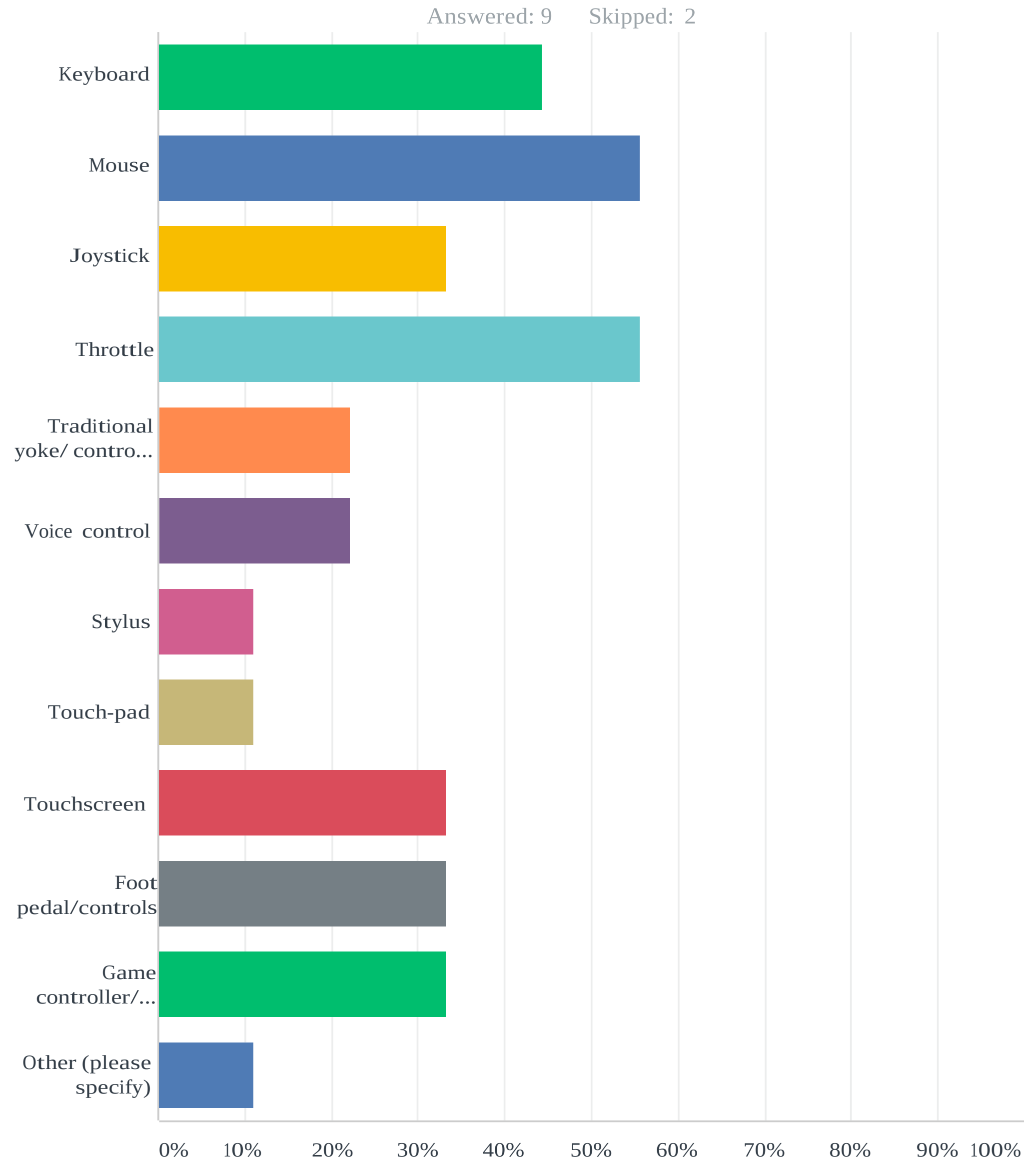
Answered: 11 Skipped: 0



Answer Choices	Responses	
Keyboard	100.00%	11
Mouse	90.91%	10
Joystick	63.64%	7
Throttle	36.36%	4
Traditional yoke/ control stick	27.27%	3
Voice control	0.00%	0
Stylus	18.18%	2
Touch-pad	27.27%	3

Touchscreen	54.55%	6
Foot pedal/controls	18.18%	2
Game controller/ Game pad	36.36%	4
Other (please specify)	36.36%	4
Total Respondents: 11		

Q13 What controls would you recommend to add to control stations to help make the task easier? (select all that apply)

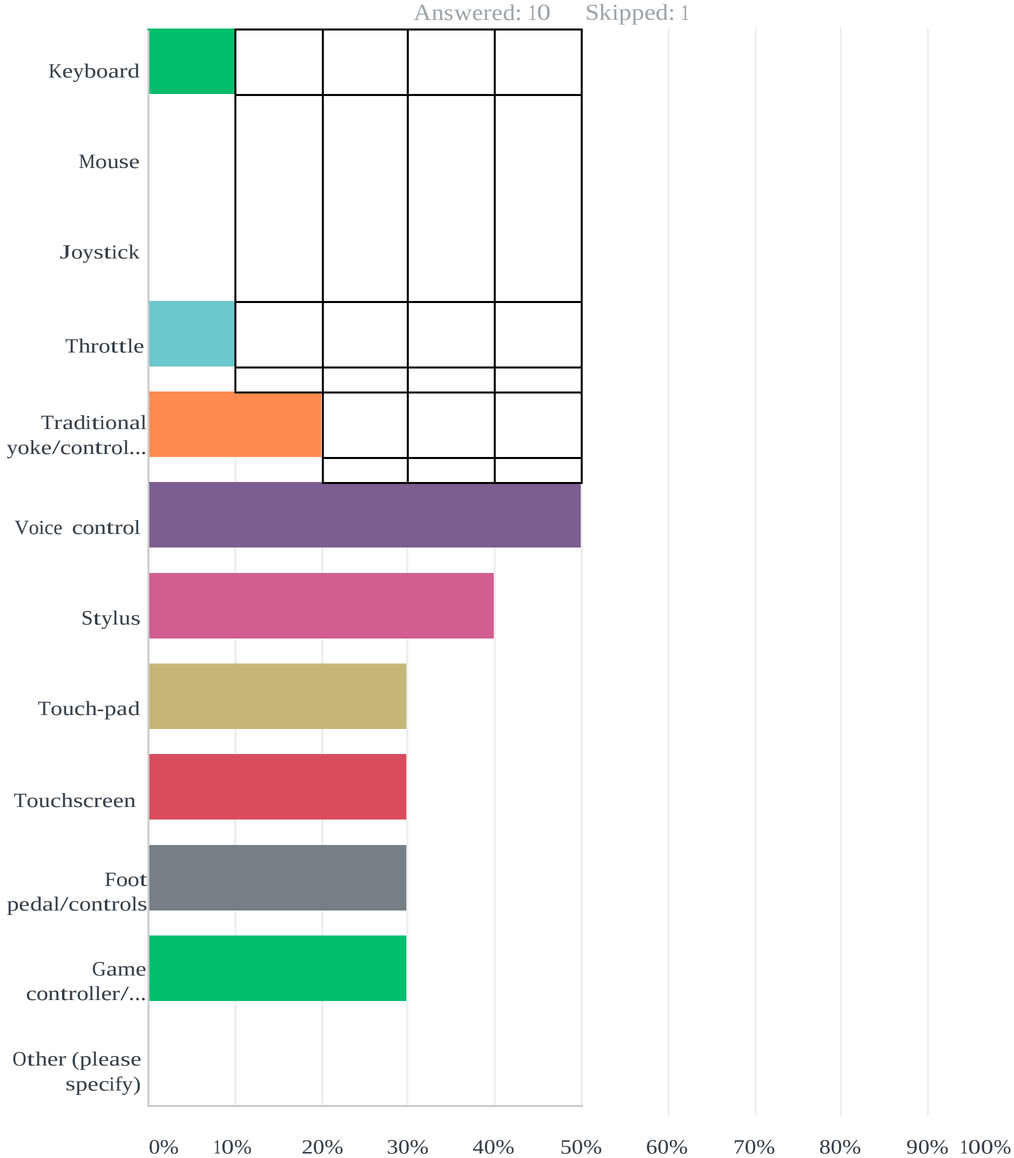


Answer Choices	Responses	
Keyboard	44.44%	4
Mouse	55.56%	5
Joystick	33.33%	3
Throttle	55.56%	5
Traditional yoke/ control stick	22.22%	2
Voice control	22.22%	2
Stylus	11.11%	1
Touch-pad	11.11%	1

Touchscreen	33.33%	3
Foot pedal/controls	33.33%	3
Game controller/ Game pad	33.33%	3
Other (please specify)	11.11%	1
Total Respondents: 9		

Q14 What controls would you recommend to remove from stations to help make the task easier? (select all that apply)

Answered: 10 Skipped: 1

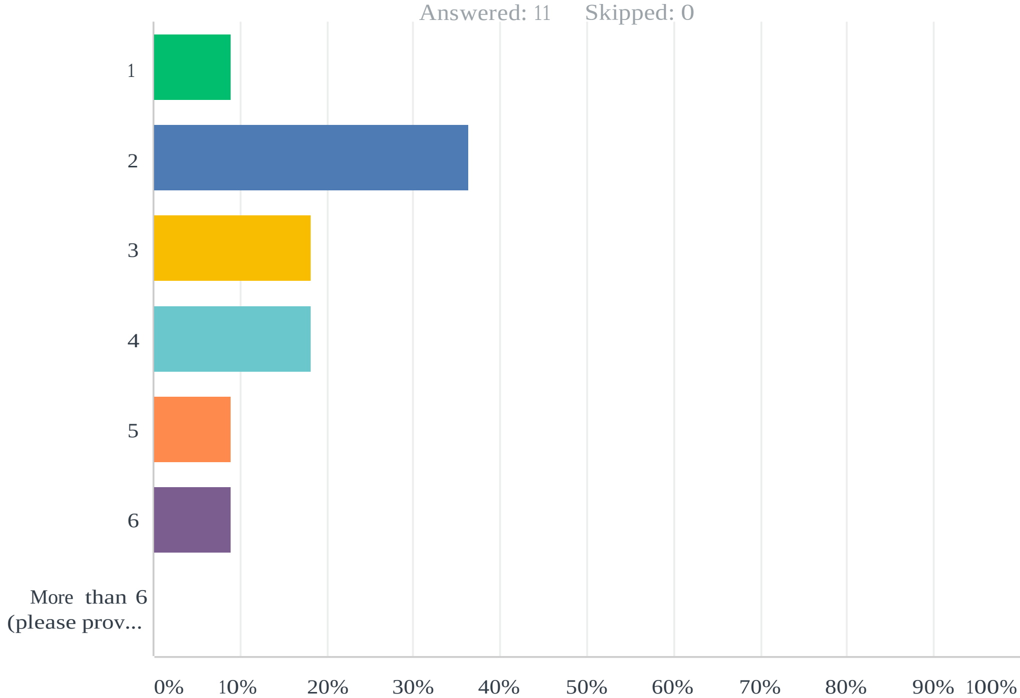


Answer Choices	Responses	
Keyboard	10.00%	1
Mouse	0.00%	0
Joystick	0.00%	0
Throttle	10.00%	1
Traditional yoke/control stick	20.00%	2
Voice control	50.00%	5
Stylus	40.00%	4
Touch-pad	30.00%	3

Touchscreen	30.00%	3
Foot pedal/controls	30.00%	3
Game controller/ Game pad	30.00%	3
Other (please specify)	0.00%	0
Total Respondents: 10		

Q15 How many displays are most commonly available in control stations that you use (have used)?

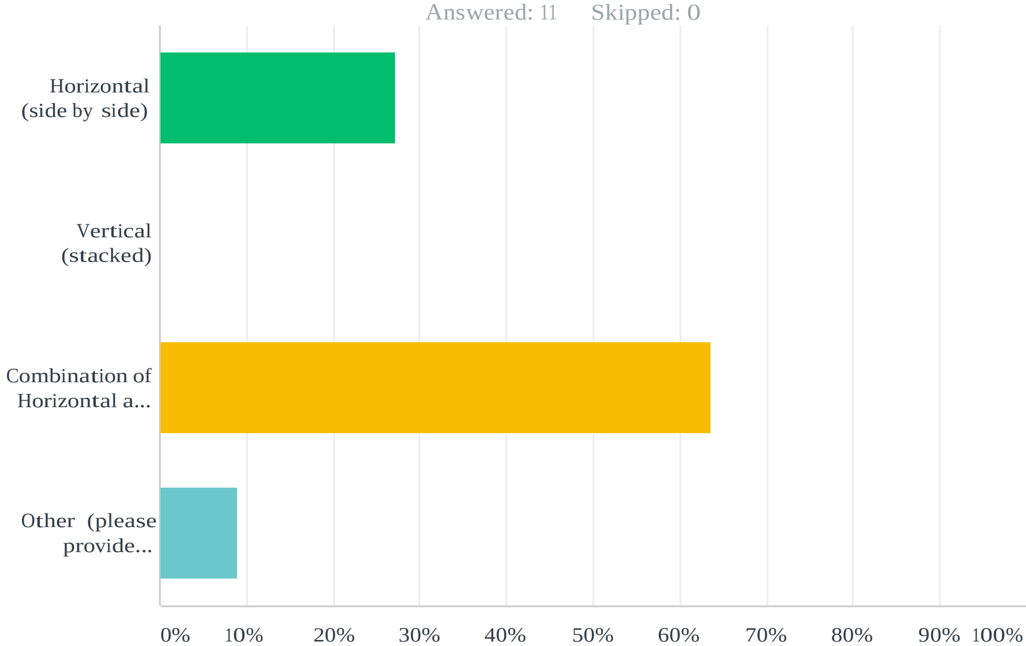
Answered: 11 Skipped: 0



Answer Choices	Responses	
1	9.09%	1
2	36.36%	4
3	18.18%	2
4	18.18%	2
5	9.09%	1
6	9.09%	1
More than 6 (please provide number)	0.00%	0
TOTAL		11

Q16 How are the displays oriented?

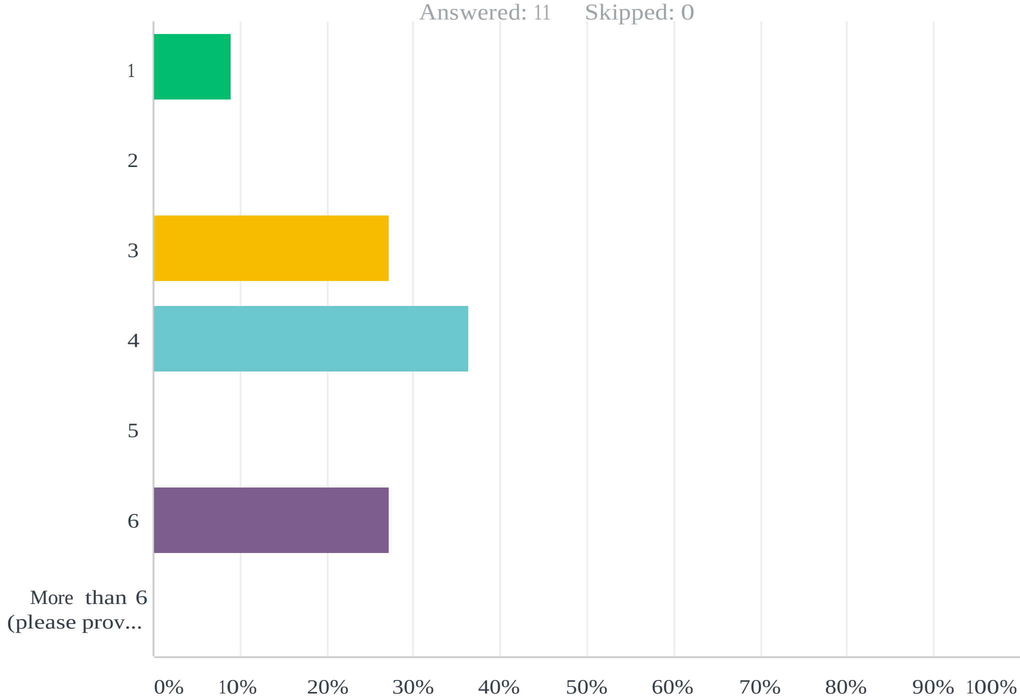
Answered: 11 Skipped: 0



Answer Choices	Responses	
Horizontal (side by side)	27.27%	3
Vertical (stacked)	0.00%	0
Combination of Horizontal and Vertical	63.64%	7
Other (please provide description)	9.09%	1
TOTAL		11

Q17 How many displays are you comfortable using to control a UAS?

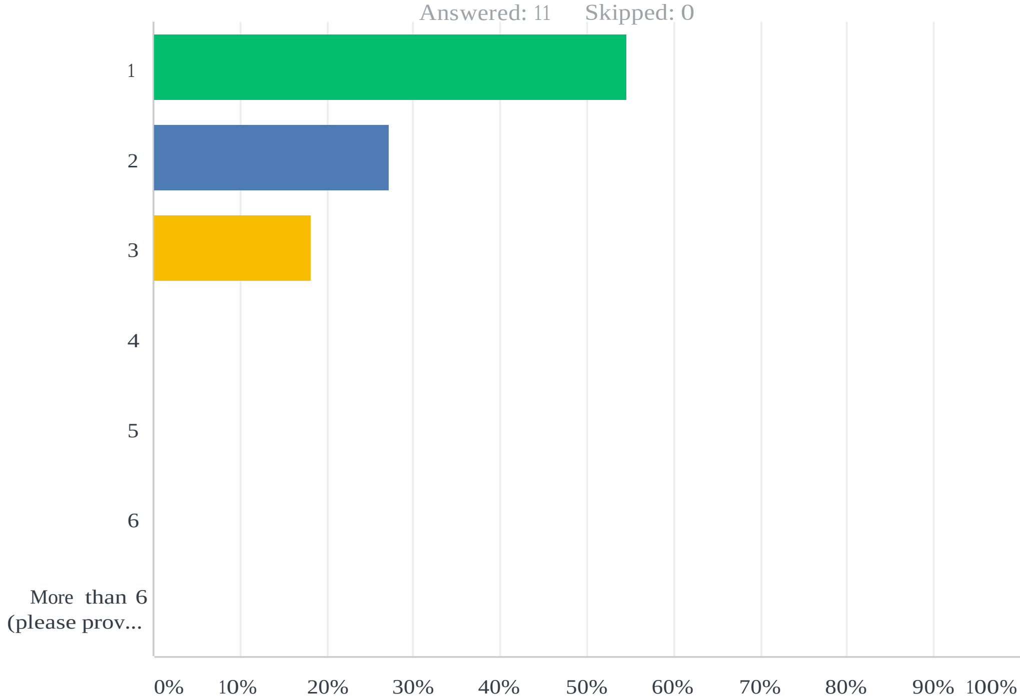
Answered: 11 Skipped: 0



Answer Choices	Responses	
1	9.09%	1
2	0.00%	0
3	27.27%	3
4	36.36%	4
5	0.00%	0
6	27.27%	3
More than 6 (please provide number)	0.00%	0
TOTAL		11

Q18 What is the minimum number of control station displays needed (for flight and performance data) to pilot a UAS?

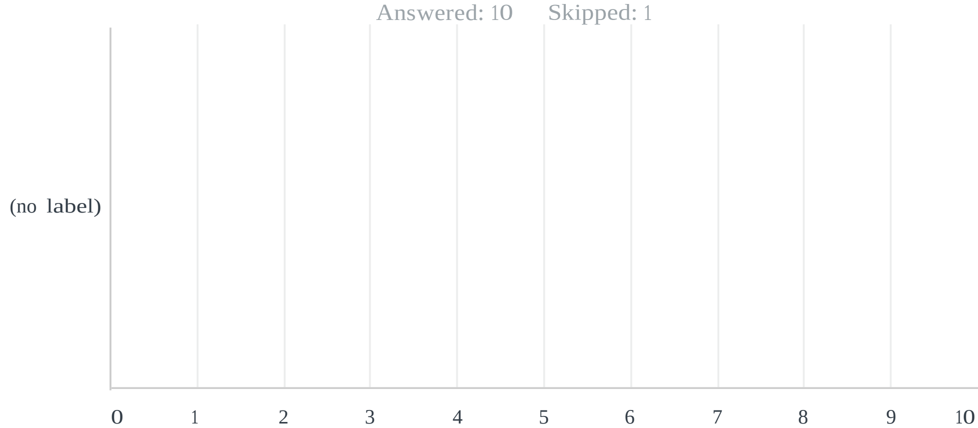
Answered: 11 Skipped: 0



Answer Choices	Responses	
1	54.55%	6
2	27.27%	3
3	18.18%	2
4	0.00%	0
5	0.00%	0
6	0.00%	0
More than 6 (please provide number)	0.00%	0
TOTAL		11

Q19 To what extent do you agree with the following statement:My control station mimics the layout of a cockpit.

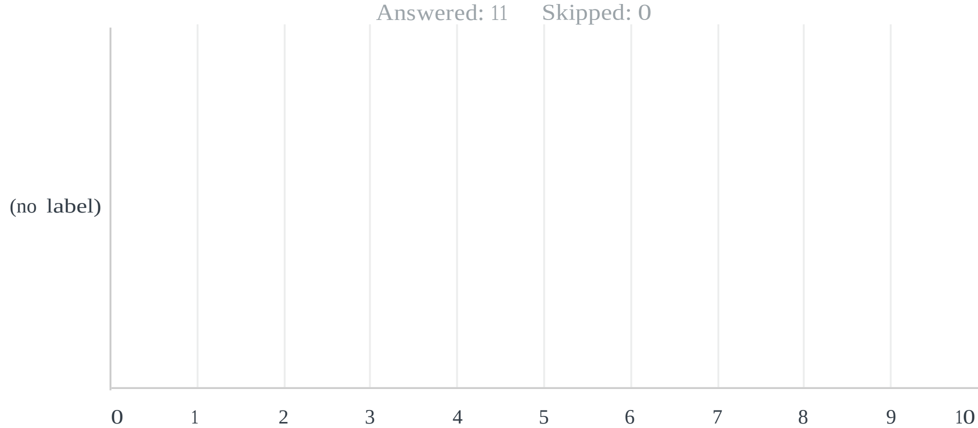
Answered: 10 Skipped: 1



	Strongly disagree	Disagree	Undecided	Agree	Strongly agree	Total	Weighted Average
(no label)	20.00% 2	50.00% 5	0.00% 0	20.00% 2	10.00% 1	10	0.00

Q20 On average what percentage of time per day do you sit while piloting in a control station?

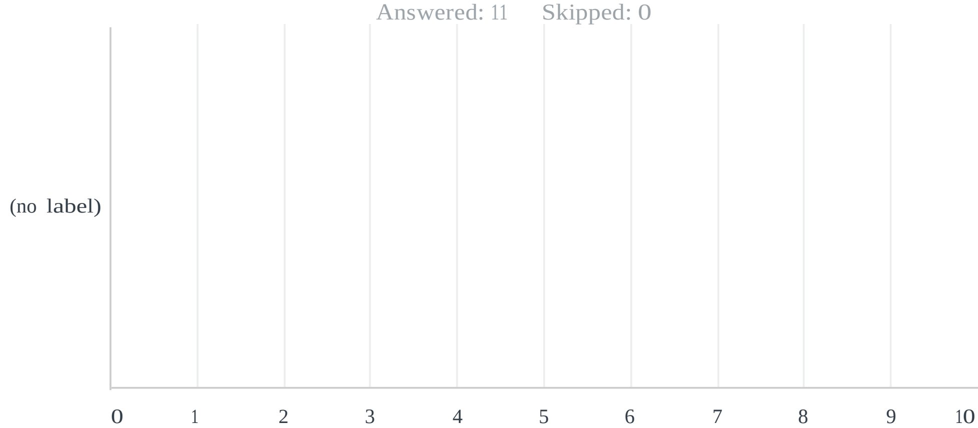
Answered: 11 Skipped: 0



	Never	Seldom	Sometimes	Often	Almost Always	Total	Weighted Average
(no label)	9.09% 1	18.18% 2	18.18% 2	9.09% 1	45.45% 5	11	0.00

Q21 Using the scale below rate your level of comfort when using UAS control station.

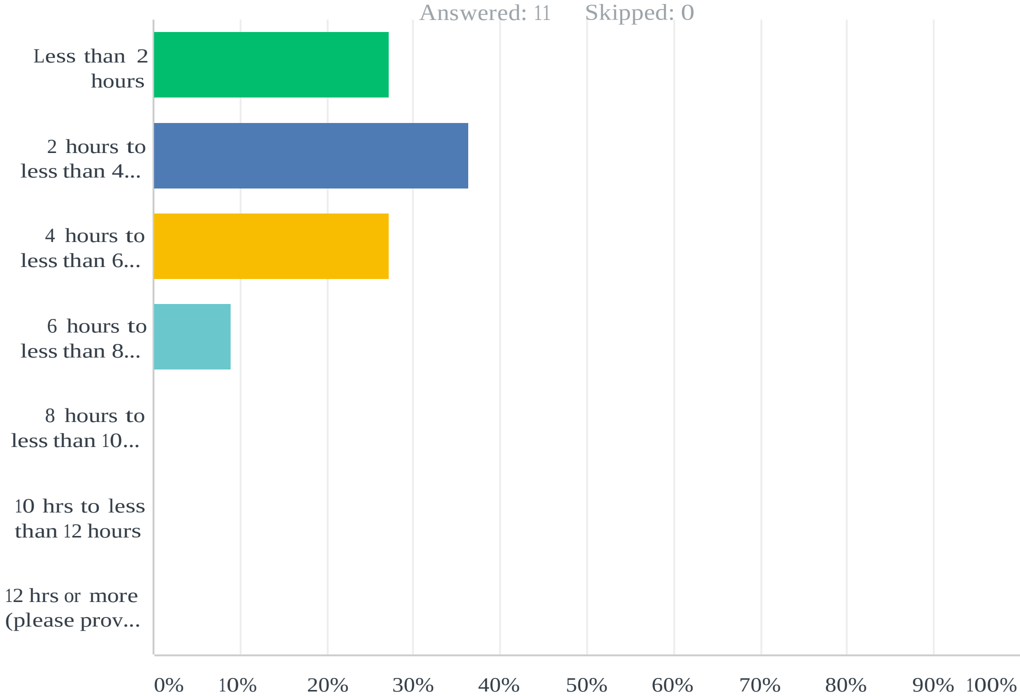
Answered: 11 Skipped: 0



	Very Uncomfortable	Uncomfortable	Neither Uncomfortable nor Comfortable	Comfortable	Very Comfortable	Total	Weighted Average
(no label)	0.00% 0	18.18% 2	18.18% 2	45.45% 5	18.18% 2	11	0.00

Q22 How much time do you spend a day piloting in a control station?

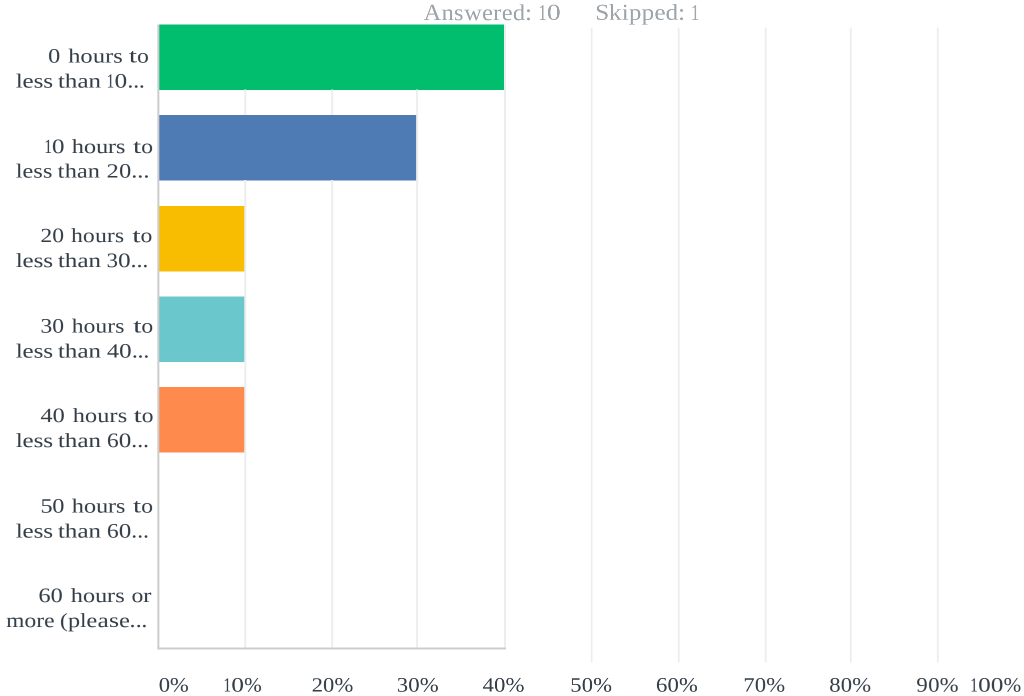
Answered: 11 Skipped: 0



Answer Choices	Responses	
Less than 2 hours	27.27%	3
2 hours to less than 4 hours	36.36%	4
4 hours to less than 6 hours	27.27%	3
6 hours to less than 8 hours	9.09%	1
8 hours to less than 10 hours	0.00%	0
10 hrs to less than 12 hours	0.00%	0
12 hrs or more (please provide number)	0.00%	0
TOTAL		11

Q23 How much time do you spend a week piloting in a control station?

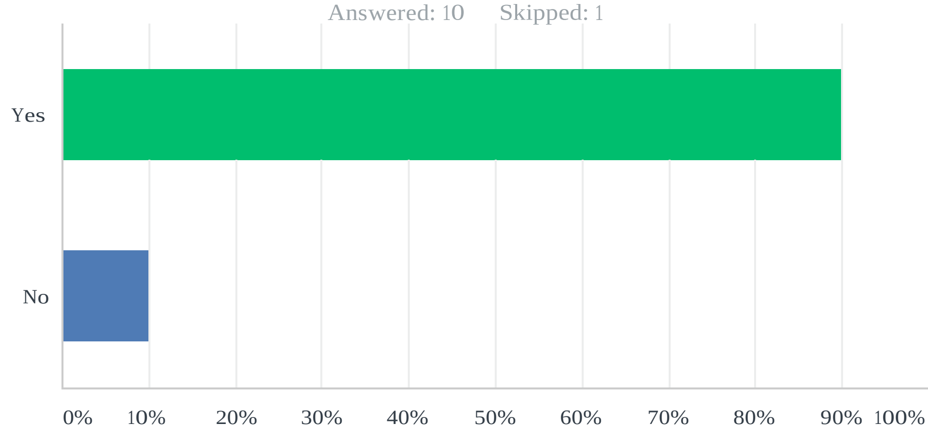
Answered: 10 Skipped: 1



Answer Choices	Responses	
0 hours to less than 10 hours	40.00%	4
10 hours to less than 20 hours	30.00%	3
20 hours to less than 30 hours	10.00%	1
30 hours to less than 40 hours	10.00%	1
40 hours to less than 60 hours	10.00%	1
50 hours to less than 60 hours	0.00%	0
60 hours or more (please provide number)	0.00%	0
TOTAL		10

Q24 Are other people frequently in or near the control station while you are piloting UAS in a control station?

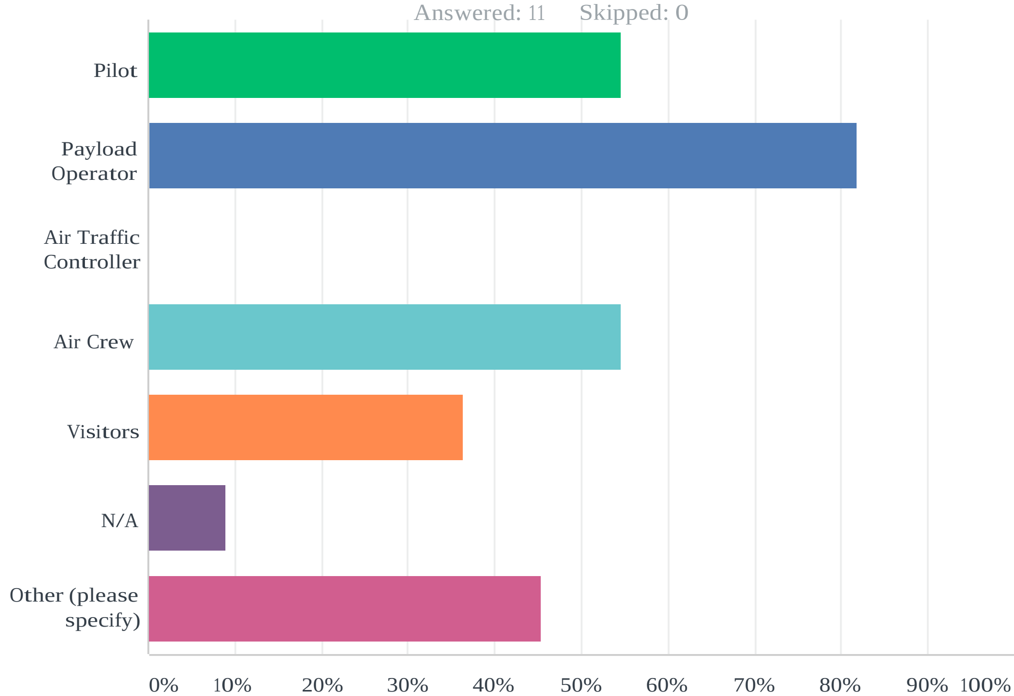
Answered: 10 Skipped: 1



Answer Choices	Responses	
Yes	90.00%	9
No	10.00%	1
TOTAL		10

Q25 If there are other people in or near the control station while you are piloting a UAS, what is their role?

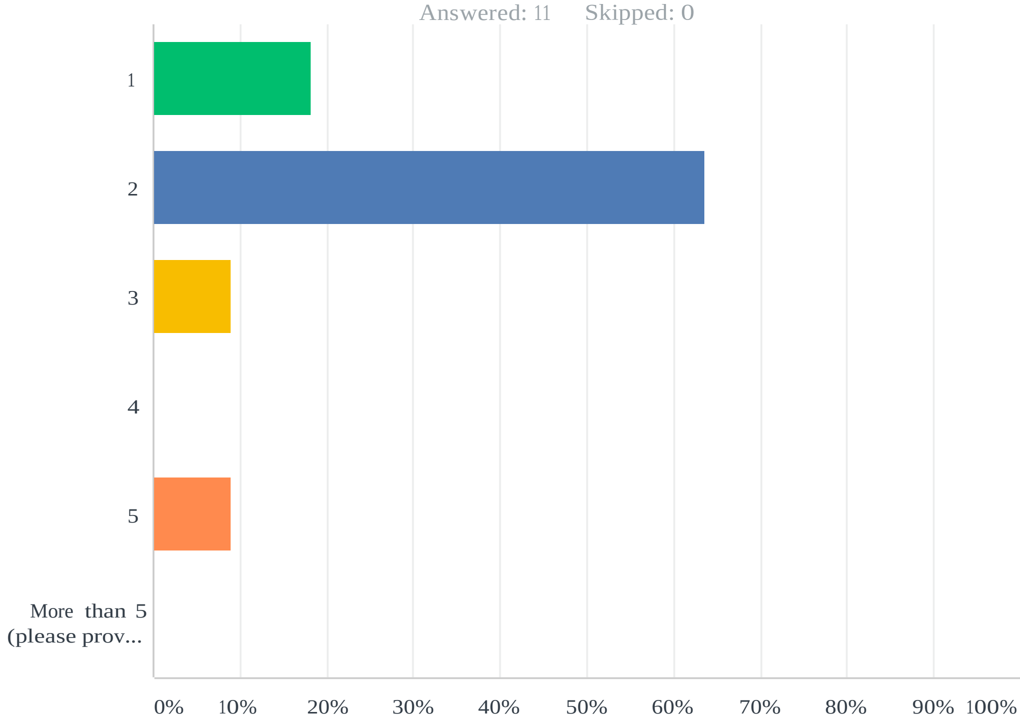
Answered: 11 Skipped: 0



Answer Choices	Responses	
Pilot	54.55%	6
Payload Operator	81.82%	9
Air Traffic Controller	0.00%	0
Air Crew	54.55%	6
Visitors	36.36%	4
N/A	9.09%	1
Other (please specify)	45.45%	5
Total Respondents: 11		

Q26 How many people are usually working in the control station at any given time?

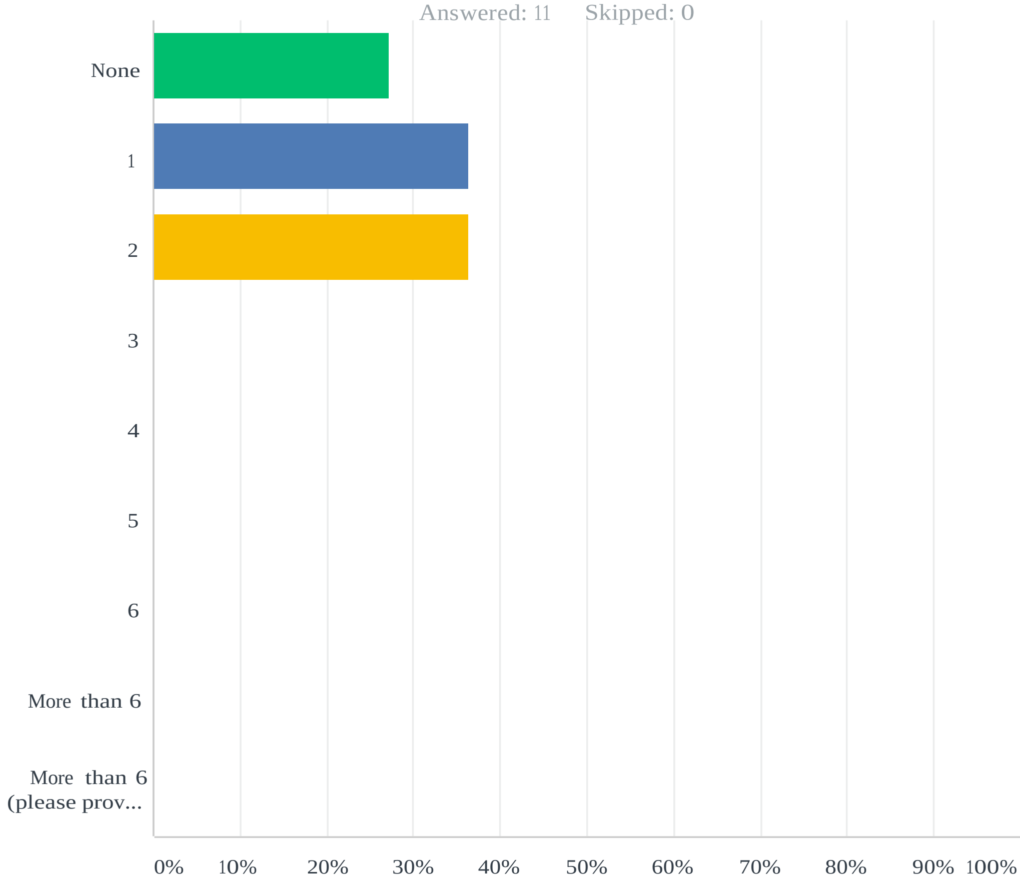
Answered: 11 Skipped: 0



Answer Choices	Responses	
1	18.18%	2
2	63.64%	7
3	9.09%	1
4	0.00%	0
5	9.09%	1
More than 5 (please provide number)	0.00%	0
TOTAL		11

Q27 How many monitors are shared by multiple people? (e.g. common navigation screen)

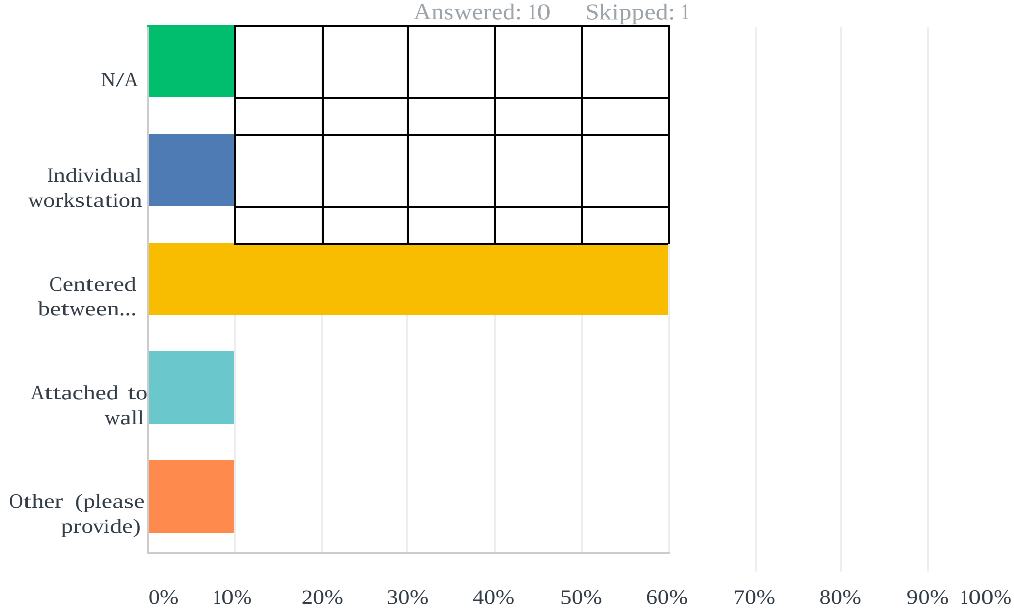
Answered: 11 Skipped: 0



Answer Choices	Responses	
None	27.27%	3
1	36.36%	4
2	36.36%	4
3	0.00%	0
4	0.00%	0
5	0.00%	0
6	0.00%	0
More than 6	0.00%	0
More than 6 (please provide number)	0.00%	0
TOTAL		11

Q28 Where are the most commonly shared monitors positioned?

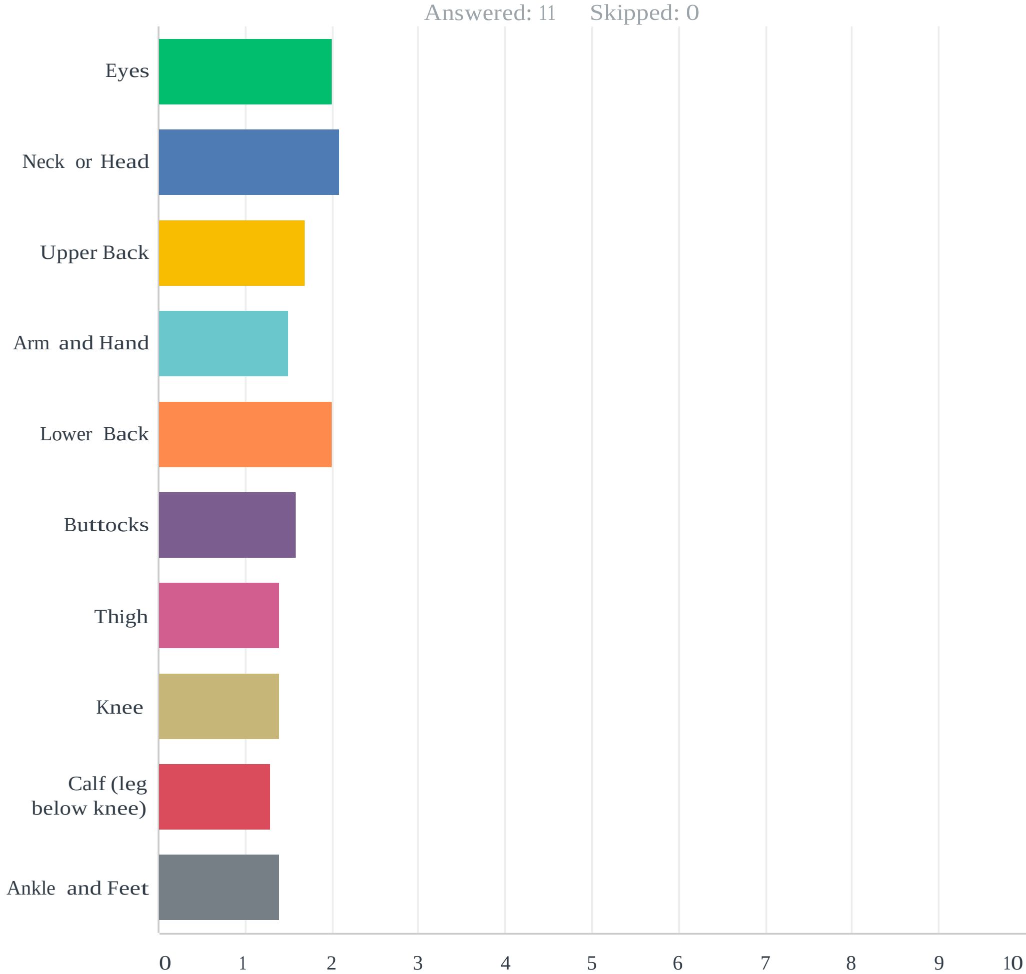
Answered: 10 Skipped: 1



Answer Choices	Responses	
N/A	10.00%	1
Individual workstation	10.00%	1
Centered between crew-members	60.00%	6
Attached to wall	10.00%	1
Other (please provide)	10.00%	1
TOTAL		10

Q29 Do you experience any discomfort or fatigue while piloting from your workstation? If so, please mark the discomfort map below. The human body is split into sections and discomfort levels can be expressed for each section by selecting a number representative of the level of discomfort. Greater number values are associated with more discomfort.

Answered: 11 Skipped: 0

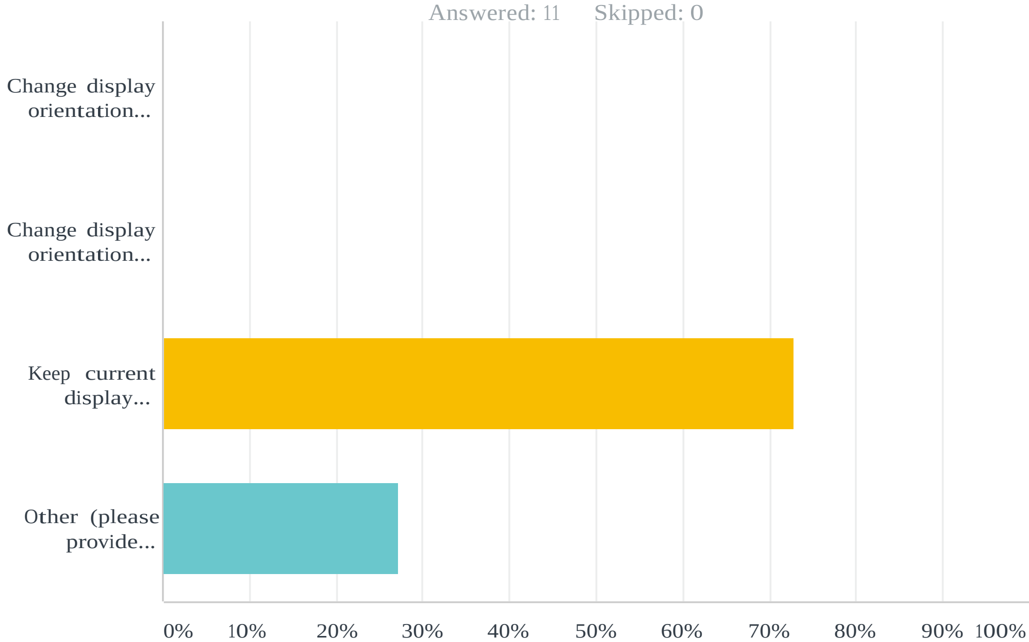


	1 - No Discomfort	2 - Slight Discomfort	3 - Moderate Discomfort	4 - Severe Discomfort	5 - Extreme Discomfort	Total	Weighted Average
Eyes	20.00% 2	60.00% 6	20.00% 2	0.00% 0	0.00% 0	10	2.00
Neck or Head	30.00% 3	30.00% 3	40.00% 4	0.00% 0	0.00% 0	10	2.10
Upper Back	50.00% 5	30.00% 3	20.00% 2	0.00% 0	0.00% 0	10	1.70
Arm and Hand	60.00% 6	30.00% 3	10.00% 1	0.00% 0	0.00% 0	10	1.50
Lower Back	27.27% 3	54.55% 6	9.09% 1	9.09% 1	0.00% 0	11	2.00

Buttocks	50.00% 5	40.00% 4	10.00% 1	0.00% 0	0.00% 0	10	1.60
Thigh	70.00% 7	20.00% 2	10.00% 1	0.00% 0	0.00% 0	10	1.40
Knee	80.00% 8	0.00% 0	20.00% 2	0.00% 0	0.00% 0	10	1.40
Calf (leg below knee)	80.00% 8	10.00% 1	10.00% 1	0.00% 0	0.00% 0	10	1.30
Ankle and Feet	70.00% 7	20.00% 2	10.00% 1	0.00% 0	0.00% 0	10	1.40

Q30 If you could change the display orientation of the work station, how would you change it?

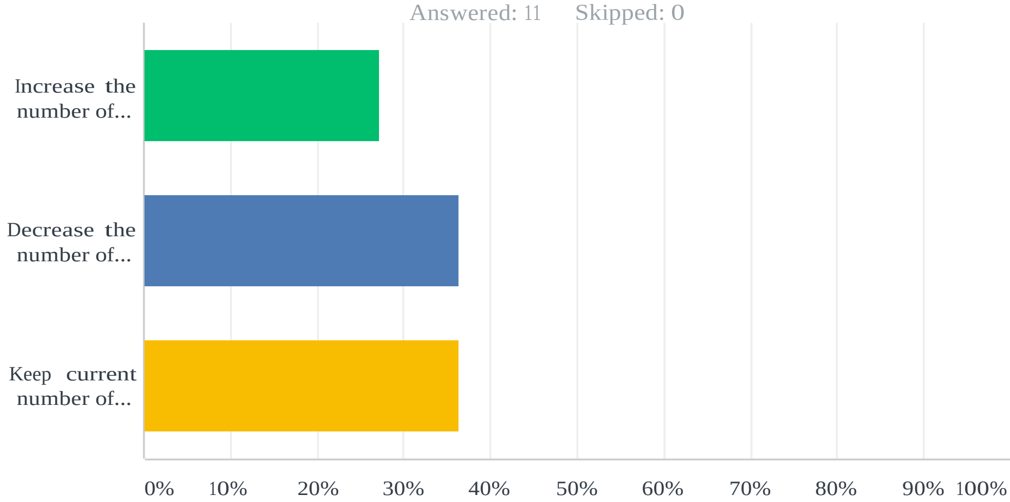
Answered: 11 Skipped: 0



Answer Choices	Responses	
Change display orientation from horizontal (side by side) to vertical (stacked)	0.00%	0
Change display orientation from vertical (stacked) to horizontal (side by side)	0.00%	0
Keep current display orientation	72.73%	8
Other (please provide description)	27.27%	3
TOTAL		11

Q31 If you could change the number of displays of your workstation, how would you change it?

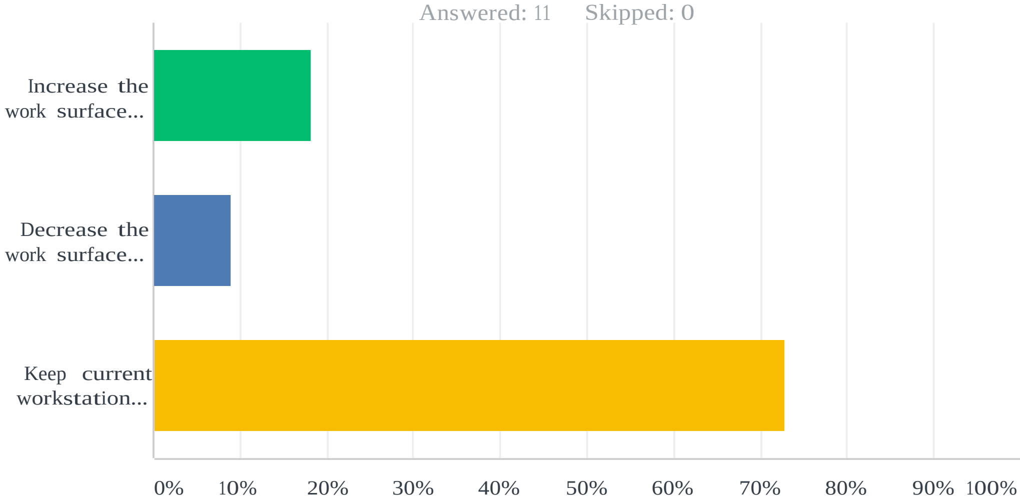
Answered: 11 Skipped: 0



Answer Choices	Responses	
Increase the number of displays	27.27%	3
Decrease the number of displays	36.36%	4
Keep current number of displays	36.36%	4
TOTAL		11

Q32 If you could change the work surface height of your workstation, how would you change it?

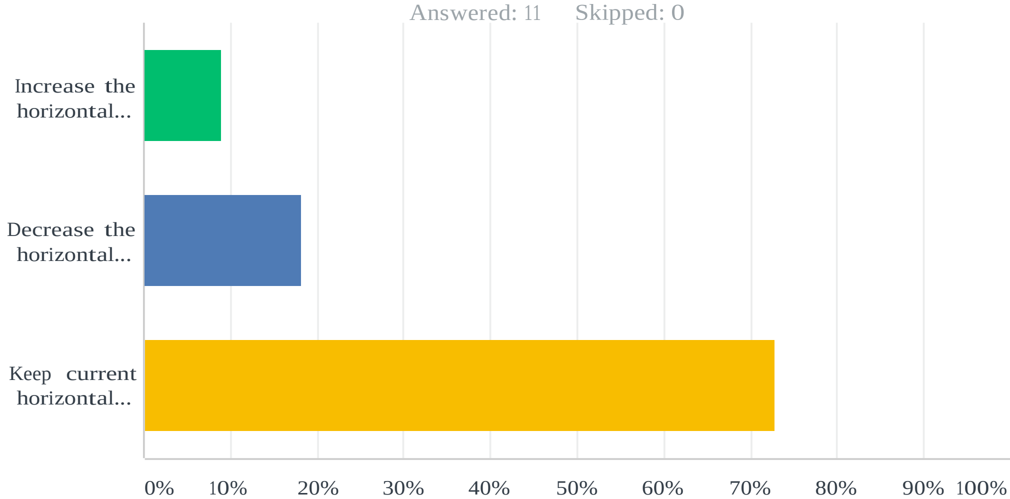
Answered: 11 Skipped: 0



Answer Choices	Responses	
Increase the work surface height	18.18%	2
Decrease the work surface height	9.09%	1
Keep current workstation height	72.73%	8
TOTAL		11

Q33 If you could change the horizontal reach distance to manipulate controls of your workstation, how would you change it?

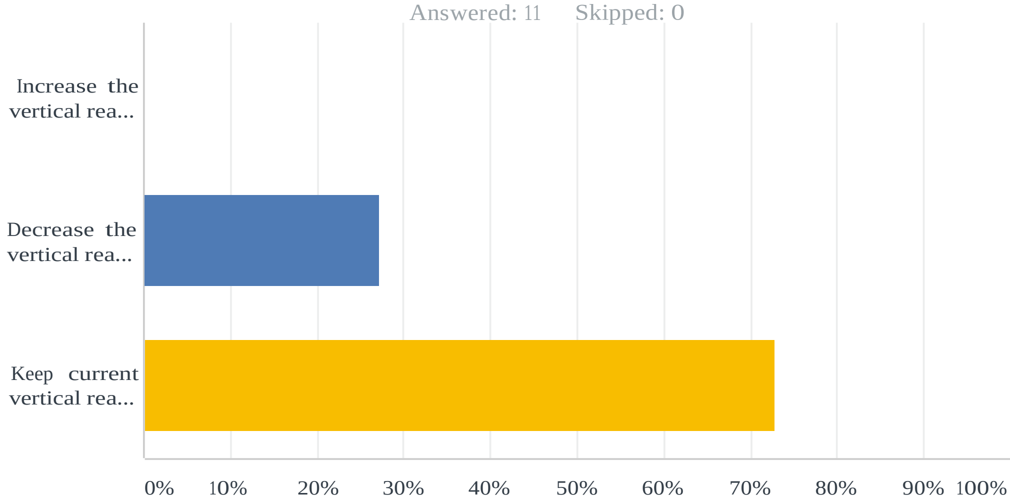
Answered: 11 Skipped: 0



Answer Choices	Responses	
Increase the horizontal reach distance to manipulate controls	9.09%	1
Decrease the horizontal reach distance to manipulate controls	18.18%	2
Keep current horizontal reach distance	72.73%	8
TOTAL		11

Q34 If you could change the vertical reach distance to manipulate controls of your workstation, how would you change it?

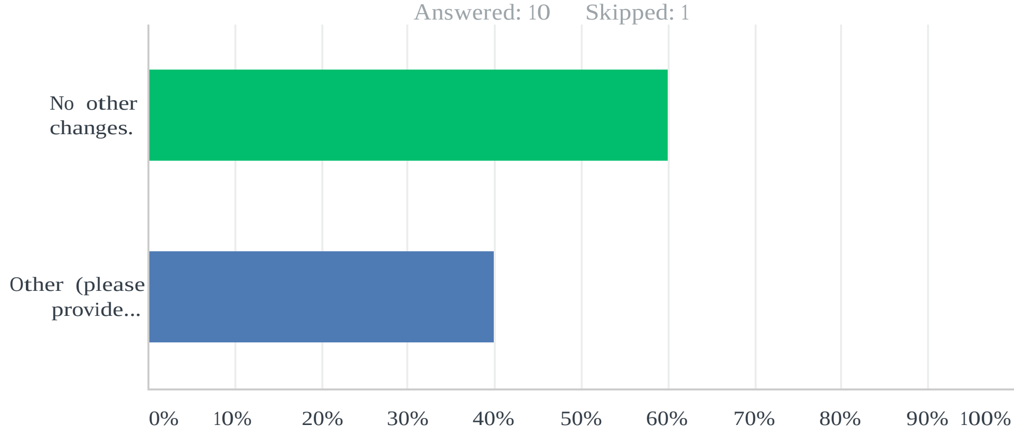
Answered: 11 Skipped: 0



Answer Choices	Responses	
Increase the vertical reach distance to manipulate controls	0.00%	0
Decrease the vertical reach distance to manipulate controls	27.27%	3
Keep current vertical reach distance	72.73%	8
TOTAL		11

Q35 If you could change anything else about the physical layout of your workstation, that was not covered by questions 30-34, what would it be?

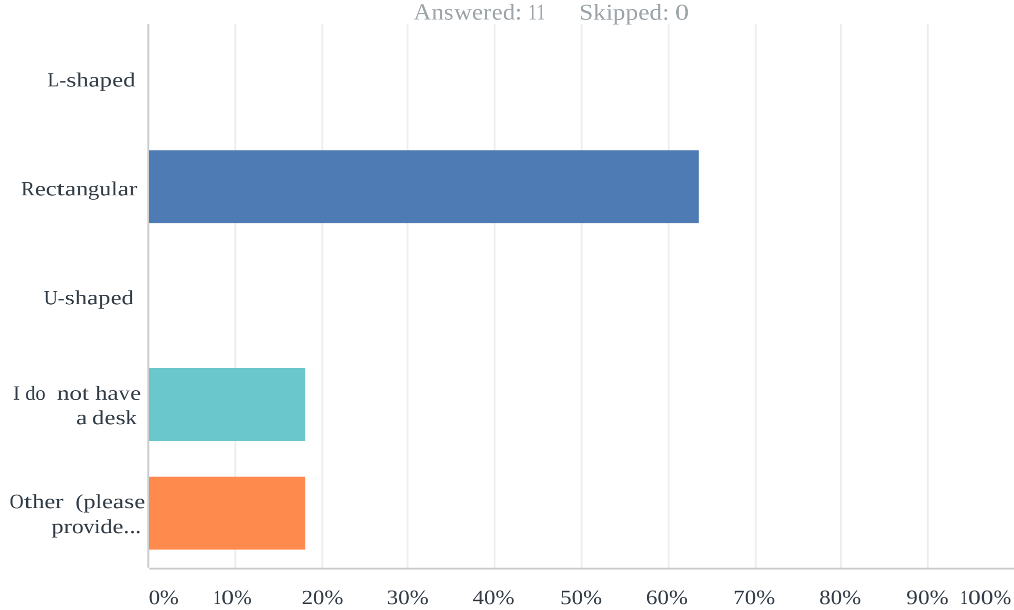
Answered: 10 Skipped: 1



Answer Choices	Responses	
No other changes.	60.00%	6
Other (please provide description)	40.00%	4
TOTAL		10

Q36 What does your work surface look like?

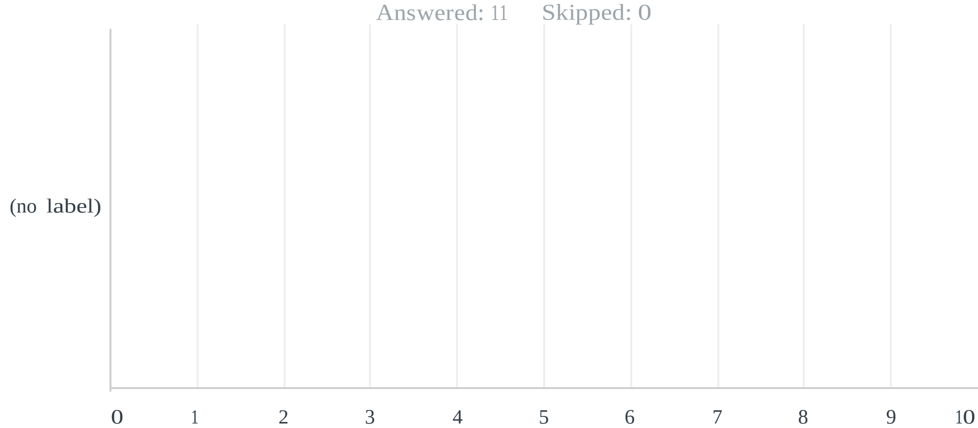
Answered: 11 Skipped: 0



Answer Choices	Responses	
L-shaped	0.00%	0
Rectangular	63.64%	7
U-shaped	0.00%	0
I do not have a desk	18.18%	2
Other (please provide description)	18.18%	2
TOTAL		11

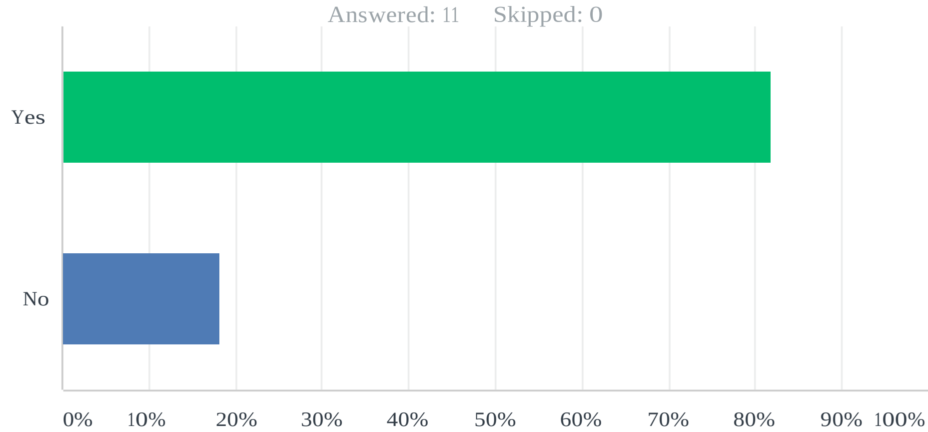
Q37 Do you agree that your current work surface is the best design for your operations?

Answered: 11 Skipped: 0



	Strongly Disagree	Disagree	Neither Disagree nor Agree	Agree	Strongly Agree	Total	Weighted Average
(no label)	18.18% 2	36.36% 4	18.18% 2	27.27% 3	0.00% 0	11	0.00

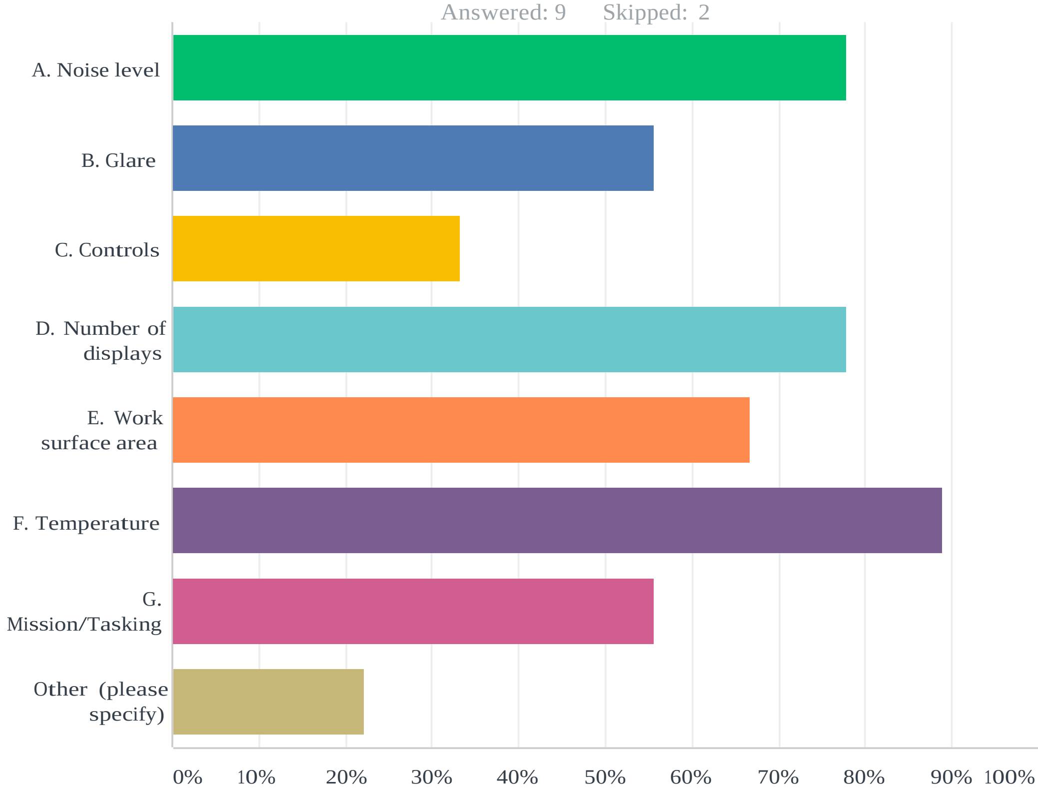
Q38 Do you or someone you know control UASs in a mobile environment?



Answer Choices	Responses	
Yes	81.82%	9
No	18.18%	2
TOTAL		11

Q39 What is different between the mobile and fixed ground control stations? (select all that apply)

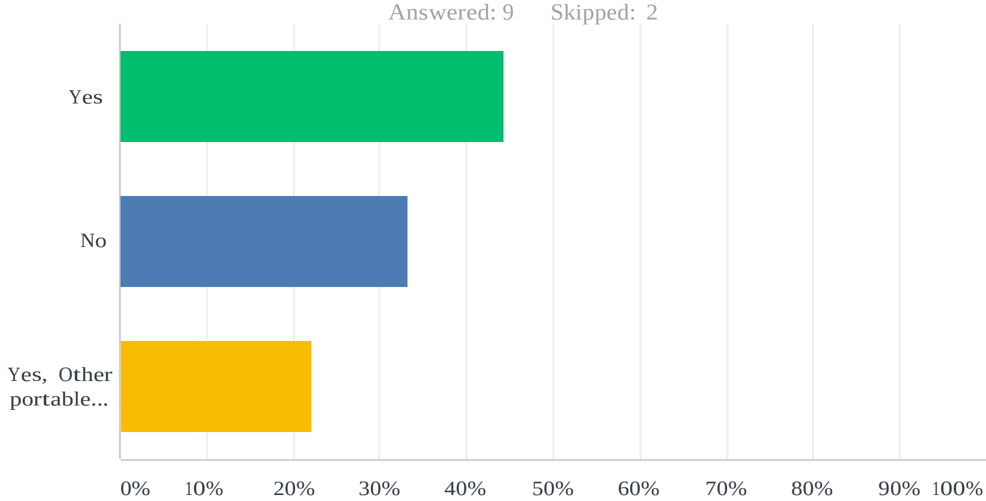
Answered: 9 Skipped: 2



Answer Choices	Responses	
A. Noise level	77.78%	7
B. Glare	55.56%	5
C. Controls	33.33%	3
D. Number of displays	77.78%	7
E. Work surface area	66.67%	6
F. Temperature	88.89%	8
G. Mission/Tasking	55.56%	5
Other (please specify)	22.22%	2
Total Respondents: 9		

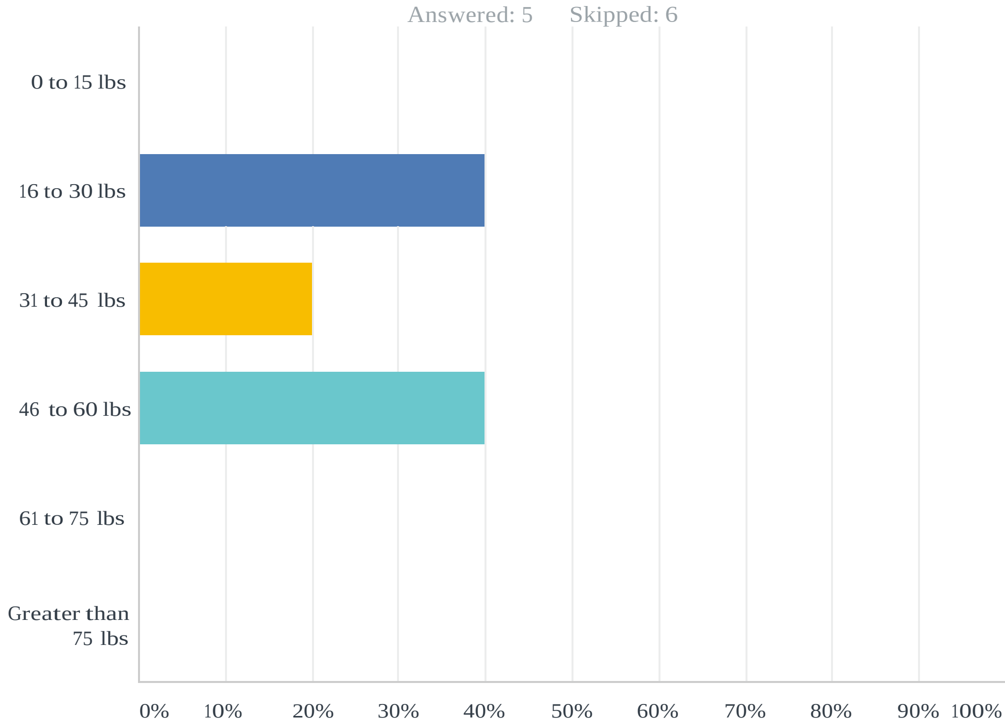
Q40 Do you use a backpack or other portable solution to transport UAS specific items when mobile and controlling a UAS?

Answered: 9 Skipped: 2



Answer Choices	Responses	
Yes	44.44%	4
No	33.33%	3
Yes, Other portable solution (please specify)	22.22%	2
TOTAL		9

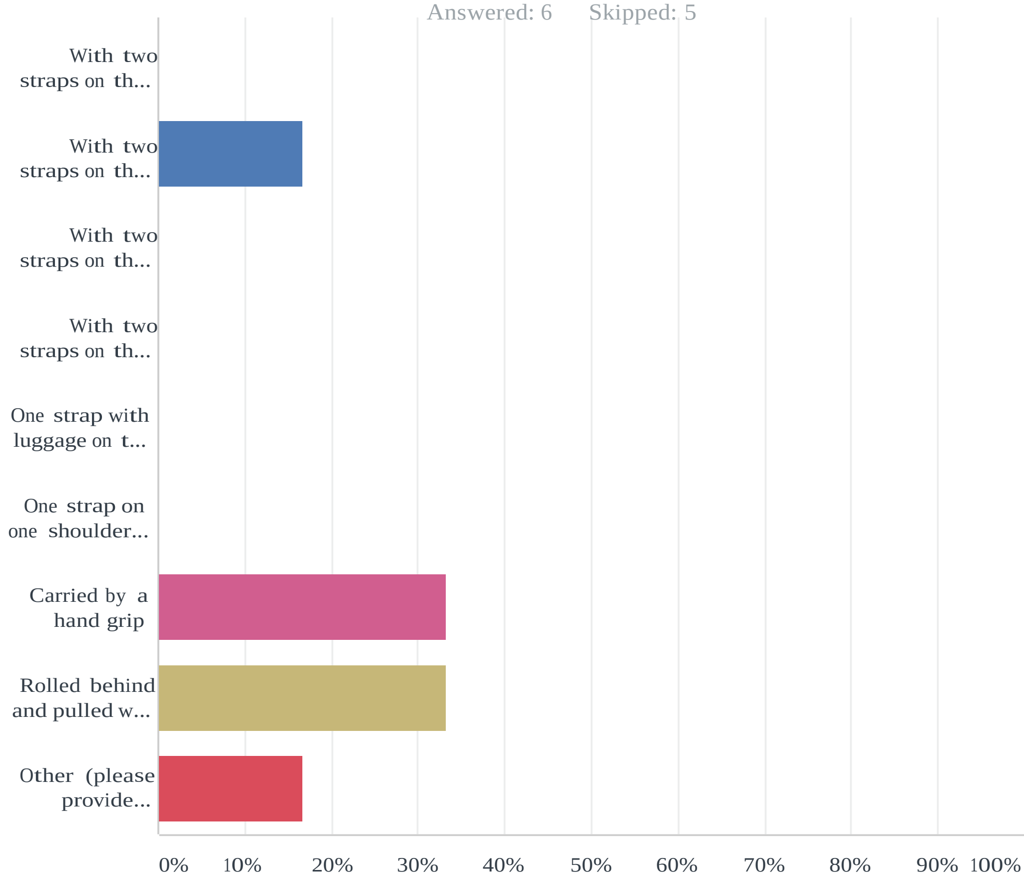
Q41 How heavy is the backpack or other portable solution when loaded with UAS specific items?



Answer Choices	Responses	
0 to 15 lbs	0.00%	0
16 to 30 lbs	40.00%	2
31 to 45 lbs	20.00%	1
46 to 60 lbs	40.00%	2
61 to 75 lbs	0.00%	0
Greater than 75 lbs	0.00%	0
TOTAL		5

Q42 How is the backpack or other portable solution worn or carried?

Answered: 6 Skipped: 5



Answer Choices	Responses	
With two straps on the shoulders - Pack on front	0.00%	0
With two straps on the shoulders - Pack on back	16.67%	1
With two straps on the shoulders - Pack on front and back	0.00%	0
With two straps on the shoulders - Vest	0.00%	0
One strap with luggage on the same side of the body	0.00%	0
One strap on one shoulder and the luggage on the opposite side of the body	0.00%	0
Carried by a hand grip	33.33%	2
Rolled behind and pulled with a hand grip	33.33%	2
Other (please provide description)	16.67%	1
TOTAL		6

Q43 If you would be interested in participating in an interview to provide more detailed descriptions on control station design, please provide an email for us to contact you.

Answered: 9 Skipped: 2

Answer Choices	Responses	
Email:	100.00%	9

11. APPENDIX C: INTERVIEW DATA

11.1 FIXED QUESTIONS

1. What type of work are you involved in that requires you to pilot a UAS? For example, is it agriculture, military, etc. related?
2. Do you operate from a fixed control station or a mobile control station? Please answer the following questions based on your experience with (FIXED) or (MOBILE).

Fixed:

3. From the responses to our survey we found that the top three control devices used in control stations are joysticks, touchscreens and traditional yolk/control sticks.
   I. Do you agree with these findings? Why or why not?
   II. Do you like using these controls? Why or why not?
   III. What other controls do you think would be best to use? Why or why not?
   IV. Do you use foot controls? If so, please explain why they are used and their positioning.
4. According to our survey results, most pilots use 1 to 3 displays.
   I. Why do you need multiple displays?
   II. What goes on each display?
   III. Does it matter where certain information is displayed such as navigation information or live camera feed?
5. From our survey, we found that most of the participants did not agree that the control station they worked in mimics the layout of a cockpit.
   I. Is this true for the control stations you have worked in?
   II. Do you think it should? Why or why not?
6. Survey results indicate users sit and stand while operating.
   I. Why would an operator stand during UAS operation?
   II. If an operator is sitting, what kind of seat is used? Please describe the seat.
7. Operators indicate multiple people are in the control station at once including "visitors".
   I. Why would individuals be within the control station who were not operators?
   II. Is this usual for your job?
8. About 52% of the participants say they do not have a desk in the control station.
   I. Why would someone not have a desk?
   II. Is the control station considered the desk?
   III. Is there room to sit or change posture?
9. A few participants left comments that there is not enough space on the work surface to take notes or spread out necessary documents. Is this a problem for your workspace?
10. What do you like about the control station(s) you have worked in?
11. What do you dislike about your control station(s) you have worked in?
12. If you could design a control station from scratch, how would you design it?
13. Is there anything concerning the physical design of the control station you think is important to note that we did not cover?

11.2 MOBILE QUESTIONS

1. What type of work are you involved in that requires you to pilot a UAS? For example, is it agriculture, military, etc. related?
2. Do you operate from a fixed control station or a mobile control station? Please answer the following questions based on your experience with (FIXED) or (MOBILE).

Mobile:

3. From the responses to our survey we found that the top three control devices used in control stations are joysticks, touchscreens and traditional yolk/control sticks.
   I. Do you agree with these findings? Why or why not?
   II. Do you like using these controls? Why or why not?
   III. What other controls do you think would be best to use? Why or why not?
   IV. Do you use foot controls? If so, please explain why they are used and their positioning.
4. According to our survey results, most pilots use 1 to 3 displays.
   I. Why do you need multiple displays?
   II. What goes on each display?
   III. Does it matter where certain information is displayed such as navigation information or live camera feed?
5. From our survey, we found that most of the participants did not agree that the control station they worked in mimics the layout of a cockpit.
   I. Is this true for the control stations you have worked in?
   II. Do you think it should? Why or why not?
6. Survey results indicate users sit and stand while operating.
   I. Why would an operator stand during UAS operation?
   II. If an operator is sitting, what kind of seat is used? Please describe the seat.
7. Operators indicate multiple people are in the control station at once including "visitors".
   I. Why would individuals be within the control station who were not operators?
   II. Is this usual for your job?
8. About 52% of the participants say they do not have a desk in the control station.
   I. Why would someone not have a desk?
   II. Is the control station considered the desk?
   III. Is there room to sit or change posture?
9. A few participants left comments that there is not enough space on the work surface to take notes or spread out necessary documents. Is this a problem for your workspace?
10. Glare and noise level appear to be common issues in mobile control stations. Why are these issues and how do you suppose these issues could be diminished?
11. Many respondents indicated the need to transport UAS/control stations using a backpack.
    I. Is the load equally distributed throughout the backpack? Are there certain pressure points associated with the carriage?
    II. Do you use anything besides a backpack to transport the UAS/control station?
12. We found that most people that travel with a backpack or other portable solution are carrying about 16 to 30lbs.
    I. How far do you travel with this amount of weight?
    II. How many hours are you expected to be able to carry this amount of weight?
13. Have you ever had to operate a UAS while driving or riding down the road? Were there any issues with the operation of the UAS?

14. What do you like about the mobile control station(s) you have worked in?
15. What do you dislike about your mobile control station(s) you have worked in?
16. If there is one thing you could or would change about UAS control stations, or you think is essential, what is it and why?
17. If you could design a control station from scratch, how would you design it?
18. Is there anything concerning the physical design of the control station you think is important to note that we did not cover?

11.3 INTERVIEW DATA: PARTICIPANT RESPONSES

As described in the Methodology section 2.2, participants were separated into mobile, fixed and mobile, and fixed categories. Some participants had experience with multiple categories and were questioned using both sets of questions (Fixed Questions and Mobile Questions, see 11.1 AND 11.2). All interviews consisted of one interviewee except Interview 5 which contained five interviewees. Categorical information can be found in the table below followed by raw interview data. Interviewer questions and comments are denoted by bold text and interviewee responses are denoted with unbolded text.

Interview 1	**Mobile**
Interview 2	**Mobile**
Interview 3	**Past Fixed, Current Mobile**
Interview 4	**Fixed and Mobile (Aircraft)**
Interview 5	**Past Fixed, Current Mobile**
Interview 6	**Mobile**
Interview 7	**Fixed and Mobile (Shipboard)**
Interview 8	**Fixed and Mobile (Trailer)**

11.3.1 Interview #1

Do you have any questions about what it is we are researching before we start off with some questions?

Well, everybody research ___?___. I'm just a retired military. I was infatuated by drones couple years ago and thought there was opportunity. So I bought two drones about to going to an adventure with drone services here in Alabama. I got your email and I didn't know how I could help but I'm willing to help where I can. I don't have a lot of technical information but if I can help you in anyway I will so go ahead.

What type of work are you currently involved in that requires you to be a UAS or drone pilot?

Well it doesn't require, I'm actually retiring from a manufacturing job company I opened 25 years ago. So I'm getting out of the day to day operations and taking this up as a hobby initially and then looking for some income down the road.

Any specific area like agriculture inspection or just any good thing that comes along that kinda fits your skillset?

Well we have a website and the name of that site, which can you know give you all that kinda information is XXXXX. And then there's page for each function that we do. We're planning on getting some thermal imagery going on for the farmers. And we're gonna be doing some aerial photography for the realtors. We're gonna be doing some search and rescue for local volunteer fire departments. So things like that is where we are headed.

When you typically operate a drone, do you operate from a fixed control station or a mobile control station? Mobile meaning that you are out and about in the world.

Yeah I'm always out and about.

From the responses of the survey we found that the top three control devices used in control stations, in mobile control stations, such as what you do, are joysticks, touchscreens and the traditional yolk and control sticks. So those are the three that we recorded the most in the survey.

Operating the drone I'm using the joystick.

So you currently use a joystick.

Yes.

So have you ever used a touchscreen or the traditional yolk and control stick configuration?

No to the traditional yolk and no to the control screen_?__ because I have a visual observer with me a lot. And I stay in line of sight of the drone, and I react to the joysticks the way I see the drone respond. So I have a visual observer when he is __??___ Look at the controls of my screens of my iPad which I have on the control and he will tell me elevations and stuff like that but everything is pretty much done with joysticks.

And what kind of joystick is this? Is this like a almost like a video game controller or something similar?

It's a Phantom 4. We got a Phantom 3, we got a Phantom 4 and we just got a new DJI's Spark. We haven't __?_6:16__ yet.

So related question, do you like using these controls?

Yes.

Are there any other controls that you've had either encountered or had experience with that you think would be the best to use in addition to the controller?

I would have to say no actually because when you have the freedom of the joysticks and just ___? 6:47___ of the screen. You have the luxury of watching what's going on around. And my buddy wanted to get invested in one of those goggles ones that it over your face of your eyes. To me that's just an imitation for me to trip on which wouldn't be cool. I stay away from that kinda stuff. And then you know to keep it simple, straightforward, I find the control joysticks work for me. I am an old Army vet and I was a BGR ___7:26?___ operator, a tank retriever rather, so I'm familiar with sticks.

The helmet or the goggles, are those kind of like a augmented reality where they give you heads up display information?

Yeah that's what I hear but that's something that I would not even be interested in to be honest.

But based on your experience and your work and life experience you're very comfortable with just the controls because you've got the experience needed to control without the other augmented information.

Yes, sir.

Also, according to the survey results, most pilots use between one and three displays. But if you are working line to sight, it sounds like you are not using any displays. Your controls are limited to the control stick, controller?

Correct, correct.

That also means you don't work in a control station that has a layout of a cockpit cause again you are out and about walking about.

Yeah. Of course the DJI software has the impression that you are in the cockpit looking at the screen. All your aeronautical stuff on the screen would be software included with appearance __? 9:25__.

In the goggles with that solution right?

No I'm not talking about the goggles I'm talking about on the screen. On the screen it's giving you elevation, air speed, battery life, you know all of this comes up and as well as some navigational things. DJI's got a very nice set of very nice software that's user friendly. That I've been using successfully and starting to get comfortable with. And of course I know they're gonna change everything now that I got comfortable with. The fact is that they've got it down, they've got it down very good from novels to beginner and then you can switch out of those modes on software and go more advanced. So I'm real happy with that.

The person that helping you out with the line of site observer, are they also looking at the screen? Or is it just you?

Typically just me. Like presence for real estate shots. You know we are doing panoramics for some __? 10:49__ hiring out drone pilots. So the find multiple listing of real estate for sale, they contact the owner find out if they would like some aerial photography or even the ___? 10:57___ for the real estate company. And then they ask us to go out and take panoramic pictures of the property. They put it together with the software and if made with google maps stand somewhere and look at the house and turn around and see 360 degrees around you. We are doing that for real estate right now. So that's the kind of stuff we are involved in and my observer, when we go to do a job like that will stand right by me. He will help me with the control and the images and stuff we are looking at on the controller. And more importantly he is watching out for power lines, kids on bicycles, you know dogs just gonna run up and grab my leg. So he is observing, scouting, and helping me monitor the controls by looking at the screen. While I maintain visual line of sight and constantly watch the drone. Something else I like about the toggle switch is if you quit messing with em, as if you had to take evasive action, then the drone stops and hovers in place.

So to protect itself and anything around it.

Yeah if something happens, if you trip, fall, have your hands on the controller on the toggle then the drone will stop and hover in place. You can recover.

So based on the situation you described, it sounds like when you are working with the drone, you are standing the entire time. You are sitting anywhere you are standing.

Yeah. You pretty much have to stay standing for the glare, you know certain position you have to be in to see the screen. Don't get me wrong I watch the screen, like you watch your instrument panel while you're driving down the interstate cruise controller. You know you'll glance down just see your stuff and you'll carry on but the observer is really most careful when I'm working with the screen and the drone while it's airborne, he watches out for obstacles and things that might present danger to people or the aircraft.

The fact that you mention glare that's definitely, that was the next thing. We are interested in and not just glare but noise level. When we did the survey those were fairly common issues that came up from the people in the mobile control stations. We can make assumptions about why glare is an issue but why are these issues and how do you suppose these issues can be diminished both glare and noise?

The glare has been resolved actually. By DJI's no glare screen. The Phantom 4 pro plus, I believe is what I got. Came with an integral screen. It's integrated into the control, so it's one piece control with like a iPhone 6 size screen. And that particular device has a screen on that that virtually eliminates the glare. So out of the three drones we have I would prefer that for the simple fact that I can always see the screen. I might work in the shade or sun there is no glare problem if you invest in the anti-glare screen.

So even when the sun is directly overhead and shining right on the screen you can still see the different contrast in colors and things like that?

Yes, absolutely. No glare at all, I was really impressed with it. No the screen isn't as big as the iPad, but if you got a iPad and have those pull out screens you know back in the day camera man had to be covered. It's a hold up and hovers over the top of the screen like looking into a box. But since I have the Phantom 4 that's just my preferred machine because of the anti-glare on the screen. Now the Spark on the other hand will operate even without a controller. The technology today in this __? 15:52__ is incredible. You can make hand gestures, and fly this drone.

Have you used on of those before?

I have not. I just got it. It just came out. And it's a very very interesting drone. They actually advertised this thing landing on your hand. Taking off, landing, out of your hand.

And you said that was called a Spark?

The name of it is Spark ya. You would never wanna do that with Phantom. Slice __ 16:31?__.

So gesture control is another one. Wasn't very commonly talked about.

It's pretty awesome. I've just started looking at some of the videos. You guys really wanna see the most informative way to deal with gathering this kinda information look up on YouTube the

Spark videos. Tons of em. And DJI just sent me an email with tutorials you know showing how to spark it up, charge battery, how to link the aircraft to the control, how to bring it up on Wi-Fi and it goes through each step. And the beauty of it is you can stop it you know. Do the step, stop the video, go to the next step, stop the video. Video tutorials that DJI has on the Spark right now are exceptional. And when I set it up that's how I'm doing with a series of videos. First step set up, second step controller, third's how to fly. And then they have more on just the different functions that this thing has. Highly technical.

In terms of items you use to control the drone. A lot of respondents in the survey indicated that they needed to transport some type of control components using a backpack. Do you use a backpack anytime you are out capturing video with your drones?

No we got a ___? 18:54__ on wheels and we usually operate on the back of a pick up truck. I've got a newer model Nissan that has a A/C chargers. So you can charge the drone batteries up on the truck while operating. And it gives you a stable platform. Allows you to get in out of heat kinda thing so. That's how we operate __? 19:17__ the job.

The moveable transport piece, do you keep that with you fairly commonly or do you kinda keep that stationary and then you're the one roaming with the controller?

I'm the one roaming with the controller.

How many hours would you expect on average that you were out and about using the drone? And I know that probably varies by the job but what's kind of the general average week for you?

An average week in hours?

Yes sir.

Well we're just getting into it right now so you know phasing out of my existing company into this we just really kinda been out as much as you would think because I'm putting this other company to rest. And we are doing our due diligence and research to find out where we are going to fit into the market on basically drone services. So the last three months I would say we spent 15 to 20 hours a week but that's not just the operation of the drone that's setting up the website you know the research we are doing. You know computer work all involved we probably put in 15 to 20 hours a week for the last 3 months.

And how much of that would you say was exclusively out with the drone standing for the video?

About half of it. About half an half yeah. And this is gonna get progressively more intense as we leave the other venture and get more time to devote. I'm actually trying __21:09?__to join the Baldwin county for the realtors here locally. And once I'm in over there then they all have me come in to their conferences show em what we can do for em. In the real estate sector so. We are planning, we are making you know, we have a business plan, we have a plan plan, and when we implement this plan we've got to be available to pull it off so. We haven't done that much advertising everything we've done it's been kinda word of mouth. And we have signed up for couple of these companies that are hiring out drone pilots on a local level.

… *real estate topic*

This is kind a of an odd question I think I know the answer to it, but have you ever had to operate a UAS or drone while driving or riding down the road?

No. It's like racing, you don't put yourself in that position.

… * safety topic* 24:00

So you've touched on some of these but I just wanna make sure that we captured everything. What do you like about the mobile control station that you've worked in? And like you said, you've touched on some of those but I wanna make sure we capture everything.

It's just the smartest option, ____? 24:43__.

What do you dislike about your mobile control station that you currently use?

Nothing.

If there were one thing you could change or could or would change about the UAS control station or think is essential, what is that thing and why would you change it?

Well, I can't really think of anything that needs to be changed cause I'm still trying to catch up to things they've done to date. So I just don't know enough about it to answer that question intelligently. I will tell you that thinking about you know what I'd like to have from Phantom is not anything to do with the operation of it, it has to do with term __? 25:45__ so it's not gonna help you. But you know the cameras are high quality cameras but they don't zoom in. If DJI was to call me and say hey what do you want I would say zoom on camera.

So the ability to zoom or at least change orientation or some aspect of the camera that's doing the recording.

It would go up and down and side to side but you can't zoom in on a fixed location. I feel like that would make flight safe, if you could zoom in on without going above or below, if you could zoom in before you went there, I think you safe ___ ? 26:30___.

True right if you are doing an inspection or something like that you wouldn't have to hover next to it.

As far the function ___? 26:46___ I'm just amazed. I certainly couldn't __? 26:52__

This last question is a little redundant with the others so but I definitely wanna ask anyway while your gears are turning there, if you could design a control station from scratch how would you design it?

I’m not technical enough to answer that question. I don’t have working knowledge about engineering to give you a good answer so.

But I guess the point is you’re pretty happy with the configuration you’ve got right now that you’ve been learning on.

Absolutely thrilled. I feel like once to I get to learn how to use the Spark I’m even gonna be ecstatic. This thing is awesome.

Do you think there is any questions we should also be asking in addition to these for mobile pilots?

… *safety topic* 29:20

11.3.2 Interview #2

Give us kind of a brief outline of the type of work you do that requires you to be a pilot for UAS.

I work for Innovative Imaging and Research. I am a Senior Scientist with them. I am a ME by trade. I have a feedback (? 1:52) around with NASA's commercial remote sensing program that down here at Stennis. It's kind of been changed into something else right now. So those are my roots. Kind of in aerial and satellite imaging. Basically we had a Department of Homeland Security science and technology project about 5 years ago that required us to do some initial UAV studies on the potentials of using an Android phone to both avionics and the imager for a quadcopter so we developed a successful project and did that. And from that we kind of got our feet wet deep into the technology of UAV control, flight controllers, mostly the open source ones that are out there, the APM, the Fixar (? 2:41) suite. And to this day we continue to use those particular open source flight controllers and that code. And most of our projects, we are training some people in some of the other common packages like DJI and those as well. But we prefer the open source. Basically the work I've been doing of late past couple years we've been quite a bit of work with Department of Marine Resources, mapping coastal marshland, doing baseline studies, low level flights over that, either flown at 80 or 100 meter, to do a baseline kind of a shoreline evaluations study, for the Hanker county living shore line. And also for the __3:29?__national reserve as in Jackson county. For some kinda hard to get areas down there. And we've done particular studies and initially we flew a dual camera system in rgb and an ngb, near infrared green blue, co-registered cameras. So we were able to do some NDBI products, normalize differential vegetation in the seas. And also do some vegetation low level classifications of those areas with those products. The mosaics and the elevation models that were created with those. Of the late we've also, thanks to Dr. Moorhead, pointing him our way, been working with the Senior wildlife biologist in the wildlife crane refuge over in Jackson county, developing techniques to be able to detect __? 4:27__ cranes in the nest, and also eggs, we've been successful with that. __? 4:32__ methodology for that. Those determining altitude flight speed in order to cover the thousands of acres they have. And the imaging methodology. We're also doing some training and also work over some industrial sites, to be able to apply, industrial sites provide people with the use of their top of their factory's industrial structures and things like that. Their __? 4:58__. And some of those kind of things. And I'm also training, I am also training people both here, we've set up classes at Stennis Space Center train people on how to become, how to use UAVs for their particular applications weather its science research or just you know common use. I'm also a national trainer for civil air petrol. And I'll be going there in week and a half now. To __? 5:23__ National Emergency Services Academy for civil air petrol and training approximately 9 to 10 squadrons, state squadrons. And how to use UAVs for emergency response in the future.

training information 6:20

So it sounds you not only have experience flying but you also have experience in designing the control stations. Maybe more from the software side but you know some level of hands on with the design as well?

Right somewhat. You know in the RG (? 7:54) copter code that's out there that's using the __? 7:57__ and formally on the APM's that were out there that were basically built on the Arduino structure but they moved on and the __? 8:08__ are coming out right now which are very interesting with the triple IN (? 8:11) use.

** design information *** 8:14…11:06

Do you operate from a fixed control station or a mobile control station most of the time?

When I'm flying the large hexacopters with the dual cameras, I have a laptop with me and of course my hand held radio. Laptop is used for kinda heads up display for tracking and to be able to take control. It is a backup as far as a check list in case for some strange reason I don't charge the battery enough on the radio controller, I never run into that but it is a redundant system. With a 900 mega hertz radio it's __? 11:39 that's on but a laptop. So that's the basic system with larger hexacopters. Smaller quads we're flying now it's usually just pure RC controller with smart device attached so with large tablet usually what we use a 8 inch tablet on there with a hood on it. It's working nicely as well as far as a small system.

And you're mostly out and about in the field when you're controlling a drone or UAS you're not in a building or facility you're out with the aircraft?

That's correct yeah. I'm either on the boat, on the shore, in the field, next to a building but never inside. No __? 12:29__ control.

And you mentioned laptops, joysticks and tech screens as your typical control mechanism.

That is correct.

Do you ever use traditional yoke control sticks?

No.

Do you like those controls that I mentioned?

I do. Mainly I guess I'll address the smart device RC control first. Mainly because of the proximity of the screen to the actual control sticks than my view shed is looking on both of them pretty much simultaneously so my time spent maintaining visual line of sight of the bird can be quickly tuned down to the screen with the sticks right next em in case I need to do adjustment or throw a switch. So in that it is good because of the proximity of that. And with the laptop and RC separate of course the laptop sits on the ground on top of a case or something like that so it's pretty close. But you know it could be 4 or 5 feet separating the laptop screen __? 13:36___ the hud display. And RC controller which does not have a display on it. So a little difference there in flying with the flying and with the laptop system we are flying a bigger bird, we are flying a hexacopter so it's more visible in the air I guess you would say so I guess I can pull my eyes away from it a little bit more without losing it if we are at the extensible leg flying out or something like that so in that it works fine so that. But there's a difference between the two systems we primarily fly.

What controls do you like to use the best? I know it depends on the type of blood you're flying but…

Right and the mission. I actually like the proximity of the screen to the joysticks on the RC controllers. So yeah I do like that. The main deal is being able to __? 14:30__ depending on the antenna system you have on there. We went to some flat panel alphas on our RC control which are kind of directional. There's been a 45 degree field of view on each of the paddles. So you do kind of keep your minds __? 14:46__ keep those pointed at the birds so you can't turn around or anything like that. And also if you kinda tilt the radio controller down if you don't have your smart device display __? 14:55__ optimal manual if you tilt it down you run the risk of lowering your control signal if you are at great distance. Now if it's fairly close to you, you know couple hundred meters or something like that it doesn't really matter. I never run into any things where it's you know gets low signal or air is out starts to do ___? 15:14__ something like that. It is something you have to keep in your mind as a pilot if you're using directional antennas and tilting a controller down to look at your panel.

Do you ever need multiple displays when you're flying?

The only time I would need multiple displays is if I have a subject matter expert with me on the field. And we have a methodology where we can hook up micro HDMI to a controller and provide the same view that I have, my first person view of my HUD display, on my _?__15:52__ device to an external monitor which that would not be something I would look at. That would be something I could talk to my mission while I'm doing it and have the subject matter expert give me feedback as to I see a crane, or I think I see a nest, or can we fly over this area, __? 16:11__ by you out there, or I need you to fly over this part of the factory those kinda things. So if we need to do that on the external monitor would be purely for someone that was approved as an observer or subject matter expert.

Okay so the most you would ever have would be two isolated displays one for you and one for the observer?

That's correct.

And would the type of information be the same on both display so you would have I guess the HUD and the general information on yours?

Yes information would be the same on both displays. So they would have the HUD as well. And I can minimize or maximize that depending on what kind of communication, without inhibiting my flight control capabilities I can make the live video be full screen if I want to, if I'm in a particular app or I could swing it over so I've half screen, half screen or partial screen first person to view. And they would be able to see the same thing so if I wanted to speak to the fact of I'm on the third leg and we think we see something, do you want me to pause right here and speaking to the subject matter expert and you know continue on if so.

Do you mostly stand or do you ever have the opportunity to sit while you are flying the UAS?

I always stand because I wanna be mobile. In case, during any of the flight lines any unforeseen obstruction occurs. So say that a __? 17:45__ pine that's in my way I wanna maintain visual line of sight. So I'd like to be able to move around a little bit from the LZ __? 17:55__ landing zone area. And so yeah I'd like to stand.

What about the subject matter expert when you share your view with their monitor I'm assuming that's a wireless connection? To share over to their monitor?

That's actually wired at this point and so I am kind of tethered within 10 feet of that.

So you're up and mobile and standing but the subject matter expert they could be sitting at a mobile station or something like that if necessary?

That's right, so make em comfortable.

Are those the only type of visitors or observers you typically have, the subject matter experts to validate your methodology?

Yeah it's usually that or the team that we're actually doing the research work for some I guess DMR ?__18:45_ personnel there might be people from the factory or facility and of course the wildlife biologist he's gonna want to be there and he might have some interns out there. So there might be some guys that are under studies that are co-subject matter experts you might say that are out there watching and they can all watch on that usually is a 22" monitor. So they've got plenty of viewing space.

Is there fairly usual for your job do you have people out there performing your functions fairly often?

I'd say yes. There's always usually somebody with me that's interested in the data that's being __? 19:29__.

Based on some of the information we got back from the survey we did we found that glare and noise level appeared to be the most common issue when you're using a mobile control station so why are these issues and how do you suppose these issues could be eliminated?

Glare of course because most of the smart devices that are out there as we know are abysmal as far as anti-glare screens, matte screens they really don't have em. So you need to have a little hood on whatever screen you use out there we typically use those that they make em for the 8 or 10 inch tablets so we do those. I had to fabricate one kind of for the 22" monitor out there black hood like device and also for post-mission data look up we review things on the laptop or something so that that can be moved over to laptop to allow the subject matter expert to review that they once again watching it live. Now as far as noise yeah I like to hear the whirring of the bird but when we get out of distance some the situations the whir of the bird is not a good thing so we wanna keep it at an altitude that doesn't disturb the wildlife and those kinda things. So I would imagine they are referring to noise as it disturbs other people around them or something.

Other noise that would disturb the pilot is what a whole lot of em…

Yeah a lot of people are talking I try to when I go through protocol or just a simple check list I try to establish the line for a sterile cockpit so I ask everybody please no one get in front of me at anytime everybody stay behind me. That's actually the __? 21:28__ I go through before I take off so we have sterile cockpit and I explain to them what that is beforehand. And I've never really had a big problem with that people make too much noise or being too much noise around them in these situations.

But I guess you've learned just through experience to kinda issue the commands to be quiet so you can go through the process…

More or less yeah. I guess I go out in the field with respectful people so they tend to focus on the task at hand.

Right they are out there specifically to do their own job so it'd be different than if you had crowded observers or something like that just watching what you're doing.

Now I had that crowded observer we had a demonstration for, through __? 22:15__ it's actually through the MSU extension down here Kelcey Johnson I think was the name down at the coast this Monday for boys and girls club there was about 40 kids from the boys and girls club that I did a demo over __? 22:27__. Now there were a little noisy but I passed authority to those in charge of them for them to quiet when necessary __? 22:37__.

You probably weren't forming a standard work function you were just demonstrating for an audience, right?

Correct and I flew a mapping mission but it wasn't crucial __? 22:50 that one.

Also from our survey we found that a lot of respondents indicated they used a backpack to transport either some of the UAS controls or other type of equipment. Is that something you commonly use?

Yes. Typically I'll have a hard pack everything that I need as far as electronics to keep them dry my __? 23:18__ technician's kit kinda hard case ___? 23:20__ or something like that. For the bigger bird. And then normally just a backpack is necessary with you know smaller __? 23:29__ box cases for the smaller deployments I have enough stuff in there. And I also usually bring a spare, spare bird.

What all do you typically keep in your backpack?

The laptop, power, any additional cables, adapters. In the case of the bigger bird if I need a back up radio receiver or __? 23:55__ unit I keep that on there. Back up GPS. Of course extra propellers, spare motor, __? 24:03__ controllers. Pretty much redundant on any part of the avionics or flight control or flight control flight system. That might need to be replaced out in the field. I've got that in the backpack. Battery operated sauter (? 24:20) and kit.

Is the load of the backpack fairly equally distributed meaning do you have any kinda pressure points or any level of uncomfort associated with using your backpack?

No it’s really light weight everything I have in there. Yeah and also for the big or small bird usually I carry the batteries either in the actual case for the bird. Or in case for the hexacopter I’ll bring out an ammo can, to carry the spare larger 6S larger lithium batteries in. Both for safety and for protection from the sun.

So you have the backpack with various equipment and spare parts and you’ll often have a hard rugged case that you’ll carry with you.

Yes. The hard rugged case if I’m out in the marsh I’ll usually leave that on the boat. I don’t actually carry that out to the watch point if I’m going of off land. I just leave it on the boat and that’s adequate. Something happens I’ll go back to the boat for stable planes structure that I can do repairs on needed. But batteries go to the field with me.

Is there anything else besides what you’ve mentioned you might have a need to carry around with your for…

For going out in the field especially for places that don’t have well defined man made structure that you’re able to get survey points around control points off of, we usually, before mission go out and actually lay ground control points with targets out in the field. So there may be instances where I’m concurrently bringing other GPS unit to measure things. But that’s usually done before the mission. Or after the missions cause you can apply it and get measures of the points to high resolution if need be. So there might be rare instance where I might bring a GPS out.

So some type of small instrumentation possible in addition to the case and the back pack.

Right.

You mentioned the backpack was fairly light. From the survey we found that most people said their backpacks were between 16 and 30 lbs. Does that sound too heavy compared to what you would carry?

They must be putting their bird in there too along with all the batteries and stuff. I’ve got a separate case for that. For the smaller bird the quad, I’ve got its own little backpack that fits over one arm. And then my materials and things like that might go over the other. Dual backpack situation for that. But for the big bird, the hexacopter, I just carry it by man handling it from proper position on the body of it and that one backpack for that but it is only about 10 to 12 lbs maybe. 10 lbs I would say.

Would everything you would carry out there in total maybe be closer to that 16 to 30 lbs?

Yes.

Alright but what you would actually put in your backpack would be at most around 12 lbs?

Right.

About how far do you usually travel wearing this amount of weight?

Let’s see some of the __? 27:46__ of Hancock county it can be half km, I might have to track to get into them I’d say 500 meters max.

About how many hours would you expect that you would need to wear the backpack or carry the case?

A total of about 20 minutes maybe.

So not that long. As long as it takes you to walk to the point where you do your observation.

Yes.

For any reason have you ever had to operate a UAS while driving or riding down the road?

No and I will not do that.

Or in the boat?

We have watched of the deck of the boat out of necessity at several times and actually the modality for that is that the bird is actually is placed on land and I will take it, the boat beyond the beach, so beached, and so I will take the bird off and do all its pre-flight GPS ok's and checks and then begin a mission then we'll provide chase in the boat to go down marsh area or something like that that would be it's only single flight on. So that's been done before but not frequently.

So it may happen rarely with the boat.

Yes.

Were there any issues with the operation of the UAS while you had to have movement in the boat?

No not at all. As long as you place the UAV or UAS on the ground for initial calibration for the flight controller because all the vibration and shake of the boat we're in as you know unless you take those things out of the code usually don't pass your pre-flight checks. As far as ready for take off.

Some of these next questions may sound a little redundant but somebody like you who has a lot of experience that they could have different answers or they could have the same answers, just bare with me here. What do you like about the mobile control stations you've worked in?

I like the, so this is in reference to the smart pad, radio combo versus the laptop radio combo, yeah the laptop I like because large screen, good heads up display, I don't usually with the laptop have a live view because I'm doing mapping mission usually with the laptop. I really don't care I just wanna see that the bird is tracking along the flight lines. And with the larger screen of the laptop checking the accuracy to make sure the bird is maintaining its __? 30:54__ along each of the flight lines. So that's a positive there for me to be able to see that on the laptop and say hey it's doing good, GPS is tracking well on our legs. Same thing on the smart panel of course it gives you a lot of display track of how the bird's doing there. With the added benefit of the live video feed. Weather we're doing a mapping mission or just a video mission. I like that. And also on the smartphone radio combo, in the sidebar of live video feed, it'll actually blank the screen whenever it’s taking an image, so that gives me a confidence ___? 31:35__ with the other indicators that are on the HUD display. That I’m not wasting a mission I’m actually taking photos. That’s one of my confirmation points that I’ll speak out to whoevers observing with me, we are taking images and the flight is going nominally on all flight lines. So that’s kind of the good points of each of those.

Kind of an opposite question, what do you dislike about your mobile control stations that you’ve worked in?

You touched on em earlier, the having to have the shield the sun shield around the sun shade and being mindful of that and your antenna angles. There’s probably some room for better design where there with that it hits around your neck, which is good but you change your focal length from time to time from looking down at your smart device with live video feed to then try to scan the sky for where your bird is. You know there part 107 training and all of that there’s given techniques for how to scan the sky for approaching aircraft if you’re flying in the air, of course that’s in the cockpit, but that also applies to if you’re on the ground, you’re flying a bird you have to locate it in the sky. So some of the part 107 comes into __? 33:01__ there where you’ve learned how to scan the sky properly for where the bird’s supposed to be and point yourself accordingly. Keeping your toes pointed toward where the bird’s supposed to be and all these kinda things. So with that and looking at the screen and looking up you also have to keep that in the back of your mind of keeping your body posture and proper alignment. Not turning around and talking to people and then coming back and losing it. You have to really stay faced forward to the bird due to its mission.

Other than possibly that sounds like the shade to prevent glares kind of an issue, if there’s one thing that you could or would change about the control station, what is it and why? Or maybe that glare shield is that one thing?

Yeah the glare shield is that one. I’m trying to think. If there is a way that you would not have to be concerned of course by antennas __? 34:00__ I could fix this, if I went to a larger panel or different panel or somewhat circular colorized options that are available out there. I guess would require some testing on that. But yeah just having a little bit more freedom to turn right or left without being overly concerned about losing radio control. I’ve hadn’t that experience with losing radio control so I don’t know why I’m saying that. But yeah I guess a little bit more freedom of movement in that. But yeah shade is the major thing. As long as it’s not difficult for me to go into a bright sky looking at it, and then come down and look into a darkened screen and readjust my you know brightness and contrast fovial eyeballs to that. There might be a benefit. So a brighter screen might be a positive too. Sometimes you can crank up the brightness or contrast on the smartphone or even on the laptop to max and it still doesn’t seem like it’s bright enough for contrast even with the screen on it. So there’s some potential for some improvement there I think. You know we are using smart devices and we’re putting em into you know a situation, they weren’t really primarily designed for I think out in the field with a screen over the top of em so possibly enhancing the brightness contrast on screen might be a plus.

Other than you know having a brighter screen or screen you could see, increase mobility, if you could design a control station from scratch what else would you add or how would you design it?

All in one. So you didn't have to snap the smart device on to the actual controller and the possible the laptop could some how with that processing power could be integrated more into that control thing for the other application. Yeah the more all in one, the less parts you have to put together in the field the less tilting, the less connections you have to make better. As far as ergonomics, and ease of use. And ease of assembly out in the field. So yeah if you could have a fold up or fold down screen or the screen could be built into the control and it had all these extra brightness and clarity features and they get popped out to glare screen attached to it. I could see that as a winner.

So would that potentially mean you know the laptop's considered like a clam shell form factor?

Yeah it is, so I guess if you get a all in one monitor that had the built in. So it wouldn't be a clamshell that might be a positive if you could mount it on to your RC without it being overweight that we can't __? 38:10 or something like that. But as a potential I mean the most of the android or iPad tablets are giving em enough theirs ?__38:21__ so the laptop could be done away with in the future and just move over to smart device, integrated smart device into the controller. We're talking apples and apples, really it's just ones called one and ones called the other. But a laptop also serves as something you would plug in your camera to download video and review it and then possible get some data processing little bit. So if the smart device could lend to that or you just use one of the all in one display that has processor built into it and make that the smart device. That could probably be a solution.

Quick follow up on the laptop what type of laptop are you using, is it just a standard like a Dell or HP kind a laptop or?

Actually it's been a very robust solution. I have a Toshiba 17" wide satellite that I've used for 3, 4 years and it's been tremendous out in the field and it's been through some serious junk out there as you can imagine. And that's the same laptop I've started and I've had it out there and it's been stellar. As far as performance and everything toughness in the field and you know we run the software they have on the boat for __? 39:42__ control and for you know for doing quick processing on the field.

Is it one of the rugged brand? Like a tough book kinda laptop?

Nope it's just a standard 17" Toshiba, Satellite it's called.

*** DJI, Spark discussion ***

Is there anything concerning the physical control station that you think is important to note that we didn't cover today? So what didn't I ask that I should've asked?

I didn’t hear, forgive me if I forgot, but I didn’t hear anything about audible feedback from the controller otherwise the British lady speaking to you say you’re in flight mode 3, flight mode 2, flight mode 1. Whether that’s aggravating or whether that’s helpful.

Tell us a little bit about that. We haven’t heard too much about the audible piece yet other than people tend to not like it.

Yeah and so the spectrum radio’s got a set of new spectrum DS8 was it GA’s that they have out now that are very nice. Yeah and the other British lady is on there and __? 42:50_ some of the trainers she started talking to me so I had to turn her volume down. But as far as for some things where you have switches on your controller that you might accidentally whack on and set it off into a flight mode that you didn’t actually want to. Even though for practical applications for mapping and things like that you should not have __43:14 any mode programmed into your controller. It’s kinda helpful in that but as far as training for me because you know I will give the guys those three modes. Beginning, you know little angle, adding the don’t have go there show em what I could do. For accidental things like that or maybe your __? 43:33__ maybe you’ve got a control knob for __43:35 gimble?__rotation or something like that I you’re actually doing some ___? 43:40__ or doing 3D structure scans for something something that will call out your angle your camera angle something like that along with any readout that you might get on your smart device is kind of a backup system. Especially if you’re just looking at the bird in the air and you’re moving a knob to change your gimble angle or something like that rather than have to look back down and see on your screens somewhere where the camera angle’s at. If you wanted to mainly rotate that and you want to set a certain angle. That would be good some instances to have that audio. But the ability to turn it on or turn it off, would of course be most important. But in some instances I feel a pilot could use those of course you could probably get to that as far as camera angle or gimble by just pre-programming if you had a priority knowledge what angle you wanted to fly and just have settings in your program that and your controller. You flick the switch and it goes to zero, 45, and 60 automatically but still. Have an audible feedback and those that, I’m looking at the __? 44:50 and I flipped it says you know gimble angle 45 degrees that would be handy to me to have a you know confirmation of that fact so. Some instances it’s good but most of the time it’s aggravating. But there’s potential for it.

It kinda sounds like just additional or better features that help with angle precision. Whether it’s the audible feedback to tell you what’s going on without having to look down or the controls itself. Or having controls that don’t get in the way that you would accidentally you know hit those or make a mistake…

Yeah and that too and of course there’s the other side of the spectrum where the controls get in the way. With the DJI you’ve got your S1, S2 switch or whatever they are on the pack, those are always getting bumped or something like that on the bottom side of the controller and it’s kind of an inverse feel really and so you gotta get used to it that as you’re holding the DJI, basically the one for the Phantom 3, you might flick something and you think it’s up down, forward back and you might even have to try to turn around the controller look on the back to make sure it’s in the right position. So having any kind a switch on the back. That isn’t tactile or give you an audio response at least for somebody that's just getting into it or might not be used to or might just programmed something into it the controller switches. Having em on the back is not so great I don't think.

I guess any switch cause your goal is to either try to look at the bird or look at the screen so some type tactical some feel that you know what current state the switches are in just by being able to put your fingers on or around it.

Right and then again without your eyes unless it's a binary forward back switch if it's a 3 position or 4 position or it's a rotary, then once again an audible might come in to being a good feedback mechanism there. But anyway I'm kinda speaking in the middle of the pack of somebody who's either an amateur or not quite versed in get enough flight time with the bird. For somebody who's an expert, say my training, know thine bird. You better know every little switch that's on there, know every mannerism it has, cause you've flown it enough. That you programmed it yourself, you know exactly what's going on, it's like driving your car. So anyway I'm kinda speaking of in the middle of pack when I say there could be some helpful things there.

Well that's good to know because I mean you could have feedback in a lot of different ways and so as long as it's not distracting or inaccurate or you have the option to turn it off once you've become the expert.

Right those in control that tells you that you are at 25% battery I think that's a good thing. So __? 47:48__ response there. That's good.

11.3.3 Interview #3

Would you mind giving us kind of a brief rundown of the type of work you're involved in that requires you to pilot a UAS?

So as a company we are really a core company that all surround a single first entity. Which is a multi-modal response robotics research and development company. And what I like to remind people is that, two things, one if it crawls, walks, swims, floats or flies or drives without person on board that's what we like to touch and play with. And two we're a 30 gallon thin tank not a giant aquarium sized like MITER ? 2:38__ or rant _? 2:38_. So that gives us some flexibility there.

So mobile and flexible and coming up with new stuff. Not having every single idea shot down by you know corporate and legal.

Exactly. It's one of the great things is because Bucks stops with me and that gives us some really great flexibility but we are you know smaller so we have to be very careful on how far we run with certain projects so. But we've __3:04__ a lot of stuff to be all over places and be kinda quirky and we like that.

Would you say that you operate more, now and in the past, operate more from a fixed control station or a mobile control station when you are flying UAS and drones?

So historically my background was in fixed control stations. Up until about 2009. So predominantly from 2001 and 2009 it was very fixed stations and then from 2009 onward the foci shifted into mobile stations. Where the you know the military concept that we run everything from a fixed site kinda fade away a little bit, and everything went to what can you put in pelican case and what can you move. And then I'm starting to see a shift back into the idea of a you know a conglomerated control site where you have something happening from a fixed location and some elements of that, mission monitoring happening from there. While some of the more active _impactuations_? 4:33__ and interventions happening from mobile site so. I really call that one a spectrum.

So you've definitely got experience in both. Let me do this then. Let me start with your fixed station experience. And we'll get through those then whatever time we have left we'll pick your brain in detail on the mobile control station. If that works for you.

Little bit of insights into the results of the survey that we did so thank you for taking that and participating. We found from the responses to the survey that the top 3 control devices used on any control station are joysticks, touchscreens and the traditional yoke control stick. So based on your experience do you agree with those findings that those are the top 3 most common.

Yes. I agree those are the top 3 most common. They are not optimized by any way shape or form but those are the top 3.

Do you like using these types of controls?

No I don't. And I'll tell you why. I was actually part of a, I'm retired military as you know, so I left at the end of 2011, early 2012. And put a lot of time and effort into the human factors and engineering psychology of the man machine interface. That's my specialty, everything else kinda fill in around that. So one of the challenges we keep running into is that you know we as people go with what we know, right. There's really neat information and tasks on there about gameplay and __? 6:21_ light controls. So if I can sit down and kill two days a weekend with a bunch of Cheetos and mountain dew playing Destiny using a X-box controller then when someone decides that we need to build an aircraft controller that will give you the same type of duration and comfort I'm gonna go with that cause I know it works. The same thing with when you ask a pilot say okay pilot I need you to fly all their flight trainings, all their muscle memories tells them I need a yoke, or I need a joystick depending on what type of pilot, whether __? Plane 6:52_ or a helicopter or some combination thereof. So we're still feeding off some legacy human interaction. We haven't quite done the ergonomics research of what would be a better way to go. I think I've said this in survey you know I do like the Ho-taps ?_7:13_ approach the hands on throttle and stick, not necessarily for the physical instruments themselves but with the concept of all the buttons should occur off of one hand or of the only, we should be able to do that with, without using a very complicated control system.

What you just said is something we found to be pretty common. People weren't directly out saying it but you stick with what you know so you know it could be better, but when I ask how could you change it a lot of people wouldn't change it. Just because again that's what they are familiar with.

And if I have a break on the way to a job site I can run into BestBuy and buy one for 20 bucks.

True, availability is definitely a valued component there.

What are other controls do you think would be best to use aside from the ones we talked about that are most commonly used.

So you know the challenge of the joystick is it's a joystick and there are certain things you have to add to it __9:36_? I think part of the issue we come down to really is the concept of flight going from a tele operation requirement where you as a human being aspect physically fly it to one where human on the loop aspect where you're really directing the autonomy. And that in turn dictates the controls. Obviously if I'm flying a full tele operated system where I need to you know actuate the fly by wire to make sure all the flight controls move the way exactly I need them to do what I'm doing if I feel, then I need a control system that will give me that type of haptic feedback and allow me to manipulate all those things. But if I'm really telling the computer where to go when it's doing most of the driving I can run with something much easier and different right. Then the touchscreens and those sort of controls, that the stylus, I like the stylus screen better because you can't inadvertently (? 10:41) do things with your hand, a lot of people can't. So there's a level of security there but that sort of thing becomes more and more valid. I think that the challenge we talked about the screens and __? 10:52__ and also how we look at the rest of the display process so you know is a flat screen display as we try to jam everything on a little 7" tablet or we're using augmented reality to bring more information, in a more intuitive manner, there's a lot more that goes into it than, I look at the __? 11:09__ system not just the stick and rotors. I will say mouse is a no-no.

What about track balls?

I like track balls, I've seen track balls get jammed up. I think an optical mouse would probably work. Part of the problem is when we deal with, you know you were asking about fixed locations versus mobile locations. Some of the challenge gets into, you know we don't think about the dirt and dust. On mobile locations we run very heavily on dirt and dust. And you know you need to sift (11:52?) from that is it's dirt and dust resistant. In a fixed location where you can do a clean room, dirty room, a clean side, dirty side kind of thing. And you've got some servers you're protecting because you have more and more computing power on the ground. Some of the things you can get into because it's now fixed. You can get away from some of that and really have you know maybe a mouse would work because you're moving waypoints. And that sorta thing. It really depends on what level of autonomy you're shooting for.

We went back and looked at your surveys where you preferred vertical displays. You like your displays laid out vertically in orientation from each other.

I do.

Most people in the survey said that they use on average between one to three. So about how many on average would you say that you use?

So in a fixed location when I'm at a fixed location I have 6.

What kind of system were you running on at the fixed location?

You mean computer system? Or are you talking aircraft?

Aircraft.

So they were larger aircraft. And it was a variety of them together but it was you know Predators down through smaller systems that were all controlled and monitor (13:15?) at the same time.

General Atomics type systems?

That is correct.

Why do you prefer vertical over horizontal or a mix of the two?

Comfort level. It's twofold. One is, it's comfort level and it's also how I build up the scan (? 13:44). We as people we look at things on a more horizontal, we are not a 3 dimensional creature. I mean we think we are but don't fly, you know we are not 3 dimensional the way hawks are right or dolphins, right also 3 dimensional. We still look at, our feet is firmly planted on the ground and most of what we look at we scan, we scan a relatively horizontal plane. So in order to maintain situational awareness outside of just the controls if you have them aligned vertically you have to physically move you horizontal plane to go from the control station to reality and back. Right? Whereas you know the tendency especially when gamers tendency is I want full immersion. So if I have all my screens horizontal and all I do is turn left-right and everything is all horizontal I lose the situation awareness outside of that the screens.

So to kind of picture your set up you probably have fairly large wide screens so that when you stack em vertically you still have a horizontal component in addition to the vertical one you create?

Yes. And I probably should mention that in there that you know we are talking wide screens not square screens. So it's the, big fan of letterbox right? So when I have them set up and stacked that way one of the examples and this is more on the mobile than the fixed but you have a screen on a visor, you have a screen on a dashboard, but I can look out the window to see traffic and aircraft. And just to give you an idea how that set up works that was part of the transition out there. We did the same things for backseats where we had, I had a screen on my lap, I had a screen on the backrest of a car seat right, __? 15:39___. But you can look out left and right of the window and see what was happening in front of you what was happening outside the window on mobile station. So it ends up being very similar to some of the you know cockpit designs that are occurring now.

So a lot of your experiences were a cockpit layout.

Whether deliberately you know __? 16:08__ built as a cockpit or we just set it up as a cockpit.

Right, it goes back to what you're used to kinda thing.

Right.

Does it matter where certain information is displayed such as navigation information or the live camera feed?

Yes, I think it does. And again you know we go to what we are used to. And we as human beings are most used to automobiles. I realize that is eventually changing but for Americans we are the most car centric culture in the world. And how your autombiles work I think is a good, a good design to use when you're looking how you're weighing out control stations. So technical on __? 16:55 type data, viewing something you lean forward and focusing on, so you're looking down off your normal horizontal plane. Some of the ancillary information that you would put on center console like your air conditioning, your radios, moving map type things there __? 17:13__ where the GPS displays are. But now you start moving more into the moving real world aspects of it. So then if you're looking at and trying to find a camera information that's where it comes up more on that center horizontal plane before you get to the ceiling where you can just have extra ancillary information. A two or three level thing depending on how you want to build it out.

Given your preferred layout, do you find that you stand most of the time or sit most of the time, and we are talking about fixed, the fixed control station still, how are you oriented in respect to the control station?

So fixed, depending on the expected duration of the flight, a two hour you can sit relatively straight up. If you are going for more than two hours in a seat, a slight recline is often a little better so what you have is maybe a 5 degree off, 5 degree raise vertical angle between where you are and where your stuff is to allow your body's fatigue not to impact your flight. You also wanna be in position where you're not causing what I lovingly refer to as a __? 18:29__ or stagnant hypo__? 18:30_ where you are sitting on one spot for so long that parts of your body falls asleep and you don't realize the affect it has on your blood flow to your brain and your cognitive functions from there. So you wanna have a good place where you still have good blood flow and that takes a slight recline.

Would you ever stand at a fixed control station?

I would never stand at a fixed control station. I know sitting is the new cigarette. We are kinda going away from that. If I was actually you know the, if I was actually flight crew I would not sit. If was monitoring, assisting and augmenting I might be convinced to stand if I didn't actually activate controls. And I say that is because what that does is if you are sitting, I talked about all those layers technical controls, that are at that lower level if I'm standing that they are no longer at my lower level, or at the lowest level, so my view is that the top end is already data, and that middle dynamic data, and I have to be very deliberate in order to __?19:37_ and get involved in planetary (? 19:37). And based on the __? 19:40__ that would be good way to __?19:44) any crew roles without actually having to get __? 19:47 about it. It just keeps people __?19:49__ whether attention gets focused or not looking in someone's lap. When people have phones, if you have your phone in your lap, you don't have the same tendency to kind of peer over __? 19:59__as you have laid out on the table or on their desk. I know it sounds silly, I actually put a lot of time and effort in this particular subject.

*** literature review background talk***

26:18

Talking about other people, so visitors in the room, other people performing other functions with the UAS control, a lot of people in the survey indicated that at least one more or multiple people might be in the control room while the pilot is flying the UAS. So has this been your experience?

Oh completely. And there's a couple of thoughts behind why that is and how to control it. So one of the issues is that you now the thought of a single pilot aircraft, __? 27:00 all the time, there's military people who talk about they fly single pilot all the time, so all you need is one pilot doing it. And again to get back into our original discussion about how much automation versus tele-operation and really human in the loop aspects of the flight there is, additionally every pilot is not an imagery analyst or sensor analyst or a camera man or a videographer or an insert x whatever you are doing. And we had to forget that the idea behind flying unmanned aircraft is not to go from point A to point B, but to do something while it's in the air. So you have to have someway of bringing that expertise into the control station. So there's always this another person. And there's that challenge that we run into because it's not an airplane and we used to do this pre 9/11 you know how many people would fly somewhere and get up and go up to the front of the cabin and talk to the pilots during the flight because it was so cool. And I know I did that as a kid all the time. Part of why I wanted to become a pilot, but 2, if you are not actually flying and you're staring at a fixed station there is a human tendency to wanna go look. And it's very hard to have a reason not to. So I think even whether it's on the military side where you know someone full rank can come walk in, or on the corporate side where you know the people who you're trying to sell the service to wanna look at what you're doing so, you let em in or you're probably not gonna get the contract, there is that tendency to have that sterility of the cockpit violated. So you have to build a control station with that in mind. And I think that's also part of the challenge. You know additionally there's this other pieces of why do we have two people in flight and safety critical, mission critical, environments anyway. Doctors don't operate by themselves, ambulance drivers aren't alone, those sorta things because you wanna have that second set of eyes on everything. So you have someone who can operate the radios, and handle some of the discussions, or check weather or, even the Google searching which you wouldn't think you would do on an airplane but you know Google searching for map or Google searching for weather or getting back data for the you know the area you are flying on so you have a better view of what it is you are looking for or what it looked last time to compare of it this time. There's a reason for other functions that are __?? 29:33_. It also allows us as human beings to get you know to rest our primary focus and kind a do some mental palette cleansing. Where if I'm flying I'm fixated on the flying portion to make sure it's good and if I'm not directly flying I might be, you dangering a little bit (?29:50) but I might notice something out of periphery that if I wasn't actively involved I wouldn't notice. Kinda like when the navigator driving with somebody you oh the light's red, oh hey there's pedestrian, there's this, you can see things that the other person doesn't. So I think that builds on some of the human characteristics of it. So you don't wanna, one I'm obviously very huge fan of 2 people crews but two you have to have something like that built in just to be efficient. Especially with a fixed location.

So from your experience you had people that were just general visitors, observing, not really contributing, in best cases you had at least one other person helping provide those, additional pieces of information, awareness of other things going on.

Right and I think the largest crew we ever had actually plugged in together was 5. You have pilot, you had a sensor operator for the camera, a sensor operator for the radar, and then you had a specialist who didn't actually control any __30:59 ? __ equipment, but had a specific and special role when it came down to some of the radio communications and air to ground integration. And they were all working together as one cohesive unit that was fantastic but we had to and we joked about it, and one of the great things about unmanned is you get to open the door of a cockpit and you start adding seats. And that's what we did, __? 31:23__ that worked.

Was that for like a military operation or just a commercial proof of concept?

No that was a, the fun part is a lot of things people are doing commercially now, military's doing for years. So all of our precision agriculture we have __? 31:41__ someone realized during the 50s that if the Russians ever had a wheat crisis or famine it would cause a war so we need to figure out how well their crops are doing. And we forgotten that sometimes. So this was a military operation we were looking at pipelines and other things. Doing now what we call infrastructure surveillance that Shell and Exxon everybody wants us to go do. So there is a correlation in there, not a traditional military project of yeah we are gonna go drop bombs. It was a __32:15?__ we were making sure there were no leaks in the pipeline, we were checking road construction, we were checking this, all of these that are now commercial activities.

Continuing with the theme of the fixed control station and probably having a limited amount of room especially if there's multiple people in there, about a little over a 50% of the participants of the survey say that they do not have a desk at their control station. So in your opinion why would someone not have a desk if they are in a fixed control room?

I was getting ready to ask you that question. Why would somebody not have a desk or are we just defining desks differently.

That's part of it too, you know is the control station, considered the desk so, people were visualizing a desk, separate to the control station itself possibly.

Right so as an example, one thing that we looked at as a centralized design for central fixed location was a drafting table. Right so if you think about, I wish I had picture I could send you, cause we actually bought a couple for my IKEA ? 34:07, that we started playing around with, they had a little, the modern TV dinner table thing right. You put your comfortable chair in, you lean back, there was a sub-level for you to put a mouse and other things. And then there was a relatively small maybe 2 foot by 18 inch table surface that you could then tilt. And the whole table is set up on a metal rollers, and then we could add everything to that. So we could put the monitors we could put the computer, the flight controls, whatever it is we need to add we just added that and you had a comfortable station. I wouldn't call that a desk, but it fulfills that desk type function.

Maybe that's where the confusion was for why so many people said that they didn't use a desk.

Yeah you look at the red verb simulator right. An FAA certified simulator for a general aviation light aircraft __35:12?_. They bring out you know 3 monitors, and some control, a control panel and you put that on top of your desk with your flight controls and then you fly. Or you put it on a table, again I wouldn't call a table a desk but serves that same function. So I'm interested if that's where some of the confusion came from.

That's what we were thinking so I think you kinda helped clarify that. And for the other people that we are going to talk to that mention they work at a fixed desk, we'll have them clarify that too. So that definitely helps.

What kind of chair, you mentioned, you know if it's a shorter flight, you would prefer to sit up, if it's longer one you recline a little bit, what kind of chair, you typically use in a fixed control station?

So that's a funny one. So there's the chair you get stuck with right which is usually an office type chair. And then there's you know had a chance to actually kind of, kind of build it out yourself, you know a slight recline is very important, and that gives you it gives you some of that I wanna say comfort but it does it takes away some of the stress for your actual flight right. You're not as beat up. There's an IKEA chair we keep gravitating back to which is kind of funny I'm trying to pull up the name of it. We went out and bought a few of those just because they were comfortable and they are, they are not traditional recliners but they bend and recline. The "poang". And we like those because they don't move right you don't want a chair that slides around, if you have a control it's locked to the table, you don't want it to cause in fulcrum or lever points where you're moving yourself interfering with your controls. Right so you wanna have a good solid base. But it needs to be comfortable and it needs to be slightly flexible. We as people like to move a little bit and that helps us stay focused. It also and that's the funny part, because of the way it's constructed we found you can attach things to it. So if I need a little table to put a, if I'm gonna put a mouse if I'm gonna put charts to reference or I need an extra control box, it's very easy to attach it to. And it gives you an idea where we are running with but the slight reclining and the adjustable chairs is probably the most important aspects of the human. Because we are all built differently, and unlike the military which gets to go okay you can't fly this aircraft unless you are between 5' 6" and 5' 8", and the length from your ankle to your knee has to be, you know 19 to 21 inches. If it's too long or too short we don't let you fly. Commercially, we wanna make sure we have that adjustment.

A few participants mentioned that there wasn't enough space or enough of a work surface, I know there's probably a little confusion, for some of the participants on what qualifies as a desk or control station, but do you find that you ever need work space when you are working in the control station?

On a fixed station no. On a fixed station we are very deliberate on how we assemble our fixed stations. We also teach people about knee boards right. And I've transferred some of _? 39:01 over from traditional aviation. So that whether you are strapping iPads to your knee for additional reference whether you have a little clipboards attached and that's part of your equipment your kit when you sit down and go to the flight. So we take a slightly more traditional approach to some of these things. We've also taken a look at how Formula 1 and NASCAR do some of their, you know how they equip their drivers and how that's put together. So you know you're not taking space of things you don't have to. One of the great examples I've seen be a problem is that if you have a traditional non-laptop you know computer CPU based control station and you slap that on top of a desk, you just took up a whole bunch of real estate for the desk. If your monitors are sitting on monitor stands on the desk you just took up a lot of space on the desk. So there's ways to optimize that.

What are the things you, what do you like about the control station you've worked in?

So I like the flexibility. One of the things that we've really taken advantage of is the logical, the fact that you get multiple architectures and multiple logical systems together but they are physically co-located. So I get two different computers running information. One that's secure and just for flight. And one that provides me access to additional information. Whether it's for flight or air map or you know some type of additional data that I'm getting related to __? 41:08 weather or those sorts of things. And I can just add that onto a control station I needed. And that's probably the best thing I'm not in the military so I can add things and not get yelled at for it. Right so you're not stuck with the same type of size restrictions, weight restrictions that you are in the aviation world. Same thing would happen with a 747. If I was wanting to add a new monitor, add a new feed to a 747 it's just not gonna happen. Because it won't necessarily fit you gotta rewire things _? 41:38_. You know fixed station it usually ends up being a matter of you know getting out of Amazon or Newegg, buying a new monitor, stand or arm, connecting it in someway to the table desk or post and attaching some wires and then. You know we can tap them to the cloud that way. There's all kinds of different things you can reach out and do. Especially on a fixed station. So I really like the flexibility and adjustment because you can add additional data, you can add additional people you're not trapped with just the one answer. And I think the best station that takes account for that (? 42:16) are modular in nature.

What do you dislike about the control stations you've worked in?

I really can't stand the ones that I don't adjust and be flexible with. And that's one of the issues. But things that are built for a certain type of person I think is also part of the challenge. So I'll be the first one to admit I am a pilot and I flew and I like things that way. So if I'm unable to adjust things to fit my need then that becomes very uncomfortable and becomes the source of stress and anxiety for me. The same way the other way. If you're used to you know __? 43:03__ video game design right. So if you see information provided to you on a video game and yet you can't, and you can't get that same feed because forcing you a HUD type display I understand that. So there's some taking in to the software aspect what type of flight _? 43:22__ you have I think becomes important. I think the other thing that really just frustrating is the when people throw out the aviation human factors thought and you have multiple layers of many user displays to get to in order to conduct routine things and routine information. So if I'm trying to put everything on a single screen. __? 43:45__ as far as a manufacturer but me as a operator or one of the pilot we need I need to know information that has to, I've got to pull away from the camera, pull away from the flight controls, and dig down through separate menus in order to get to, that creates a problem. It's very similar to my GPS right. So I mount my phone on my dashboard when I'm driving with my GPS. So that for me it's in the same field of view as I'm looking out in front of the car. If I had it on the seat next to me where I had to keep looking down and start focusing on my phone figure out where I was gonna go that is an accident waiting to happen. And same thing happens in the aircraft.

I'm gonna jump over the mobile real quick. And some of these things you've touched on a little bit so we'll kinda get right through em. Going back to control types, control devices so you discussed the most common ones joysticks touchscreen and the traditional yoke and control stick. Are those the same ones you would use when you are mobile? Or do you have other control types that you would use when you're in a mobile control station?

Right so smartphones and what I call the flight control box, which is your traditional RC hand controller. Are probably the two most popular that I've seen. So we are running off of smartphone and tablets and we are running off of control box and sometimes we get really complicated we ? 45:15___ the two together. So from a mobile station I'll be the first one to tell you, smartphones are the worst way to control any type of flight anything. And there's two significant reasons why, one half of the value of smartphone is for communications and if someone calls you in the middle of a flight you have a problem. And two I live in southern Nevada. We do a lot of flights at a hundred plus degrees. And as an example my smartphones overheat in my car on the way to flight site. So if we are there you now we are flying a solar power plane. And you know midflight the smartphone we were using as a backup, we got the big yellow thermometer symbol saying we are too high you're done, and the phone shut off. Because it overheated. So one of the challenges on the mobile stations is you can't just take a phone and make it your mobile station. You really have to do some level of hardening and toughing to handle the vibrations, dirt, dust, wetness, the cold, the heat. Phones by themselves just don't do it. And the same thing goes for laptops and tablets. By themselves just doesn't work that way.

What other controls would you prefer to use in a mobile environment? Or do you find that the joystick and the control yokes and sticks are enough?

It goes back to the level of autonomy. You know do I need, do I need two joysticks controls so I can fly an aircraft, or can I do it with a single one. It really depends on how that control is put in place. I am flying with, we don't have a lot of issue with the, some of the traditional controls types when we built on based on that type of control system where we had really basically just an X-box where we had an d-pads and a controller, kinda bounced back and forth between what I needed. And that works and it's relatively useful. But you're also not flying those type mobile for you know a very extended period of time. You're not gonna do 6-8 hours sitting in a car, standing out in the field by yourself. Those are much more crew intensive because you wanna reduce the environmental exposure your flight crews and your systems and kinda keep things running flexible that way. Does that make sense?

Yeah that makes perfect sense. That lines up with some of the other comments we've heard so that's good….

What about displays, you like multiple displays in the fixed control station. What about when you're mobile?

I do. I love multiple displays when I'm mobile. And that's very difficult to put together because you don't have you know when you start breaking wires out __48:22__?__ either you have a large system and you end up __? 48:26__ in a box. Or you have to use the components. One of the things that we've been playing with is a modular you know a couple different modular components that we can set up. I like to say when you hang the screen off the back of the seat in front of you, because you know __? 48:44 in a hundred degrees, so if we can fly from inside a vehicle we have extra power, extra cooling we do that. Same point of time is if I can put it the receiver and some of the wireless access points and those sorta things inside of vehicle to get that information the pilot can still be outside doing you know the appropriate collision avoidance self-separation. And flight aspects of it. And they just take turns switching people inside outside. So you're meeting the regular __? 49:12__ requirements as well as the information requirements in the monitor. So that's worked out pretty well. We're starting to play with some of the augmented reality where you know the __? 49:25 monitors, it's a virtual monitor so Google glass or something like that. And when you look own you can look down and there are hollow lens you know the __? 49:36 as an idea. You look down at a certain table and that's where you see your controls and information. And you look up at the sky and it highs the aircraft flying around, where the aircraft is, your flight areas. You know some of those areas I think are really neat, potential. I don't think we are quite there yet but I think there's definitely some growth in that area as well.

Do you have the same type of information on the displays when you're in a mobile environment that you would in a fixed one?

Well if I had my way I would. I'm weird that way. I found that there is a streamline aspect of what you actually need to go fly. It really depends on if I'm just watching again solar power plane is a great example. So you have several pre-programmed routes, you have to fly the same way every time because of the way data's collected, you launch the aircraft and basically all your pilot is doing is monitoring the health of the aircraft while they are flying, everything is automated as far as __ 50:50?___. They can run with a much smaller amount of information and data. Because it is it's truly a _? 51:01 type of flight. I mean there's a high level of autonomy in that preprogramming involved. That I think is the way better for some of the mobile stations if you have a field person out there doing work. Even with wind turbine,?__51:17 with wind turbines. They have an autonomous pattern. When you take off you say fly this pattern and it flies a pattern, collect the data, and optimize way for that particular wind turbine. And it just lands you pick it up swap batteries charge it over do it again. So you don't need a lot of extraneous data however, I am weird I do make all my flight crews track air space data and monitor radio and those other things. So there's a level of equipage?_51:50 that you have to have on that mobile control station. The other thing we do that is relatively neat is we put up the __52:00? __ the velvet rope that's around our mobile station. So even if it is someone standing there with a yellow vest and a hard hat on, flying for a construction site, there is a space around them with cones and hazard tape, so that people don't go into interfere. I mean it's really funny. We are very well trained as people to respond to certain patterns and colors. You know the big vest, the hard hat and the orange cones, that's a really easy universally understood way of stay away. Flashing amber lights, same thing.

What about things that can kind of get in the way when you're doing mobile control. Such as glare and noise level?

Noise. So we use, there's some construction quality noise cancelling headsets that we use. Called Riobi (? 53:23) It actually allows plug-in communication devices as well so it cancels out hyper _? 53:30 noise. It thrives some intensification of people talking to you within a certain range of sound. And you can plug it into your phone and kick the monitor, radio, track? 53:41 other communications that way. So we've used those. And again it all comes down to part of the scoping out the area and blocking things off. We also do something unique, fly from moving vehicles. We do so day and night. And that requires slightly different build to our mobile configurations. Because you have to worry about you know day and night adaptation for screens. You go from bright screens look outside that doesn't do any good. So there's some light solution aspects that we work in there as well. You know the comfort level of you know being you know in a moving vehicle, looking at screens, going different ways and then spatial disorientation occurs in there. So again slightly different views and you probably get from 99% of the people __ 54:32__? Because that's one of our unique things that we've been doing for quite some time. But that's part of the disorientation. Just like don't distract the driver, just like the sterile cockpit we treat the entire areas as much as possible for sterile cockpit.

What about getting solution on noise. How do you handle glare?

So couple of dangerous things to worry about you know sunglasses are great to handle glare but people seem to forget that polarized sunglasses have an effect on depth perception. Which is why there's actually restrictions to what pilots are allows to wear for sunglasses and I've actually when I was learning how to fly a system almost 10 years ago, I crashed twice into some trees during some low level flights. And you now in anger I would take my sunglasses off and point and yell and I see just exactly what I did wrong, put the glasses back on and did it again. And after the second one I was talking to one of the other instructors he kind of looks at me and goes polarized sunglasses right? I'm like yeah but and then it hit me that was the problem. So with the sunglasses on because of polarization the depth perception ques all the skews weren't there. When I took them off I could see very clearly, forgot when I put it back on I couldn't anymore. So the neutral __? 55:59__ 15 unpolarized sunglasses in a grey or one of the things that we work on standard as far as glare off of displays you know part of that tracking is how you have things set up and using some of the polarized filters off of the displays that works well. Some of the privacy filters if you have the ability to adapt to it that works as well. As does the enclosed boxes again you know IKEA is fantastic for some of these but there's these folding fabric boxes that IKEA sells that we've been able to use. If you fold em up flat while you're driving, you unfold em and they create this little shadow box you put the system in, it really high lights some of that the resolution, the screen, the brightness of the screen. Again we talk environmental factors. Keeping everything from overheating, have to having that direct sunlight is very important to us. So if you block everything out to get no glare, you have to get that cooling in there as well.

Do you ever have the need for a backpack?

I hate backpacks. I think that's the worst design for a system you could ever get to. And I say that for a variety of reasons. Top of the list which is you know to carry the things that you need to carry to be sufficient a backpack in my mind is not the right way to go. Plus, it's really uncomfortable. When you're getting from an ego centric point of view to exo centric point of view, which is what you have to do flying aircraft and we are piloting, you forget that you now have this giant weight on your body and the tendency to move and trip and potentially injure yourself and impact the flight unexpectedly is much greater with the backpack in place. Even if you take it off and put it on the ground which is also pretty funny. Most of the times we use bags. We use a dry bag kinda like you use for scooba diving, we have a diving program that we do for underwater robots. So a lot of things that we brought over equipage is tied into some of that. And then you hang it off of a table or hang it off pole or antenna mess, something that you're using as part of it, so you have an area of don't go near me this is where the equipment is, and you have the whole thing blocked off from there.

I'm kinda old fashioned that way but you know pelican cases and those type of hard cases are not only much better they also provide work space when needed. So it could turn into a desk, turn into a chair, if you have to. The 1850s by pelican we've used as chairs desks and all kinds of different things. Also backpack gets wet. And there are pretty horrible things that happen to aircrafts when their equipment gets wet.

11.3.4 Interview #4

[00:00:44] So I guess what even though we've talked about it a few times before. Let's just kind of revisit the type of work that you do that involves you're required to or requires you to pilot or work with us and drones.

[00:00:59] So again just to level that I don't I don't have any direct experience controlling UAS but my job is an air traffic controller. an airborne air traffic controller basically.

[00:01:12] So I sit at a console and monitor upwards of 80 to 100 plus aircraft at any one time passively and then I actively you know communicate with probably up to 16 at a time and control sending them to specific air spaces and things of that nature.

[00:01:39] **OK. Would you say that you work at the we know the answer to this would you work mostly with a fixed control station configuration or mobile controls.**

[00:01:51] I would say fixed because I know your definition of mobile would be more a person carrying it. I'm in an aircraft so that makes it mobile. But it's a I would still call it a fixed station. **OK.**

[00:02:07] **Yeah. There's also that configuration like the in the back of the vehicle or in the trailer we would consider that mobile even though the station itself probably looks more like a fixed one.**

[00:02:22] I would say it's mobile then. Because like I said it's within an aircraft I'm controlling from the air while doing a hundred and seventy nots.

[00:02:30] **OK. So in this case is the aircraft flying itself and your you're observing and doing some level of control remotely on their aircraft.**

[00:02:41] I mean is that your question. **Yeah.** Right there are two pilots flying the aircraft and myself and two other controllers in the back with me. **OK. Well.**

[00:02:54] Let's I guess let's call that kind of a fixed configuration for now even though you are moving. So we'll stick with that line of questioning. When you talk about doing the controls. The remote type controls. What controls do you typically use? So.

[00:03:14] Again that's the somewhat gray area when

[00:03:17] We're using the word control; I use voice control; I provide guidance to the aircraft through radio communications. There is a capability and I have used it on one or two occasions to remotely take control of the aircraft and that's conducted through a keyboard and variable action button interface where I can punch in a heading and airspeed for the aircraft and it will execute. And the pilot is hands off at that time even though he is in the cockpit still**. OK.**

[00:03:58] So this is a background for the students here in some of the aircraft. The pilot can hand over control to someone remotely. And so in essence I guess the aircraft you could say becomes somewhat autonomous. There is a person physically in there who can take control back over. So when they're, when they're in control the remote pilot, you know,

they have their own control system that they use to enter commands. “Are these commercial planes?”. No these are military planes. So this is this is one of the military type scenarios. So.

[00:04:40] **What other controls have you seen other people using to remotely control or are they all fairly standard based on the configuration you use.**

[00:04:51] No I would say mine is probably unique. I've seen wrist mounted joysticks, wrist mounted keyboards, basically, and then full of cockpit mockups.

[00:05:07] **OK. How does the wrist know it controls looks and work?** It was a. I don't know probably about**...**

[00:05:19] I think of the Nintendo Power. Reuben, you know what that is; I don't know if the other guys in the room know it.

[00:05:26] **So it was a glove with kind of controls that go back on the forearm**. Yeah**. OK**. And.

[00:05:37] You know a little bit bulkier than maybe the size of an iPad maybe that overall size of an iPad but five six times as big as that. OK. And then it's pretty large. And this was a pretty early model of it that I saw a close. A pretty thick, electrical bundle running from that wrist mounted control back to a conex boxer.

[00:06:11] **Did it severely limit mobility of the pilot or would you never really move around much anyway.**

[00:06:19] It didn't limit them too bad this was on an aircraft carrier flight deck. So there's not a whole lot of room that you need to move anyway. **OK**. That tether was long enough that it gave the pilot the movement they needed it to maintain eye contact with the aircraft the whole time.

[00:06:37] **OK. From kind of seeing that configuration and maybe observing people using it. Were there any notable pros or cons to that type of configuration.**

[00:06:50] The con would be that that tether still, I would think the overall I don't know how heavy it was. I would imagine that if you could down size that it would be better; the size of that seem like it might get a little cumbersome. Obviously the pro was that it was Mobile worn on his arm so it was really easy to access and move around with. The aircraft in that instance was only controlled through that up to a certain point and then the operator basically hit a button and executed a full autonomous state and the aircraft went full autonomous at that point and just executed its own routine. **OK. Is that a configuration that would be more?**

[00:07:43] Conventional for an aircraft carrier; a place where there is limited space.

[00:07:48] I think so yeah**. OK.**

[00:07:52] **All right. In addition to having that wearable or even thinking back to the configuration that you're mostly used to tell me a little bit about the display configuration that**

you would have would, I imagine your system had multiple at least one larger if not multiple displays and then were there displays in addition to that that hand or wrist mount wearable. So for my aircraft, my control space is one I think at 17 but one large screen for each of the three controllers. And then. It's

[00:08:33] a Windows based software so you could bring out multiple windows inside of that 17-inch screen. But then we typically have one additional per controller. We have one additional screen just to the right or left of that 17-inch screen for. Some other functions.

[00:08:56] **OK. Not necessarily core functions but just some supplemental information or other things you may need occasionally.**

[00:09:02] Right. **OK. And you would typically have. You mentioned three controllers. Would that be you know three people at three configurations all next to each other**. Correct. **OK. With you. Do you ever feel the need to have more displays or possibly have those displays laid out differently?**

[00:09:26] The only layout difference would be that secondary screen. In my case it was positioned to them. Trying to think. There was positioned on the left of the 17-inch screen and being the majority of people being right handed I think would have made more sense because each of us tended to default to the one to our right which is actually stealing the other person's control interface. So. I would default you know probably to the right to have some if you have a secondary or tertiary screen. That has to be manipulated. I would default to having that offset to the right of the main screen.

[00:10:19] **Yeah I remember you telling me about that. That was one of your main issues with it is everybody's looking on everybody else's screen because.**

[00:10:27] maybe some type of maybe configurable layout where you could you could shift where that secondary screen is.

[00:10:36] Yeah. Yeah. And that's as far as a 17-inch screen. The main screen that I use and that one is sufficient because it's Windows based. I can actually make duplicates of you and I can actually extend it and do things like extended desktop type and make four main screens within that one if I really wanted to. But you get into the question of your ability to actually effectively monitor that much information if you're here are starting to subdivide it. So. The one large screen in my opinion is sufficient.

[00:11:19] **How big is that other supplemental screen?** I would say again about the dimension like.

[00:11:29] 8 by 10 or six by ten.

[00:11:33] **OK so a little bit bigger than a tablet but smaller than a conventional monitor.**

[00:11:38] Yeah. **OK.**

[00:11:41] **Let's see. You mentioned that one of the layouts that is common is like that of the cockpit.**

[00:11:49] Is that configuration a lot more common for the type of task that you do. Or is it more like just a standard you're at a desk in a keyboard and monitor.

[00:12:01] The cockpit configuration. And from what I understand and the people I've talked to is more common in the in the UAS around where there is a rated pilot sitting at the controls flying with the remote pilot in an aircraft.

[00:12:22] **At the configuration you typically use. Would you ever have a need to stand or want to stand while you're performing the controls.** My want to stand is only to stretch my legs because.

[00:12:37] We're flying for two and a half hours at least usually for just to be able to stretch a little bit. Now as far as standing to control itself isn't on our environment frankly.

[00:12:52] **OK it is two to two and a half hours. A fairly common duration for how long you're in control.**

[00:13:00] For my aircraft yes. I don't know how long some of the other aircraft can stay airborne.

[00:13:10] **And what type of aircraft is yours. Again**. The E2 Hawkeye. **You mentioned that there's I guess it sounds like up to three operators working at a time controlling different aircraft as necessary. Are there other people other visitors that may be in the area that are either near you or observing or participating in the control in some way?** No, like is said the two pilots are about 15 ft. forward of the control compartment in the aircraft and there may be an occasion where one of the pilots could walk back and

[00:14:00] Look over you know look over the shoulder of one of the controllers or something but that's not very typical.

[00:14:06] **OK. In reference to your work area. Would you say that you have an actual desk? Like is it a desk type configuration that has your controls and your displays.**

[00:14:22] It is, it’s a pullout, we call it a bullnose, it is a pullout desk with a built-in keyboard and trackball on it.

[00:14:31] **OK. Would you ever do any work on that. That bullnose desk. And in addition to flying would you ever need to have books out or take notes or anything like that.**

[00:14:45] Yeah, yeah we do that pretty regularly actually.

[00:14:49] **Is there enough room for you to do those types of things are you. You're finding your kind of having to set it on your lap or.**

[00:14:55] No there's not enough room typically. **OK. All right**.

[00:15:08] **What other things might you need to do. On your desk.**

[00:15:23] **Or would you even prefer to do if you had the space to do it.**

[00:15:29] I can't really think honestly. I mean the main one is note taking in the process of controlling multiple aircraft. It is common take half a dozen sheets of paper with you with expected call signs and a lot of flight information. So. That's the main thing is record keeping and note taking is really what you need to do. OK.

[00:15:59] **That makes sense. What do you like. Yeah what do you either like or like most about the control stations you currently work in.** I would probably say

[00:16:14] Ease of access and I'm very familiar with the keyboard and mouse. So. Using those I could train most anybody to. Keyboard and trackball. I'd say that familiarity, that it is not a foreign control device.

[00:16:38] To anybody. **Are there any other control types that you would like to try or you think would work better than the typical keyboard and mouse configuration.**

[00:16:51] For my specific task. Not really. I like the idea of a touch screen but with the vibration and everything that is produced, I don't think it's feasible.

[00:17:08] **OK. All right that makes sense. Have you seen anybody try to deploy or heard of anybody trying to deploy a touch screen type solution.**

[00:17:16] I have not. **OK**.

[00:17:18] **All right. You told me what you like. Tell me a little bit about what you don't like about your control station**. I actually don't like the trackball I would prefer a.

[00:17:30] Optical Mouse**. OK**. I just.

[00:17:34] I feel like it's faster to maneuver when you're having again a 17-inch screen moving the cursor from the far right all the way to the far left. I feel like it's much faster with a mouse but that could be user preference

[00:17:53] **Do you have any experience with the trackball getting dusty or gummed up?**

[00:17:57] And er yeah. **Is that a fairly common thing after you've been using it for you know many flights**. I wouldn't. I wouldn't say it's really common but it is kind of

[00:18:13] Expected but it's not overly common. It doesn't happen every second or third flight. But it happens.

[00:18:21] Often enough.

[00:18:23] **OK. Given your job function and what you're doing if you could design a control station from scratch. What would you do differently or how would you design that.** I would probably start with the. Honestly I'd probably start with the ergonomics of the seating. Especially if you're looking for long durations of control. That would go into the probably other biggest dislike is our seats. **Tell me a little bit about your type of see. What it what you don't like about it like about it specifically**. Basically is how Hard it is. I was going to say rigid but it's an adjustable seat as far as you can slide it forward and back you can turn left and right. And you can actually even tilt it. So that if you can picture how I can’t think of the best way to describe it but if you can picture an aircraft with a nose up attitude and.

[00:19:41] You're able to actually can’t the seed to offset so that you're not leaning as much. If that makes sense. Can you follow visually what I'm describing? **Yeah I think so**. If an aircraft is flying sideway or flying forward I'm actually not facing forward with the nose of the aircraft, I'm facing to the left of it. So if you then put it nose up attitude I'd be leaning to my left the entire time. OK. You're able to can't the seat to offset that leaning to the left so that I'm actually closer to even.

[00:20:21] **That must be fairly easy to do. I would think that there must be a feature you like and you're able to adjust it pretty much at will**

[00:20:27] Yeah adjusting it is really easy. It's really the discomfort comes in the seat cushion being pretty hard. And so after two and a half hours it's not really comfortable anymore.

[00:20:45] **OK. So. Tell me a little bit about common issues that you had outside of the control station itself. For example, depending on your lay out glare or noise level here appears to be pretty common issues based on the feedback we got from the survey. Are these issues for you too?**

[00:21:06 Glare is not. we're able to close up our windows.

[00:21:10] We have a windshield basically that we closed out the window to eliminate glare and we can adjust our lighting so we can turn down the lighting. So glare is not an issue the noise is definitely an issue. And that's again being in an aircraft you have engine noise and everything else. And then wearing earplugs on top of that for hearing protection. What has helped with that is that newer aircraft have a greater functionality with adjusting volume on radios listening to multiple radios. I used to only be able to control all the volume for all the radios through one switch. Now I can control each individual radio.

[00:22:01] Independently. **Do they use any type of noise canceling headphones where you can still kind of hear what's going on?** It is not a fleet wide issued item, Noise canceling headphones. But you can. People do use them on individual basis. Some people do.

[00:22:28] **OK. Do you ever have to wear or carry any equipment? Or which I guess you really have to carry too much given that you're seated. But is there any type of equipment you have to put on.**

[00:22:43] In order to perform your function.

[00:22:47] I do. I wear a full. Flight gear so a harness, vest, and helmet.

[00:22:56] **OK. Does any of that get in the way with the with a chair that you have.**

[00:23:02] **Or does the chair get in the way of it**. No

[00:23:06] OK. Is there anything about the physical design of control station that you think is important that we haven't talked about here.

[00:23:20] **Not that comes to mind**. OK.

[00:23:24] **OK. I've run out of my questions if you don't have any additional questions. Yours is definitely a unique scenario right here flying something that can either be manned or autonomous. I mean I guess it remains may and but it can still become an autonomous just like other U.S. configuration types. So.**

[00:23:45] It's definitely good to get your perspective. So I'm kind of going off the cuff with some of the questions I had to try to accommodate.

[00:23:57] **You want to ask anything specific about comfort. We touched on it with the chair. You want to dig a little deeper on the areas of discomfort**.

So the question was related to comfort with where is the pressure of the seat coming from that makes it uncomfortable. Is it lower back or a higher back in the seat as you mentioned. You mentioned firm and rigid.

[00:24:32] And I would say in the seat itself as well as lower back.

[00:24:40**] OK. Is the chair back high enough that you can rest your head on it? Or does it does it stop below your neck**? It goes it has a headrest and it goes up high enough.

[00:24:55] The back is not reclinable. The entire assembly can be pivoted along that axis if you will. But then you feel like you're going to slip out of the front of the chair if you were to do that. Generally, where I'm seated kind of on the edge of the seat. And so I'm not really back against the backrest while I'm controlling.

[00:25:23] **OK. Are you having to lean over or your still seated straight but you're just not back into the seat.**

[00:25:34] Yeah I'm still seated straight. I'm just not seated all the way back against it in any way.

[00:25:40] **The chair I'm assuming that connected to the floor so there's no rolling that chair up under the desk or anything like that.**

[00:25:47] Again it can slide. I slide it forward under the desk.

[00:25:53] **OK. And then you slide it back to get out of the chair when you're done**. Right. Or. **Do you have our arm rest on the chair?** No arm rests **OK. That's interesting.**

[00:26:06] **What about discomfort in other areas like eye strain. You mentioned the hearing so obviously if you're having to wear earplugs there's going to be some.**

[00:26:16] You know over long exposure there's probably going to some discomfort there. But what about eyestrain and things like that. No. No eyestrain**. Is lighting appropriate**.

[00:26:28] It is **OK.**

[00:26:37] **Oh that's a good question. You mentioned that you prefer when you can use the optical mouse but do vibrations get in the way of using that type of control.**

[00:26:46] It can. If you take your hand off of it, you'll see it process across the screen. But at the same time the same goes with the trackball. Oh.

[00:26:57] **OK. So that the track is definitely worse because I mean there's nothing you can do. You can pick the mouse up and quickly recover but the fact is attached to it.**

[00:27:06] Right

[00:27:12] **Do you ever find you need to communicate with the other two operators around you.**

[00:27:16] Yeah we regularly communicate we have internal communication through that head-set.

[00:27:24] **OK so you're not having to yell at each other over the noise.** Yeah. **OK. Let's see.**

[00:27:32] **What were some of the other areas of discomfort. We got eyes ears.**

[00:27:38] Back. Right.

[00:27:44] **OK. Do you ever experience any shoulder or forearm discomfort given that you have your flight gear, your straps, and that very rigid chair?**

[00:27:55] Funny that I have persistence left shoulder pain but maybe from other things. But the combination of the flight harness and just the sitting and everything and they all work together to aggravate it.

[00:28:10] **OK. So you may go in before the mission feeling fine and then two hours later you're getting up and you're feeling kind of creaky and achy.**

[00:28:20] Yeah. It's not uncommon for my head it's my left personally that hurts most. But after a flight I'm definitely sore

[00:28:29] OK. What about neck strain from having to look from one monitor to the other. No problem with that. **You're right handed aren't you.** I am. Yes.

[00:29:08] **So what is the height of your desk? is it the elbow height where you can easily you're your elbows on it. Or is it more a shoulder height.**

[00:29:19] I would say of those two, elbow height. That's definitely not shoulder height.

[00:29:27] **You can comfortably rest your elbows on it.** Yeah. **Which you're pretty tall too so.** Yeah. **So I guess somebody my height or a little bit shorter maybe a little bit taller than elbow height.**

Yeah for some people, but you can adjust the seat height anyways.

Are there any other mobile control questions?

11.3.5 Interview #5

What type of work are you involved in that requires you to pilot a UAS either now or in the past?

For one in the past um I know two of us have had experience working with the military and being in the military flying UAS. You know one requirement of it for stuff like yeah specifically for ISO support. You know and then all of our research and development and testing that we do here

What type of aircraft did yall fly in the military?

I flew the shadow and then as the civilian contractor I the airzone for the Marines.

And as a civilian contractor I flew scan eagle for army and marines.

I actually flew the tiger shark tiger shark and had a lot of experience at airostaff.

Would you say that the majority of you have experience with more of a fixed control station or did you get some experience with that with a mobile configuration that I described earlier?

Mine would work best for the Shadow and Arrazon. And it went from shadow was at the back of a humvee shelter, airzon was at a table desk you know in a tent, something like a desktop computer style.

Scan eagle systems are um we won't particularly classify them as mobile even though there was a mobile ground station available. This was more of a transportable ground control. So everything was in a series of Pelican cases that were connected to each other and then run to a fixed point in a building. So more transportable that you would once you set it up then it was fixed. And so it would probably be there for like five or six years.

OK. Pretty fix. OK. Well what I'll do is we kind of we have two sets of questions one that focused more on fixed and then some questions that deal with mobile. So what I'll do now is I'll start with a fixed questions because I think that these kinds of questions may pertain more to your experience but also if there's time I'll touch on some of the mobile aspects as well toward the end.

That the more recent experience is that we had been with mobile stations.

Okay. Well I'll try to hurry so I can get through to both sets then so that we can get your input. Some of the results from the survey we found and we were able to get a decent number of responses here this last week in terms of the top three control devices used in control stations whether they were fixed or mobile regardless of what type of those three types were joysticks touchscreens and the traditional yolk and control sticks. So those three were used in the majority of the time based on the survey respondents. From your experience do you agree with those findings.

I've never flown a yolk system.

I've had it control stick but it wasn't to fly the aircraft it was to drive the payload.

OK. I haven't flown anything that. Anything that required anything like Logitech or a x-box controller but I have used a system that had a astromopad on it that was also an additional hockey control to the payload.

Table. OK but no touch screens in your experience.

Go ahead. Yes. OK. Some of the DJI stuff right. Yeah. OK. Patriot had touchscreen. that was mostly small.

And then when you when you mentioned that survey of joystick control touch screen and I'm sorry what is the other one the traditional yolk and control stick. OK. So in the unmanned world when you mention those all of those can be used for completely different things aside from controlling the aircraft. So when I answered the questions to the survey I've seen joysticks sitting next to stuff and I've seen controllers sitting next machines that the controller does a flight check and doesn't actually do anything in flight. The joystick only controls the payload it doesn't control the aircraft there is standard mode to RC stuff if there is just computer point and click even so there is, and I am not trying to be your survey up that's not what it is about. But because the unmanned world has no standard like you've already discovered. And there's no. You can't even say there is a normal way to control an unmanned system. Currently because in this room we all have flown Piccolo

basic RC, DJI I did and I mean I'm you can go and then whatever name was using to operate his machine I think it was proprietary. So how do we answer your question the best, I guess, I think we are trying to get you the right information. the facts are very. Low and you can bet that he has. And what I'm trying to make sure we give you get information. [18.4]

Well let me let me rephrase a little bit differently and so we can get that specific to that being the U.S. pilot actually piloting the aircraft. From your experience what controls do you like best. Or would you would you prefer to use when directly piloting the aircraft. That's probably a better way to ask that question.

I think some of our more mobile systems for that maybe to have a touchscreen or something smaller, a mobile a mobile device right or a larger for flexibility.

I'm not a big fan of the touchscreen. Yeah. Scout e line is terrible. But they made it really difficult to respond quickly to a change in events.

Can we all agree; we would like some method to directly affected flight to possibly a joystick or mode two controller. Is that fair to make the aircraft turn for a direct length of sometime to the aircraft. And based off of mode two or standard aviation control function. OK. And just to determine that is what you want to direct control of the aircraft or entire control station.

Well we did. It's a little gray in that area. We want to learn about the entire ground station but given as much variability as there is like what you mentioned I think we are time to be best man focusing on just control of the UAS for now and learning about it because we know there's all different types of ways to control it but there's a few that are preferred

and reasons why they're preferred. So that definitely hone in on that particular piece of information.

The preferred method for me, only going to speak for me right now, that it works for the computer.

Point and click through as much audio mode that it can handle. And then if there is a problem we have a way to directly interact with the aircraft. That. Have a lot of heads shaking up and down.

OK that's good. And that's when we specifically spoken with experts that's kind of what they would prefer is that you interact with when it's exception based or when it's necessary not constant interaction to control it. You'd prefer the aircraft control itself except when you have to intervene right.

Yeah. There are a lot of auto functions in these. And that's what they're designed for. And then if I had my way it's me speaking again those controls with joysticks the. We come up with some kind of standard that I don't know how you would do this but make everyone agree that you know pull back on the joystick it goes up and push forward on a joint stick the nose goes down, you twist the joystick it goes? You know if that's the standard then that way you transition from different aircraft much easier.

Right. Yeah that makes sense and I think ultimately that's what the FAA would like to help with from a commercial perspective. But you know narrowing it down to what that specific control is that's definitely going to require phases of research after this one. Like what we'd like to do next for phase two that we've proposed FAA is we want to actually build some control stations some mock control stations and bring experts in and you know actually evaluate how they're using them and what they like and don't like. And you're really only ever going to narrow it down to what is usable when you bring in experts like that and you have my hands on. So that's something we were targeting to do next once we get through this first phase which those control station designs would be based on feedback from people like yourself.

I like that you are bringing the pilot in earlier too make sure that you get a good mix of manned pilots that would be a good suggestion too so that the manned guys can bring the unmanned under their wing to bring him into the FAA.

We actually just had an interview right before you were we were working with manned aircraft. So I'm glad you said that. So that reinforces that we're. Hitting all the right groups that we can get access to. So you mentioned a little bit earlier about this displays and I know there's displays that are you know kind of mobile and used for control but think in terms of the larger displays that are actually part of the control station itself based on the survey results. Most pilots that respond to the survey use one to three displays. There's a few that use more but the majority of them fall it in one to three range. So the first question is for your work and your past experience why would you need multiple displays if you are one of the ones who use multiple.

One of my displays would always be generally like a moving map would my aircraft with my artificial horizon without there being like that. Even the army shelter had it and the rest of the other screen will be able display all my interface options and things like that. Even run to a monitor set up with you know run the payload as well you know. Generally, you would have one display set so you could sit and monitor everything you do on the aircraft without having it taken away from your site to interact with other things in the system. OK. That is similar answer for me as well the. Primary monitor would be for navigation and basic control of the aircraft systems. And then the other monitor be a like the engineering pamphlet and the things that help data and diagnostic of the aircraft and room for checklist where needed. You will find that to try to do that with a single monitor that is crowded really quick and you get and end up oversaturated.

Right. So. So primary stuff most important stuff in the monitor is directly in front of you then supplementary information as needed to the other monitors to the side or above.

Yeah that kind of layout.

And it may be something that comes across your primary? displays. Warning if you need to check something.

OK. Standard. You know what do I here. Now we're in the aircraft. OK. You got your primary by the way and you might say that was you know I really you know like I have the idea that if you need to carry on a normal thing in aviation and then a moving map.

Would be good on a primary display and then warning, actually if you have the option to 3D review of the environment you could visually check your training equation. OK.

How are your displays normally laid out? Is like a horizontal configuration or vertical or a combination of the two?

Side by side, there are plenty combinations though

Clearly if I have ever done a three monitor set up it is like a pyramid stack and two are side by side. Don't like everybody there it's like up here and. Do it. But.

What would you like to use or was there a configuration that you liked the most that you would like to expand upon. You know you mentioned the pyramid display, so you kind of keep all three of them close together so you don't have to turn your head down that much to get the full view. Are there other configurations you would have liked to have used?

I would like to use could take pictures of laptop configuration and put that on a desk.

OK. I'd prefer to look up rather than down. Yeah.

In front of me and I'm OK with it.

And would that mean have a chair that you could possibly tilt so that you could get a better view of everything in front of you.

Yeah.

I'm from manned aviation and I think it should look very similar to a cockpit so that there's more of a mentality of you are actually flying machine. As opposed to you know something that is a I don't know what the right word it. But. It needs to be some kind of connection between this is an aircraft that you're sitting in. You know include like it enclosed doors so people don't come in and bother you when you're flying. **Right.**

Do a lot of the configurations you used in the past kind of mimic that cockpit layout or that's more just the preference you have for being a pilot.

I have not worked with anything that mimics a cockpit. And I found it more things in the unmanned world are going to mess my guys up for learning instruments in general aviation when they need to, because its opposite of what General Aviation uses. OK. Weakness that community has because engineers are phenomenally smart people and they make amazing stuff but they don't know that the FAA has and then the FAA has the weakness that is that. They don't want to go to the metric system. For example, where is everything in the engineering world is a metric system because that's what makes sense. Right. When you say things like I want to fly on the airspace but you can't talk feet and knots.

That's the problem. OK. Yeah. That's pretty consistent with what we found from the surveys. Most participants did not use control station layouts that looked like a cockpit. But again when you're looking at literature and you know you're looking at pictures that you largely see that cockpit configuration. So I think it's based on what's available to learn about versus what people are using don't always match up in that particular case.

The only system that I've ever been more on the cockpit door behind me it was the military. Every other one. And you know I'm like out in the open people are walking around me like. Yeah you're more like oh I hate putting that label on it.

Well you mentioned other people dropping by I guess visitors observing. How often do other people come in your control station area? Are they just observing what you're doing or are there other people assisting in the flight the aircraft look like a payload expert or something like that?

Let's say that we were on a project and it's a tracking project that they wanted it supposed to be aviation minded. And I'm literally bringing an aircraft in for a landing and the lead of the product is asking me questions as I am trying to land in a windy environment. This is a norm in the community that are our observers worst then probably when spend probably 40 percent of their time keeping people away from the pilot. And. They. That's that that is the problem. So we end in the community is a problem not just. You know I mean we can't even blame it on other people. This is our problem that we need to own and develop controls for.

So very common to have other people and they're not necessarily there to help you they might be associated with the project but they're not doing anything to control

the media cameramen of people walking along a trail next to where you have people who are in league of a big project that you're doing and it has happened multiple times. I don't have one coming up and asking questions of my pilot while they operate after a briefing by the way by leave us alone we put up cones and tape they walked right past them.

So you do get up cones and tape. OK.

And that way we do have some control measures.

Do you ever have someone working with you whose intention is to deflect all the questions and attention from other people. Do you have someone just standby?

Usually I'm the grumpy old man that does that a lot of time. Visual observer

And the observer because they're are actually I guess participating in some way that they know not to buy the pilot unless it's absolutely necessary.

The observer and the pilot work together as a team the observer is giving the pilot information he needs to make intelligent decisions know and is also aware of timing. And we've trained them. And when you know you know take-off and landing is critical for example and they know not to bother them. So they would pick a proper time to discuss with the pilot.

What other measures have you tried either successfully or not successfully done to keep other people away from them from the team?

And we did a project we did a project recently where we were doing a ground control station and down in a trailer or door on it and a sign on the outside of the door not to enter. And how many times did you know that during that one hour during. About a two-hour flight probably 4 times. Hang something on the doorknob itself so that you know they might have read the sign but when they reached for the doorknob they would actually see something there. UAS community problem

I know we had overseas we had a dark control station and people come on and turn the light on. And our answer for that turned out to be duct tape. But I always thought that if you could have put a second switch near the pilot to get his turn off the light and it wouldn't be able to turn on at the door. But of course will never ever thought a thing. But you know how always wanted to make a big difference changing from the dark to the light over.

Removed a pin for the door knob so that it would just move freely when people tried to open it. I think we have we have that as well. We weren't allowed to use it because if we locked ourselves in and had a heart attack people couldn't get in easily.

But you know they can kind of full circle back to not liking touchpads because I couldn't change direction quick enough. We had a problem with bother the larger scale but some of the smaller stuff gets intercepted by birds all the time. Basically I was working for half an hour trying to avoid a crow and I didn't time I'm shaking. The battery was low. Come back.

So in addition to animals glare and noise level were also very common issues with the mobile control station configuration. So are these two issues that you experience a lot with the

types of controls that you use when you're in the mobile facility or even in a fixed one. Is glare and noise an issue for you.

Polarized glasses do not work

What about glare on your screens with when you're mobile like your Whatever solutions using you have to use a tablet or something with a screen on it. Is this glare an issue to the point that you have to use like a hood or some type of you know way to deflect the light off of it.

We just recently spent a good amount of money, probably too much, getting harden laptop. They are day daylight readable screens. We intentionally spent a lot of money to get those screens that would work in the environment that we work in. We just launched from a boat and came back to that boat on a sunny day and we don’t really have time to mess with other shields or rig stuff. Now on the DJI product there is a shade that goes over the tablet to see it better. That solution works better for the tablet then a laptop

Have you ever tried a privacy filter?

It helped a little but it didn’t make a huge difference.

What about noise level, do you ever encounter any issues in noise level whether you’re in a fixed or mobile control station environment?

The boat running and things like that, normally if we know our environment is going to be noisy we have headsets, we’ve got radios. We bring things along to mitigate it. So it’s not necessarily a problem because I think we are just so use to operating in environments like that.

Ends up requiring more equipment. If we don’t know about it ahead of time that’s when the problems occur.

I have operated in some fixed stations that were very well insulated to the point it was actually distracting for me. It was scary

I have worked in a ground station where I wanted to be able to hear what was going on outside because we had a gas motor. Just felt like I knew more of what the plane was doing because I could hear the motor taking off and landing

We have a procedure for that, having the ground crew leave their mike open

Just like manned aviation, strange noise can be very bad and your ears are cued into certain sounds for takeoff and landing and everything else. Could be very valuable to hear

Just by having a mike on the aircraft would be amazing

Do you ever have anything else in the control room that makes noise?

Generators, lamps, radio

We have the monitor tower here and when we bring the radio too close to the ground station they don't get along. Usually had the radio off to the observer

Something else that kind of goes along with it is the heat generated by these things is a problem. As a matter of fact, for Scan Eagle we had to keep the ground control station fairly cool, it wasn't for the comfort of the pilot. It was for the safety of the computers

Did that then make it too cool for the pilot or the pilot welcomed it because it could have been too hot?

Put a coat on, put a light jacket on or take a sweater

The air conditioning units can make it noisy

And would you say some of the noises are not overpowering but their irritating? Is that fairly common across mostly the fixed control stations you have used? Except for the one you mentioned that was completely quiet

Absolutely, especially if it interferes with radio communication. If you have to ask someone to repeat something constantly. Time can be a very finite resource when your operating something remotely.

About how long would you say your flights usually are? So I am sure they are different for when you are mobile and when you are fixed. How much time will you spend at each mission or ground control station piloting the aircraft?

Depends on the system, I've flown one were the aircraft had a max flight time of 10 minutes and another one where it was standard to fly 13-14 hours. Multiple crew in the aircraft to fly it

Our standard was 3 hour shifts at a time. If you only had 2 people for 6-hour duty day 6 hours in the seat broken up into 3 hour shifts

So when u have your desk configuration some of you may have mentioned that you may have a cockpit, but I guess it's more of an actual desk with monitors and keyboard and mouse with a chair. And that kind of comprises your standard fixed control station

Yeah for the most part

When you have to use that type of configuration for a long period of time do you tend to experience some discomfort? Whether it's the chair is uncomfortable or the desk isn't high enough? Any particular pain points that you can recall from the configurations that you have worked in?

Its uncomfortable because your sitting there for so long, no matter what your sitting in it gets uncomfortable

If I were building a control station for someone that going to be flying for a long period of time, there is no way I would allow that chair to lay back. Because we are doing very dull work flying that long, definitely something bored already. The option to lay back and be super comfortable causes a whole other problem and they will be asleep. Has to be a balance

I like seats with a higher back but those seem to have an aggressive lumbar support

What about when you do have a long flight, are you ever in a position where you can kind of stand to fly or you really need to sit based on how the displays are set up?

On long flight, stand up behind my chair, can go stand within arm's length of the control station

If I was making a control station, I would make it so they could put the aircraft in auto mode and the chair would slide out and can slide back in and be in a cockpit

Would you allow them to do any type of controls to actually fly the aircraft while standing?

If it was a known tested system that you could communicate and tell it to fly to here with a mouse click or something like that, that would not bother me standing. But in a direct interaction with the aircraft such as I am going to operate with joystick or pedals or whatever configuration you have no you shouldn't be doing that standing

Critical phase operations no

But when you're in a mobile configuration or out and about that's a different story right? Because then you are only standing?

You are flying 45 minutes max; you get breaks by being mostly automated.

You can have multiple flights, having more than one battery, Systems are designed to have one battery ready to go, another one charging and one being used. So it could land take off land take off and be there for hours at a time. But have our own crew rest requirements.

Record was 21 flights in a day

Yup found a nice big rock and sat on it

Thinking back to the fixed control station desk layout. Is it a desk where you have space to do work, in your line of work would you ever need to take notes or have a book out or extra material?

Think knee boards, stop thinking another office desk.

This is when I need to be taking note, when I am taking coordinates if I can't pin point it on the screen, getting something over the phone, weather report, logging time, maintenance forms

Do you have enough space to take the notes?

You're going to always get something that you need to write down, stick a knee board on your leg

Where do you typically position it when you do have the option of using a knee board?

If I have a table or something it will be sitting next to my computer

I kind of like to have it off to the side, within reach out of sight

Small notebook, binder that can sit on knees

What about the in between, when it's in the back of a vehicle or setting up a trailer, those type of mobile environments. What does that type of layout look like or what have you used in the past?

At that point I would bring a knee board or tablet with me knowing that I am not going to have a table top to write on.

How do you usually have it set up in the back of the vehicle, the whole control station, the monitors, the controls, and all that?

Their mobile version was a smaller version of their nonmobile version. It wasn't a huge difference to walk into their control station.

The shadow condensed everything to a one monitor, two pelican case set up so you could attach the antenna to a hum v 2.

Outside of the military your control station could be…. Take the responder for example, we have a pretty big size ground station with it but if we absolutely have to we can grab a laptop and a couple of pieces and go operate from that. So it could change drastically

Many setups try to mimic the mobile set up to the fixed set up, that way you can go back and forth between the set ups and it won't mess with your head. It will mess with u if the set up are different when it comes to figuring out the control set up

In order to carry around extra equipment does anyone ever use a backpack or do you carry around the equipment in another ruggedized case? How do you keep the extra equipment you might need right next to you?

Pelican cases keep things from getting wet, I want a back pack but it's also dependent on the mission because we have some that takes two trailers to operate. And have scenarios where we should just be able to throw it in a back pack and go. So a diverse community of different things

In the instance you have been able to carry a backpack, how much does it weigh?

Haven't been able to use a backpack, I would try to keep from going over 30 pounds

What about in your pelican cases about how much do those usually weigh?

Most are two-person carrier, have a lot of brief case size ones for computers. Should be two people carrying it

And you're not carrying it that far?

Floor to cart to truck to field operation, aircraft sometimes if it travels to somewhere else

Do you ever have the case where you are going somewhere that a vehicle can't get to or carrying it for long periods of time?

Currently working on a field operation that not sure how they are going to get their aircraft out there and permission to do it. The system is large

In terms of the fixed control station, the ones you have currently used and the ones that you have worked in the past, military commercial or otherwise. What did you like most about the fixed control stations that you have worked in?

Worked in system were it was more of you are stepping into an airplane cockpit, it was more of like we shut the doors, about to start mission feel. Had more of the mind set of flying

Had a standard layout, could go to another military set up and not miss a beat

Developing muscle memory while working in those systems

A manned pilot should be able to walk in a control station and understand what to do

What did you dislike about fixed control stations that you currently or previously worked in?

Wheeled chair, how disconnected you feel from the aircraft, there is a big push to take gaming equipment to control these pieces and has delays on the system

Who is making those decisions to try to incorporate gaming equipment?

Clients that you have to work for, major aerospace firms

Scan Eagle system

Have to remember on a controller what does what without any actual markers on them

So outside of what should be acceptable

So if you give me an aircraft controller, those controls if they are going to control the aircraft should only be similar to a mode 2 controller for an RC. There has to be a this does this and has to be separated from controlling the payload

Separate critical controls from none critical controls

Would like to have tactile feedback, resist the throttle or something like that

Not being so removed that you lose a sense of what's out there, it's a real airplane, something bad will happen if something goes wrong

Primary causes of accidents I have seen is something that sneaks up on the operator that they do not see

Are there any questions that I should have asked?

Biggest problem across the board is uniformity, everything looks different and nothing controlling uniformity

So a lot of our systems have multiple ways that you can change things, but when it comes to flight I think it should be limited so that you can't change it while in flight. Because you can send brand new information, whole new mission to the aircraft.

What type of systems would you lock down?

Configuration changes of the aircraft, fail safe, geo fences, safety limits

What would that leave open?

Flying back to the house

You have your parameters you have to stay in say you decide you want to fly 2 miles away, while flying you determine you want to fly 3 miles away. The aircraft should return because you should have spent more time planning and put new configuration in and go back out.

11.3.6 Interview #6

[00:01:27] **We have had some pretty good feedback from the survey but from what we found just doing these interviews especially with people that have I guess kind of cross experience between the military and the commercial sector it sounds like what you have.** That's right. **That's really where the most valuable information is coming from so. And you know it's interesting there's two pretty distinct camps of people you know people that have actually flown aircraft and those that don't have the pilot experience but still a lot of hours experience with them. And so it's pretty interesting what we've been finding.**

[00:02:02] I've never flown a military unmanned deal but twenty

[00:02:10] four years for either commercial or military flight experience. Yeah. You there are a lot of good things that can be pulled from the manned side brought into the unmanned. Fortunately, I know a lot of guys that did the unmanned/ RPA stuff and you are just a systems monitor and they tend to get overwhelmed. That can hold true to the manned aircraft as well. But I think because people think you're sitting on the ground you know you don't tend to get behind on what you're doing in the aircraft is really untrue especially from a human factors standpoint. Right. You can overwhelm the unmanned operator. I think a lot faster than you can the man because you're simply trying to feed more… Your mission where you're trying to do is more I guess dynamic than what you'd normally do in a manned aircraft. **So there's this assumption that because you're on the ground and the not actually in the aircraft that you have more of a capacity to look at more** Well, what is kind of funny is a lot of guys I know flew F-16s, F-15s you know really dynamic missions with a lot of data being fed to them real-time along with trying not to kill themselves. So they go from now world to sitting in a conex box kind of doing the same mission. But when you're sitting there. When you deploy, your mindset changes versus when you're trying to fight a battle state side.

[00:03:48] So I feel like most of these guys kind of said you sit there and it's you know hours of boredom followed by a few seconds of sheer terror. And what happens is you get overwhelmed really quick with a lot of Information and the expectation from you operating an unmanned aircraft in that environment is providing a lot of data a lot of ISR or a lot of. Just a lot of parts and pieces of it tends to overwhelm guys and so when you get to the commercial side just be careful work. For commercial operators. Right now I don't see there being any danger of anybody being overwhelmed. But I think you have to, when you are designing these systems and such, you got to keep that in mind because too much data is bad, too little data is bad.

[00:04:41] **And we're on the side of you know what's the minimum that you can possibly have and still be consistent across all types of aircraft and get the information you need and be able to control it correctly and you know the answer we found so far is it depends. You know it all depends on what your job is and what aircraft you're piloting. So coming up with a minimum across the board is coming up with a minimum for each one is challenging coming up for across the board is definitely very challenging. So there's we found the main**

thing we found is that there is a lot more research to be had in order to answer that question frankly. From my perspective and I'm not going to claim to be

[00:05:30] you know my drone that I have, I have a DJI S1000 12 octocopter. It is set up with a camera. I've done a little bit of stuff around power lines. A movie company called me and was asking fly next week so you know I'm still trying to get. In specifically to the energy sectors/oil and gas. I've talked to Chevron and other companies. So you know I'm not probably the most knowledgeable but what I'll tell you especially if you're looking for like a baseline for anything from your you know your little quad copters or whatever you know now I would say depends on the size of the quad copter.

[00:06:13] I hesitate to see too much to real estate agents flying these things. But if you look at professionals to operate these, you need standard stick and rutter to operate obviously. I personally feel like especially in an environment that these things are being flown in, we got to get some sort of a ADSBC.

[00:06:34] Some sort of situational awareness for who else is flying around. Now this is I hate to say not necessarily other drones but the manned aircraft they can sneak up on you especially helicopters and especially when you get an urban environment around hospitals any kind of emergency response because we've.... So you've probably read, I'm a chief of safety, flight safety operator, investigator, blah, blah, blah. Well, the problems we have are

[00:07:02] On Mississippi Gulf Coast. We've got several hospitals located pretty close together pretty much everything down here from the tip of Eastern Biloxi to Long Beach is Class D airspace. And then you get ??? that runs up north of Gulfport and out of the Gulf. Well we also have hospitals in there with helipads. Everybody and their brother has a drone now and they've actually disrupted helicopters in critical care situations from landing at hospitals.

[00:07:34] And while I don't know that ADSB feed to that particular operator would have helped. I think that as we push forward as commercial operators and the integration of these things. We've got to have situational awareness of manned aircraft.

[00:07:48] Now as a manned aircraft pilot. I really don't want these flying around looking at my TCAS and seeing thousands of hits on my TCAS and it's all drones because that's just too much. I don't care. What I want to know is what's close to me you know. And you can control some of that with the TCAS but so I think that is definitely stuff on the research and if I were you guys and I know you are looking at this. How do you display the drone information in manned aircraft as well? Because when we fly at low levels when we are 300 ft. and these aircraft are flying 450-500nots at 300ft sometimes 200ft. A TCAS hit for a drone is pretty critical, you need to know where they are at. We are getting them for manned airplanes but not unmanned. And especially with how many unmanned are flying around, we need to know where they are at. Especially when you are down in that legal structure where everybody can legally fly.

[00:08:51] **Right. And it's usually helicopters that are that the bigger issue I guess unless you're landing in an airport.**

[00:09:03] If you're in an F-16 and you're flying that low you suck up a drone down an engine is basically the same as sucking up a bird. You're going to have millions of dollars of potential damage to the engine but you may or may not lose that engine. The engine may tear itself up because it will start throwing turbine blades and just you'll end up losing a multimillion dollar jet and somebody having to parachute from the sky. **Right**. I may be going off on a tangent from what you guys are after but I think you know situational awareness is key in aviation and anything in life and I think it's a matter of determining what is the level of Situational awareness of unmanned aircraft and manned aircraft that is sufficient for safe operations. You know, your airliner at thirty-nine thousand feet doesn't need to see drones unless somebody is flying a global hawk around or some sort of big. System like that. So then yes. That kind of information needs to be fed but they don't need to see the guys, the real estate agents on the ground they don't need to see that. But if there's some sort of system that as the airplanes get lower in altitude. Now I'm trying to figure out how this would even work that they can start picking up you know within a couple of thousand feet of aircraft, a drone, you know that would be potentially beneficial.

[00:10:27] Now again you can overwhelm the TCAS which is a track and collision avoidance system you could potentially overwhelm us. Right. So when I hear questions about baseline, stick and rudder stuff, I think situational awareness of the airspace around you whether it's you know obviously most drones will have the iPad. Well I have the

[00:10:54] high definition monitors with cameras on mine and I know what airspace I'm flying my drone in and what's around me but for those that aren't sure about it, they need some sort of map in the background would be great. I don't know if that is getting away from what you are researching.

[00:11:12] **Well we're definitely interested in the controls piece so we're there is another team in ASSURE looking at the content that actually goes on the display and what we're trying to figure out is what are optimal display types, display size, configuration displays, controls etc.** In other words, like altitude airspeed heading that kind of stuff. **Right. So there's other there's another team that's solely focused on what is the best way to represent data. I mean we find that to be really important too because that usually dictates how people's displays are oriented. So it's important to know like if you're working off a multi display control station you know why is it is set up the way it is. And you know typically the information and where they're presented is the biggest explanation for why it's that way. So I mean it's definitely all of extremely important here. Well one of the big. Polarizing topics so far has been the actual controls themselves that you've touched on so you kind of mentioned that they all can control a stick I you just mentioned touchscreens. The three most common we found from the survey are those two that I just mentioned and you did as well as joysticks themselves. So based on your experience do you find that to be fairly common for the controls.**

[00:12:40] Yes I would say you know I grew up flying radio control airplanes. And so my drone is flown with a Futaba 14 Channel, same thing I had for my airplanes. So it is super simple. I don't think you can get any more basic than a standard four channel radio set up for our you know hobbyist type radio for control of one of these things. I know I know I read some guys like a single stick, in other words it can set the altitude

[00:13:15] And then use one stick for pitch, roll, and yaw which I'm not a personally I've never flown anything with that so I'm not a big fan of it.

[00:13:28] I think the Intel Falcon 8 has that capability.

[00:13:37] But yeah.

[00:13:39] That the current setup for a hobbyist controller I think is great.

[00:13:44] I think the touch screen stuff like the other team is looking at will probably be something to look at.

[00:13:53] **You mentioned that you use the DJI controller.**

[00:13:57] No I don't use theirs, I use the Futaba which the standard hobbyist... **OF the control types you've used so far, what is your preference, which ones are the best for you to use?**

[00:14:12] When you are talking about control types, I like the dual stick. My right stick for pitch and roll, left stick for throttle and yaw, which can be reversed for left handed guys.

[00:14:24] **OK. It sounds like you're mostly mobile but would you ever have the need to use foot controls.**

[00:14:33] I mean I wouldn't.

[00:14:38] For the stuff I've done so far, I would say no.

[00:14:42] OK. Now. I know I'm sure there's going to be situations where people want to have. You know there may be operating the camera with their hands and they want to be able to control the drone.

[00:14:58] With their feet.

[00:15:01] But I'm sure there's somebody like that. But no I don't think foot controls are needed. I think frankly I think it could be overkill. I mean does the control of these things are so simple. Now you get into the bigger stuff.

[00:15:17] Yeah, I'd love to have foot controls for that because it's set up like foot controls for the rudder and those wheel steering on the ground because it's a set up that I'm familiar with in flying manned aircraft. Kind of like you're you know your RPA these tend to be setup similar so that the pilots can get in someone's like they're at home in the cockpit.

[00:15:40] **OK. That makes sense.**

[00:15:42] But I you know it's not necessary. You know you could fly like Global Hawk with a Futaba controller if you set it up correctly. OK. For me its ingrained in me the finesse of steering the plane on the ground with my feet whereas if you do it with your left thumb it can be more difficult.

[00:16:11] And so a big example of that is when they were flying when Dallas had that group flying the twin engine. Forget what it was. A graphic. Anyways down in Dolphin Island last month I was watching them. Do the take off with it. I saw a video of them taking off with it and you could tell are every time the pilot made a little bit of a left thumb steering slash rudder entry on take-off because it's really jerky. You'll see the nose kind of going around on the ground and I think from that standpoint two things: having the heads up display type, you know the words, instead of visually looking at the unmanned aircraft taking off and you make corrections from odd angles I think if you have a view, and my own set up is this way with all these little TV cameras where I have basically a HUD on my controller I've got a monitor with a HUD but the symbology and everything like I want it. And if you have that then you can see the airplane going down center line just like you actually sitting in it. And I think when you get into the bigger equipment you're going to have to get that type of view. Because little mistakes you know when you're doing a hundred knots and you make a small control input you know big things can happen as far as in the yaw axis and you can run off the runway. And not being from familiar that may be where you know the foot controls or

[00:17:47] Maybe a low exponential rudder-yaw control, thumb control would be better. OK That may not make any sense but if you ever see the video of that you will see what I am talking about.

[00:18:04] When you watch guys radio control airplanes, when they take off they are all over the place because you can't really see the airplane tracking straight down the runway. Like when the moment you see it drift and you try to make a little input it is really jerky because you can't finesse that control.

[00:18:23] **Right. You don't have the same perspective as the plane I guess.**

[00:18:26] Yeah exactly. Exactly.

[00:18:28] **Well, that is some interesting points about the display. What you mentioned and I think a couple of types of displays that you typically use with yours, how are your displays typically laid out when you're using them.** So for mine it takes two people to operate, I've got a substitute person. The camera operator has his own controller, and high definition screen. All he is doing it looking at the camera.

[00:18:51] For me flying the thing I've got an on screen display on a monitor on my control it shows... I don't really like the way it is laid out but it's got a line that is supposed to represent the wings if you will. So I can see if the plane is pitched or banked a little bit and it also will show how many degrees that I've got nose pitch up and down or banking the left and right. It'll show that degrees, and it kind of looks like a little airplane wing.

[00:19:29] There is no horizon. So the horizon that you're basing that off of is the real horizon which is really not a great representation especially when you get in mountainous terrain. Where we live down here is pretty flat. Where you guys are in the hills, it’s really tough too, down here it is pretty flat or if you go down to MS Delta it is really flat. Your horizon represents the true horizon. But then you go in the mountains or up where you guys are the setup I have is really not optimal. Also have airspeed in meters/sec, altitude in meters, it'll tell me range, how far I am away from myself, GPS signal/strength and that kind of stuff. It is not exactly the way I would want it laid out but it is the best that I can get, that I can find right now.

[00:20:21] OK. So it sounds like you generally have at most the two displays and the one on the control that you describe and then you have do you call them a camera operator or observer

[00:20:35] Yeah, well it is a camera operator, so I have got a second person that controls my camera with a second controller. And wherever that camera looks. They're seeing it live on the screen and I've got a wireless high definition video download that feeds real time, wherever the camera looks, that is what is on it. So I've got a DJI octocopter and DJI autopilot and that is it. Everything else I bought for my equipment is not DJI. OK. Like I don't have an iPad where you can touch the screen on the iPad to make the camera look around. Mine is setup where you have to through another Futaba controller, a popular brand for hobbyist flying radio airplanes/helicopter, the camera operator uses it to point the camera around, turn the recording on and off, take pictures. For me, my controller I fly with, I have another monitor. When I say monitor, it is like an 8" monitor, and it feeds is from my little FPB camera which is a little camera on the nose of the drone constantly looking forward. It is feeding me that video, of what is in front of, and it is telling me my flight telemetry information.

[00:22:14] And that is all I care; you know the way I have it set up is all I care about. I want to make sure I'm not going to run into anything, or endanger anyone and the best way for me to do that is instead of trying to guestimate it by looking at it on the ground, I've got that small little camera on the front that shows flight telemetry information. I can definitively see where I am at all times. OK.

[00:22:31] **So your camera operators is not too much unlike a payload specialist might be for the larger UASs.**

[00:22:38] That is exactly what it is, a payload specialist. Only, without the fancy equipment.

[00:22:46] Right.

[00:22:47] The drone I have is pretty big. And the last thing I want to do is endanger anybody and lose all my civilian pilots license much less my military career. So. Right. I wanted to focus on flying the equipment and then have somebody else that better operating with a camera focus on whatever we're trying to film. And then if I'm around the power lines I can negotiate around the power line and not worry about the camera and have someone else worry about the camera. to me feel like that's the safest way to do it versus trying to punch an iPad, point the camera at something, look up at the drone, it is headed toward the power line, where is the drone. I felt like that is the safest way to do it.

[00:23:37] **Do you ever have any other people nearby. So we've heard a lot of interesting stories about animal attacks and people coming up to you know disturb the pilot and things like that. So we've heard about people setting up you know cones and tape or some. Some people even had they paid a person just to keep other people away and to provide some type of context of what's going on the ground around the pilot. Do you normally use the two-man team or do you ever bring anybody else in?**

[00:24:06] Well I do the two-man team. The guy is an attorney so when you said the cones and trying to keep people away,

[00:24:15] He asked me to come up with him to film for a car show that’s kind of what they did and frankly it was people. People kind of are initially curious by the drone and then frankly they get annoyed by them and so I have no experienced anybody coming up to me but then again. The times I've flown mine, I've had you know seven or eight engineers from a power company and a sheriff's deputy and we were actually doing work. So I have never actually been a situation where people have come up to bother me. Now, I'll say this, when I finally brought my drone out for the car show in Madison, because it was so much bigger than the DJI and Inspire, a lot of people came out and wanted to look. But what they were doing, I had my wife operating the camera, and they talked to my wife. SO they were talking to her about it and left me alone which may be an anomaly. I haven't experience anybody bothering me while I was operating.

[00:25:35] OK. Yeah I guess having the second person out there who to the unfamiliar the camera person would seem to be less distracted by what they were doing or less consumed.

[00:25:48] So you know realistically whoever is operating the camera can sit there and talk and chat and look around. Most times people want to know what the drone is looking at. That particular day, my wife was operating the camera. She is looking at the monitor; everybody is looking at the monitor to see what the drone is looking at. They really could care less about the drone until I landed it. Then they had to go walk around it, look at the battery etc. I will say this, I get a lot of, I do a lot of public education events. I did one for Gulfport-Biloxi international airport and I'll be going to do one for the FBI in Mobile AL and a lot of people are worried about privacy. I think that is, if it is not curiosity, it is privacy, people are worried you are filming them and that kind of stuff. That is I am hearing. Everybody has a story about somebody flying a drone over there house and their daughter was sunbathing. And the next thing they say is "I was about to shoot the drone down". If "X" is there he will say "don't shoot the drone down". The reality is people are going to shoot the drone down. They have proven to do that so.

[00:28:20] **Yeah. So you mentioned the tablet controls, the touch screen. What do you think about that type of control? Have you used it a lot? Do you like it more or less than the other ones?**

[00:28:33] I've never used a tablet touch screen control.

[00:28:39] I've been told that from the Aaryon Skyranger uses that setup. I've been told they've had issues with it. They were using it to do some work with an engineering firm until they had enough of the problems with them. they just kind of would lock up and crash or run into things and there was nothing you could do about it. I don't know if it was that manufacturer or what but I have never used one. Back to the manned aircraft and first operator in me, I want to have control. So with my drone I can set it on autonomous flight but I can also flip a switch and I can manually take it over. For me, I think that is important, for me.

[00:29:32] **The physical tactile controls**. Yeah I like that. **OK.**

[00:29:40] **Now in the work that you are doing, I envision you are mostly standing, walking around, keeping line of sight or as close to line of sight as you can in physically moving. You are not ever behind a desk when you are doing your drone controls.**

[00:29:58] No I am not. However, I guess in the future, what I can see with that is one touch launch and recovery for autonomous drone flights. But I think if you have a drone, if you are trying to do touchpad in an office, I feel like you have to have a way to make the drone hold where it is at. If you lose control it, you need to get the drone to come back to the take-off spot or have it stay in its position assuming it's in a safe position so you can go out there and control it. Because I feel, there is always going to be glitches with these systems, and I think you have to have some way of control. And the touch pad may be the perfectly sufficient way to do but like you said, I just like the feel of having the control and the ability to override a computer system if I need to.

[00:31:03] **You know and we have heard that comment multiple times now. As well as that the suggestion that whenever the is an issue or perceived issues, it returns home. You are not able to sit there and continue to adjust your course or path. When certain things happen, whether there is a course correction or an issue go ahead and have it return home so that you are forced to reperform all the calculations for where it is you are trying to go. As opposed to doing changes on the fly. And apparently that leads to a good majority of the issues and accidents that happens with the drones.**

[00:31:42] I definitely can see that. I have so much money tied up into mine that I don't let it run off on automous flight because I want to control it. If it is going to crash into something, it is going to be because of my stupidity not because I miss programmed a data point for lat/long or navigation point.

[00:32:05] **Yeah I think a lot of people share that sentiment too that are on the consumer side or the commercial side. Back to the desk questions, you don't use a desk because you are moving around. What about your camera operator, do they also stand and monitor the screen and move or are they in a more control station type?**

[00:32:27] Normally they walk around with me.

[00:32:29] I mean normally we walk around together and talk. Instead of having the headset or walky talkies, we just walk around and talk. Now you can do it, but I don't. You could make it a desktop function, but I don't.

[00:32:46**] What about. Is there ever a need for you or the camera operator to have to utilize a work surface in some way. I imagine you're not going to stop and take notes on anything. But does the does the camera operator ever you know have to use something other than the information that's on the screen like maybe they need to physically write something down or look at the instructions or pull out a map and try to navigate two things at once.**

[00:33:14] So, I haven't had that yet but I can definitely see that. Now, with that being said, I guess I will go back to the other group and what they are trying to accomplish. To have the capability to make some notes. If you had a control station that maybe had a keyboard or something somehow attached to it where you could make notes with it while you are out in the field, that would be awesome instead of writing stuff down. But, again, I have not come across that issues. The way mine is set up, instead of me holding the controller, I've got this harness you wear and it hold the controller at your waist. So if I needed to stop a write something down, I have not had to, but if I need to I just put the drone in hover, I just write down what I need to write down because of the harness that I have. I have that for the camera operator as well. As far as control station, especially if you stand out there in the heat all day that has been a life saver, instead of having to hold the controller, I've got a contraption with a harness that you just wear the controller.

[00:34:34] **Does it kind of wear like a reverse backpack where you got two straps going over the shoulders and it holds it in front of you.** Yeah.

[00:34:42] Yeah. In fact, I bought online from a company called Tarat it's got kind of like a small metal plate that goes in the center of your back that holds it holds the straps together and it connects to a tray and that tray holds the controller and the monitor and my batteries that power the monitor.

[00:35:06] Its compact, It's comfortable. And for me it's a great way to set up a control station.

[00:35:16] **How much weight would you say that you're typically walking around with when you use this?**

[00:35:30] I you know that's a good question. But you know the neighborhood of. 10 to 12 pounds. OK. Because we do with the life of batteries and all that stuff, I've got a transmit and receive transmitter I've got connected onto the monitor.

[00:35:57] I would say the whole contraption is probably 10 to 12 hours.

[00:36:01] It is comfortable, don't get me wrong.

[00:36:08] **How many hours would you say you typically wear this**.
I would say, I have worn it for usually for 2 hours straight and never had issues.

[00:36:30] **So when you have longer flights two hours plus you don't really experience much comfort or discomfort issues.**

[00:36:37] No it didn't bother me because I mean it just is comfortable. OK.

[00:36:43] I mean if you're out there for 8hrs in a day you may after a while say, there is no padding in the straps, so that may become an issue. You will probably want some padding.

[00:36:53] **But for shorter flight times, it doesn't really give you any issues so far?**
No, I have not.
[00:37:02] **How far do you typically travel, when you are doing a two-hour flight?**

[00:37:07] As far as traveling, I am fairly stationary. That would be more kind of walking around the structure, or from one structure to another. For instance, a power line, walking from one tower to the next would be the furthest I've walked. So that is like an 8th of a mile.

[00:37:33] **Depends on the job but just a moderate amount of movement?**

[00:37:41] Yes. **OK**.

[00:37:45] Have you ever had to operate your drone while driving or riding in a vehicle.

[00:37:51] No, I don't even have the waivers to do that.

[00:38:01] Another thing we've started we touched on a little bit talking about common issues when you're controlling the mobile control station. We talked about when people and or animals or other you know things in the environment can kind of getting your way but two of the biggest issues that were discussed in this or came back from feedback from the survey were glare and noise level were the most common issues with the mobile control stations. So are either of these issues for you?

[00:38:32] I would say glare on the screen absolutely. On my monitor that I've got my flight telemetry information, it is an issue. You get screens that help with that but.... As far as reflectivity of the sun, I could see that especially if you have shiny finishes.

[00:39:04] OK. **What do you do to try to mitigate glare on your screen?**

[00:39:09] I've got a sun hood that goes on it. However, if you are out at lunch time a sun hood on a portable, the way my control station/setup is setup, that sun hood does not completely shade the screen. And so, I either have to turn my body or maybe lift up on the control a little bit to kind of shade the screen some more. That is only because the monitor will only angle back towards me somewhere in the neighborhood I'm guessing 30 degrees. I think if you could get it.... the two options would be to mount the monitor on a vertical pole so that the sun hood is at a ninety-degree angle running parallel to the ground, that would be one great way or for my setup, I would probably have to have a bigger sun hood.
X- Some talk about anti-glare/ruggedized screens available

[00:43:36] **Does your camera operator ever experience glare, like you do?**

[00:43:46] Yeah, I mean, the answer is yes. I would say normally though, they have the freedom, they can go stand under a tent, get in a car, they can go get in the shade to do whatever they need to be able to do. Whereas, I can't, I stay out there with the, so I can see the equipment fly. Now, the monitor we have is a Liliput, a UK manufactured monitor. It does pretty good in the sun. The glare is not as bad, but yes there is still definitely some glare.

[00:44:30] O**K. So they. Preferably you'd have a nearby so that you can talk and communicate but if it gets to where they really need to be able to see what they are doing they'll just go off and get into an optimal spot.**

[00:44:43] Yeah. I mean still are able to communicate but yeah, they will find some shady area. Or even like I do sometimes we may just take up the whole contraption, you know the controllers, monitor and adjust the angle by lifting it up so they can better see the screen which that is not very comfortable. But that is not very comfortable because now they are holding it instead of having it hang by the straps, now you are trying to hold it up with one hand and operate the camera with the other.

[00:45:11] **Right. Yeah and if you have to do that for a long amount of time that's not going to work out to well.**

[00:45:16] Yeah exactly.

[00:45:19] **Talking about the equipment you use, so you wear kind of this strap, tray, device, that can hold all of your equipment. Do you ever have to take out any other equipment in like ruggedized boxes or is there additional parts, spare batteries, redundant controller, do you ever carry any other equipment out with you when you do a job?**

[00:45:44] I leave it with the car. Now if I were to have to travel on foot like that I would put it in a backpack or something. But the batteries are almost seven pounds apiece. Now you are starting to need some of these specialized hiking backpacks, something in that neighborhood to comfortably carry the batteries. Because the batteries are pretty much the only thing I would carry. Most of what I do is I record the video and once we are done, then I download the video and use it for whatever the job is. Whereas some guys are out there with laptops, they are doing topography or that precision agriculture stuff. I know they are feeding it back, trying to look at a laptop at the same time. I guess I have less equipment per-say that I am having to work with right now.

[00:46:48] **OK. So really I guess it's a job based on the job you are doing, then you would just figure out the best way to carry it comfortably.**

[00:47:01] OK.

[00:47:05] **What would you say you like the most about the mobile control stations and tools that you've worked with so far.**

[00:47:14] I like the freedom of just the freedom of movement. So an example would be I flew an Osprey Nest. An osprey nest had shorted out some power lines and they couldn't get the environmental approval to climb the power pole to look to see if there were anything in the nest. So they had me come out and I flew the osprey nest. Well, the ability to walk around the right away because it was covered with really tall pine trees, to walk around to really look and ensure the drone wasn't going to touch a limb or any of that kind of stuff was what I thought to be critical to that situation. So the ability to walk with my equipment, my controller, my monitor with my flight telemetry info. and walk around and physically look up and see the safety of the drone I thought was required for that particular job.

[00:48:22] **OK. So fairly unlimited mobility.** Yeah **OK.**

[00:48:27] I think there are situations like in the agriculture fields you don't move around I don't think. I haven't done that but I am assuming. But when you are on these tight right of ways with these power lines and stuff. And I am not talking about transmission lines, I'm talking about power lines like going down the side of the road, those right of ways are about 20ft wide at the most and flying a big drone down that I think freedom of movement is very important.

[00:49:01] **What would you say you dislike the most about the mobile control configurations you've worked with so far.**

[00:49:27] I would say, it takes a while to get it all set up. And you have to know if you were to try to... it is great standing up, if you go to sit down with it you can work with it but you've got to constantly hook out of the harness, which that takes time. It can be bulky to move around with but I would say... thats a good question... I feel like it could be set up in all one system instead of having multiple items hooked together to have the mobile system. In other words, a controller with a built in monitor then with the strap, the harness to hold it, would be great compared to I have an aluminum tray that my controller goes in, my monitor fixed to the tray and all my batter stuff hooked to that tray. It is just a lot of stuff. And to be vain about it I guess, sometimes it looks cool because it is a lot of stuff. it may not look the most professional. People are expecting to see an iPad on a DJI controller but that's not what I have. It is not as sleek and sexy as some of the DJI stuff.

[00:50:39] **So kind of a universal, some modular approach where you could plug and play the controls and the screen and then kind of kept it all as one unit. Because I guess if you are walking around and you hit a hole or a hill and you tilt too far you're at risk of stuff getting dumped off your tray?**

[00:51:05] Yeah, well all of my stuff is fastened down but yeah I mean potentially yeah. I've got all my stuff Velcroed down, velcro ties holding stuff down in place so you may just do with what you have and that is what I did. But you may conceivably come up with a controller a portable controller with everything built in that you need and then have a switch when you could flip between operating on 2.4Ghz frequency or on the other frequencies out there. Pretty much everything is 2.4 unless it is video, then it comes back 5.8. So like if you are trying to get a global system, then you need to build it for whatever frequency is in that country or whatever. I think a universal controller that has everything built in would be awesome. For what you guys are look at I think that really the way DJI has it set up with an iPad mounted to a simple controller is the most common and easiest thing out there right now.

[00:52:34] **So that's a pretty good model. But that still sounds like there's room for improvement.**

[00:52:45] Oh I agree, absolutely. I wholeheartedly agree. To add something, we haven't really brought up, I'm doing some stuff for the Port of Gulfport because I am in the Gulfport-Biloxi Airport Class D airspace, they require me to have VHF radio communication with it on a VHF radio. And I think the capability for a ground station to have a built in VHF radio would be awesome for situations like that. Now that may be getting to be too much, I don't. So now I am going to have to carry a VHF radio with me and with my harness control station to go do this particular job. And truthfully I see that need probably happening frequently. I don't know if yall have talked to anyone else who has had to do that but I think especially in urban areas around airports, I think they are going to require them to be able to monitor some sort of frequency because relying just on cellphone coverage. I think the FAA is going to want a backup. Yeah, we can call you on your cellphone but we want to have direct line with a VHF radio as well. So if you had a control station that had the capability to transmit and receive VHF frequencies then that would be pretty cool.

[00:53:1**4] That is a good point that hasn't come up previously and makes sense. That is something the FAA should be concerned about.**

[00:54:30] All right so you see you you've talked a little bit about if you could design a control station from scratch you've kind of given us some good thoughts on how we can move forward if we were to do a mock mobile control station. if there was just one thing you could or would change about mobile control stations. What is that one thing" I know you've listed a few priorities for you but what is the top most on your list for what needs to be changed.

[00:55:02] You know I'm trying to come up with an intelligent answer for you.

[00:55:07] I hate to say I don't know but I don't know. For my setup, it’s kind of bulky. I think a slim design with all these features in it I think would be great. But I think that going back to the Intel Falcon 8 drone that they tried to combine the monitor with the control station. The monitor is too small. You need a sizeable monitor.

[00:55:47] **Well no that's important because you use you said an 8inch display right?**

[00:55:54] I use an 8inch and I definitely wouldn't go any smaller than 8. As a matter of fact, I would prefer a 10inch or bigger.

[00:56:01] OK. All right well that's really important information because we don't think there's a standard out there in terms of size of display when it's for the mobile user. I mean the displays for a fixed control station you know there's been some amount of research there just you know based on what actual you know man pilots would use. I think there is a fairly small amount of research at least available to us.

[00:56:32] I'm kind of thinking about a friend who completed her research on human factors at Embry-Riddle on automation. it is kind of pretty interesting how the two subjects combine. As far as the screen, I think from a medical perspective your eyes adjusting from looking up at what you are doing and looking down at the screen to get whatever telemetry data or whatever information you are trying to get. And then to look back up at what you are doing causes at least I notice this, sometime your eyes wont focus fast enough. Now, I think for the bigger screen and that is what I am thinking for my camera screen, my eyes tend to do better. In other words, there is not the focus, adjustment issues. And that is why I am saying I think a bigger monitor for a control station is important.

[00:57:22] **Is it because the text on the screen is bigger so you don't really have to...?**

[00:57:45] Yeah, that way you are not trying to adjust... Your eyes are constantly trying to adjust to whatever you are looking at. When you look at the screen your eyes adjust to that and when you look up to your drone and whatever you are flying around it takes your eyes a few seconds to adjust. Well, if your drone is traveling towards an object, those couple of seconds... worst case scenario, those couple of seconds may be critical because you may be getting close to something you don't intend to.

[00:58:29] I'm coming from the perspective of doing like an infrastructure inspection like a cell tower inspection, or a flare stack? inspection. I think inspections like that, it is key to have telemetry information on the screen for the controller for the pilot so he can reference that and also look at the drone... to navigate around hazardous environments.

[00:58:44] **Yeah it definitely makes sense. I think some of these other controllers that are out there they're just putting a display on them is not enough. So when you when you're looking far off like you are I guess with your line of sight to your drone and you come back. You have to sit there and focus that does take up a few seconds and then a lot can happen in a few seconds like you said.** That's right.

Ok, I think I've gone through my questions. The only other questions I have is: Is there anything I didn't ask but should have that you commonly deal with in your environment?

[00:59:24] No I mean we've we covered all of it. When you get into the goggles people can wear for racing and all that stuff, I think it's, I don't know if we will ever get there, I'm sure we will eventually, but wear those goggles and have a camera on the drone that moves when your head moves. I know the capability is out there, but one that you can legally fly that way, I think that would be cool because then as you fly the drone around you are getting immersed in the experience. Then being able to safely navigate the drone around infrastructure, I think that would be a really great way for like these oil platforms, refinery plant inspections. I think that would be a great way to fly these drones around without anything... and that's.... some of the infrared detection system that keeps drones from running into stuff. Outside of that, I really can't think of anything else. I go back to situational awareness. As long as you have situational awareness at the control station for the drone operator, I think I think that is a huge win. Especially for designing system, but again that is coming from a manned aircraft perspective.

Some irrelevant things......

If you have more data at your control stations, if you have your buttons/switches set up so that they have a different feel to them, then you know which switch... that is the other thing, it could be your layout for whether it's your landing gear retract/extend switch or some sort of mechanism switch on the controller itself, make them different as well so that you don't have to look down at whatever switch. I guess that would be a question to ask people would be the switchology? if you will for these controllers because I have got 8-10 switches and they all do something different. I don't use them all but most of them look the same.

They look the same and feel the same, so I guess if you lose orientation of where you hand is and you aren't looking at it you can hit the wrong switch.

Yeah, I know they make little color coded things that you can shrink wrap onto the switches... that's great but if you are trying to get into the environment to where you don't have to look down at your controller to flip a switch, I think if you could do it by feel, I think that would be great. Especially in environments where you really don't need to take your eye off the equipment.

11.3.7 Interview #7

[00:01:54] All right. I've got three students that have been helping out with this in the room with me. s showing, they they've been instrumental in getting all the information together from the lit review and with the survey and interview questions that you helped us out with So. So thanks again for that. We've had some really good interview conversations. We've got some good survey feedback and we got. To I guess today and tomorrow and then I get the last bit of our survey so we we've managed to capture a lot of really good information and a lot of it thanks to you and using the proper terminology to make sure we've got the

[00:02:33] Answers we were looking for. So there. Wow.

[00:02:38] **So just for everybody in here I know you have talked a little bit about it but it's always good for a refresher now that we talk to some people but what type are you currently involved in. Now that has you piloting or working with pilots of U.A S. drones**.

[00:02:55] Well I work with what the military considers to be of group 5. Which is pretty much where your highest and biggest category. So the navy calls the airplane the Tritan UAS. And it is basically the Air Force derivative or Navy derivative of the Global Hawk. So size wise we have about a hundred thirty-one-foot wingspan. So clearly bigger than a 737 wingspan. We were out of control stations in buildings, the given that the launch and recovery type devices is stored in smaller buildings. I have worked everything from those sizes down to the hand launched systems as well. But right now it's a big global hawk size.

And you from your past you've had experience like you said across the board in all different sites right?

[00:03:54] Correct yeah. Most of the stuff have been like group threes, group twos. Which would be like Scan Eagle for group twos. Group threes could be like the pioneer also a thing called the turn. Shadows and then group 4 would be like helicopter that the fire scout should fly, the most common one. I have not done predator but we had a guy here a while back when did fly those quite a bit.

Would you say that based on the ones you flew that mostly kept you at a fixed control station or were you ever kind of out and about in an environment with a mobile control station?

Depends. I mean the fire scout we had control station was on a shipboard. So I mean if you're talking about a portable system where a guy puts on a backpack or put on the back of a gator and then I would say half of those. Time most of my stuff dealt with I would probably like a semi-permanent or fixed control station. A scan eagle, same for pioneer and fire scout that sits on a ship control station that sits on a ship but is a portable system. The introduction of the ship but the ship itself made it a portable system.

[00:05:26] **Well what we'll do in that case is that we've got a few questions for both fixed and for a moment. So let's do this let's start with fixed or semi-permanent. I think you know if it's on a ship or you know once it's installed it doesn't change much. We can call that kind of a fixed control station. Right. So what let's focus on those first and then if we have time we'll circle back around and get some of your mobile experiences. So the first thing we'd like to ask you about deals with the actual control devices themselves. So based on the survey and some of the interviews we've done it seems like the most common control devices. Seem to center around joysticks touch screens and the traditional yogurt control sticks. Do you agree with that from a fixed control station perspective?**

[00:06:21] I would say it’s more dependent on the system's itself what level. And you probably would talk talking a bunch of more guys who were in the group one or two kind of areas and maybe a little bleed into the group theory. Because you could have what you could have a sixth one. And they would have a toggle but more portable stuff is going to have your toggle and portable in the lead towards the smaller aircraft

What type of controls would you typically use in a fix is that more your keyboard and mouse or trackball?

[00:06:55] Yeah it can be more to your user interface computer interfaces like you like the keyboard mouse or Rollerball. Some of the older systems like the pioneer or like the control station sent photographs of they have a box a box and it's connected joysticks. Those are just the same thing that the guys that use that RC station right.

[00:07:19] **OK. Then you said you're OK with me sharing those pictures right.**

[00:07:24] Yes those two are fine.

[00:07:29] **What do you like about the controls that you currently use at a fixed control Station. Or do you.**

[00:07:36] It. Well it can be like the one we're working on now. I mean there's nothing happening fast. So precision is not you worried about everything. And it is a toggle tightknit thing is you're and I want to go. To this waypoint or I want to take this heading or I want to maneuver in it like I was sitting in it. So. I don't have to be trying to do it with a toggle is really hard to do. So if I'm directing this this Global hawk airframe around I want you can do and heading up 270, I type in 270 and it’s going to go to 270. If I do that with toggles I might get myself in a ballpark of 270 then maybe work myself a smaller number after a while.

[00:08:26] **Give me an example in the toggle is that like a joystick or a control stick.**

[00:08:32] Yeah. Imagine holding a box with sticks coming out of them and then one's going to control your power. Another is going to control in this direction. For those nose up nose down left or right, your axis and everything.

[00:08:54] OK.

[00:08:57] More along the lines of an RC controller.

[00:09:06] Gotcha. OK. All right that makes sense. And again there are those that have a control feature.

[00:09:12] Is more towards the smaller airframe and more towards the oldest stuff. Even the smaller stuff is fading away towards Now you see now using something probably closer to what you see on an X-Box.

How do you feel about that? That's one thing we've to come across as it's pretty polarizing for people who have been a pilot in aircraft of a man pilot. And then go and control unmanned versus people who never were pilots who end up becoming you know professional or commercial pilots for you know the category one and two. You know they. They have pretty opposite preferences that people who were formerly pilots want it to look like a cockpit and are almost insulted when it's not. And then the people who never where pilots can't understand why an X-box game controller isn't enough. What's what side of that fence do you follow on.

If the guy understands the airspace, he is in per the operator quite frankly I'm OK with the X Box. Type Set up. Mainly because if I hand that to an 18-year-old, here is a controller the switches do this. Because he's played so many games he's going to adapt to that a lot quicker. OK. And if he's adapted is that a lot quicker. This comes from my training and other instructors with the helicopters. It's all about giving you that extra brain power while you're flying around. So he if he has adapted to the control of physical control. I can now provide you with more information about the airspace about the traffic out there about all of the division and he will have a little extra mental capacity to handle that. He won't be getting bogged down with everything. You know we can have that happened early on. They don't feel comfortable with what they're operating.

[00:11:19**] So just the whole familiarity aspect whether they're for pilot looks like a cockpit or a game or it's an X-Box controller you're Yeah your preference is to remove that cognitive load so they can focus on the actual environment versus what their fingers are doing.**

[00:11:35] Right and that's almost true for any anything that I'd be teaching someone flying and land and helicopter. You know we take off and the guys he's got to operate two pedals, a cyclic and a collective and you know all the things that operate in conjunction and early on it's a lot of material and you can sit there and have a horn and really have horns going off and they will never hear it. So. You know once they get that extra mental capacity if they are comfortable with a mouse like to you like you teach a kid how to drive a car.

[00:12:08] You know they're alternate They don't see all the dangers that the instructor sees all the time. The instructor hits the brake pedal for him. So far as controllers go. Down Low. Those groups 1 and 2 lower airspace that they can understand. I think if he told the pilot that the guy understood the air the airspace better if he understood the airspace environment. They probably wouldn't care. I think they worried about what the controls look like would go down.

[00:12:39] **OK. So there's not really. Neither side is wrong it's just that that's what they're familiar with and that's yeah that's what they're able to do. They don't have to think about it. When they use that configuration.**

I think if sit a pilot inside of a cockpit or into a box and I gave them a screen and a yolk instead of a mouse. And I said here is airspace and where you need to go, his mental picture that airspace is such that it makes sense that I want to go there and I want to do this, this and this. Same thing if you sit me in a helicopter UAV system. If you give me a? and a cyclic I can make it 3D point A to three dimensional point B. Turn that thing to someone that has not flown a helicopter before and say you need to go from here to there I guarantee their going to be all the all over the airspace. And they're going to miss their point, miss radio calls and everything else. But if I had a guy an X-box control and say go through that spot there, run your aircraft through that ring at that location. They will adapt to that so much easier.

[00:13:49] **OK. So I was going to ask you what other controls you think would be best to use it really just sounds like if there is a way to customize it based on their background experience**

Going to depend on who your operators are. I mean like in the military I know that if I come out of one or two. Almost regardless service the guy flying is probably going to be a junior enlisted guy. You know somebody is pretty young, a listed guys whose job has been trained to fly that that system and it's probably going to be another guy just as young operating the sensor. And then there is probably going to be an officer sitting behind listening to the radios talking to whoever they're providing data to and telling the pilot I need you to go over here. Maybe taps something on a map and taps something on a map and the pilot can see that he should go there and he can tap the sensor operator and I want you to scan this ridge line or want you to scan this bridge or you know whatever the case whatever sensor they want them to look at you he is coordinating to those two guys who are actually doing the work. Now when you get to something like what I'm working with now. It's a bit different you still have a pilot but he's a he's a guy that's flown a different aircraft before you get to tactical operator and often you get to two center operators. And there almost all the same sort of consoles almost all look a lot like the same screen set up. It's just the data that they get on the screen is different.

Do you ever or have you ever used needed to use foot controls in any of your fixed control stations.

Now the only control we had foot control we had was the intercom system.
Now it's just a reach out and tap that and talk. Global Hawk, and what ended up happening we're all sitting in five 10 feet from each other. Most of the guys would just cock their headset to one side to have one ear open to the inside and kind of turn and talk to the other guy that wanted to talk to him.

So in all your experience you never use any foot controls specific to piloting aircraft.

No, Not any UAV. Even in a helicopter that fire scout doesn't have one.

Or are you aware of any set up where they do use a foot control of the pilot a UAV in the military?

No, not that I know of and I am not quite sure why they would need too because you can use your foot pedals to take down an aircraft or helicopter is to (15:56.) So you're not flying sideways throughout the airspace because you have torque on a rotter head or torque on an engine. So because you're sending everything through electronic programming you can kind of program that out based on the amount of torque in the wind and everything else.

Yeah both of them need a requirement for a foot pedal in an aircraft or a helicopter can be programmed out, even in modern helicopters you don't have to put your feet on the pedals.

The displays so you mentioned some displays and from your pictures I saw that yall use at least you know two to three displays or use multi-displays sometimes the survey results show that pretty much everybody uses between one and three. What are the more common display configuration and layouts that you use.

I don't know. I have a common display right there are just better ones and worse ones. So have one that's set up like a triangle. Two screens that are a little higher than one screen below centered on between the two. Looks a bit like a yield sign and then another screen beside it that wasn't meant to be a display but it's kind of grown into its own on things.

What do you think about that one that you just described? You know the yield sign layout is that one that you prefer using over others or is it just that is what it is and you get us to it.

good a positive qualities or is from a pilot point of view is you develop a scan of your instrumentation over the screens. And there's quite a number of studies things like how far away from that center point. You get before that scan start to break down. In the configuration like it has right now allows you to keep that that scan area tight I can I can see things without you know that peripheral vision covers quite a bit of stuff as well. But at the same time they really defined to do breaks up what you can put on certain things. On this three screens set up the bottom screen is more of my aircraft control my aircraft information so my and my control surfaces my feedback information my emergency emergencies that come up. If I want to start looking for temperatures and pressures and stuff like that will come up on that bottom screen. The top right one is maps. The top left is usually where I put my emergency procedures my mission plan information my tactical information if I've got restrictions or task so it all comes up on that. I've seen other systems that take a lot of that information lay all over on one very large screen. And it overlays a lot of that. So I've got you know the bottom part of that screen is my feedback information from the aircraft for problems and stuff like that the temperatures and pressures come back. But everything on top is chart like I've got the aircraft and I I've got in a way to directly control the aircraft but is that in a paper that says round the aircraft. Directed it to a new heading and letting it go in the aircraft makes the turn. So is this a way of presenting information. It's when they spread the screens out a lot that you start to get a problem.

You prefer the one larger or multiple smaller screen.

I kind of like the larger one a little bit but, it's how the information is overlaid. Will have all the controllability in one spot. So my scan was that because you know it's right there I can see the aircraft I can see it flying over this waypoint. I can see that it airspeed is. Altitude is written on that spot. I for one change I'm grabbing the same thing. It's how your feeding me the information. Keeping it into a smaller box if I have to go to three screens with any information. That we start to get a problem with keeping that that situation awareness is your head. I think of the example there is one situation where they had had one scene of this incident but. It had moved a little bit. It may be that they're talking to each other telling each other where they weren't getting the information that they had all the information on other aircraft coming to you on one screen. But your aircraft and where it was a shortage was on another screen. So you basically had to be able to take one speed and kind and mentally overlaid on the other one. Which is not ideal to be here are you not leaving those things at the same spot so that I think that work was presentation of the information. OK so that information is related but destroyed it because you got a pretty good scan distance or just try to. In your head overlay like you said. Yeah if you could if you lay all that on one screen. You know I want you to think of that method. I don't think so much because I've got a picture of my chart. I've got my aircraft. You know you really have other aircraft in the area around it.

What would you say was the least usable display is that when they have multiple displays and they're laid out completely horizontal or completely vertical?

completely vertical. when they give you when they give you three screens, I've seen where they had three screens and they are stacked right on top of each other. And what ends up happening with that is you get tired. And you whatever screen is on that top screen with information that's the first stuff that is going to fall out of you're going to stop looking at it as often. This is a Marine Corps system. And it was not used to build that you made that you provided the three scenes. So they did. And they you know they put the most important information on screen number one scene and always on the top. OK so the guy sitting with his head tilted back. Kind of look at that scene and again kind of your scan going to the top screen, he didn't look up as much.

You talked a little bit about the cockpit layout. What. Would you say that. The fixed control station layout typically resembles that of a cockpit. Or is that more the exception than the rule?

The predator seems to have the closest thing to a cockpit or aircraft cockpit. Most of the other systems kind of fall into a you know you've got screen and cages around you more of what u saw in the one picture and then. You know with our system which is I had three computer screens you set up on to. The computer system but. They're looking a lot alike. Another aircraft is much more than a little.

And based on what we talked about or where it's all about what the pilot was used to it sounds like you probably wouldn't recommend a cockpit lay out for everybody. That's more for the trained pilots.

It’s what they are used too but I think though able to adapt to the other system. I don’t know if you could build a cockpit that is that flexible

What about sitting or standing in all your experience your flight experience did you ever have the need or the opportunity to stay in your control station or are you generally seated the entire flight.

I didn't because I went into one of the pictures the smaller stuff is we had really had to call the call the next gen pilot. And now the guy would do the launch and recovery phase of flight. And in that picture you saw that one I think that was an external device we moved around. OK. And I think did I send you a second picture of a guy across the runway from me and what he does is he is he physically RCing the aircraft basically. Land on the runway and then take off at the end as well. So he would pick it up, he has that box and a cable going back to the control station. And while it's in that phase of flight to takeoff or landing phase. He's got control on it. And he is standing tell he's has the thing looped around his neck following the aircraft down the runway from left to right. So he needs to stand up. And that's a system that's designed as kind of starting to fall out of favor. Now that he has an auto takeoff auto land features that technology is getting better. So more and more systems that can have that. That's where my experience that external standing system otherwise everything's in a chair and then you can get up and walk around. But everything is in a chair.

OK. So this is kind of that intermediate case where I guess the equipment is either portable. Yet fix it in use or the back of the vehicle. But in those cases, staying walking around there was some use for it. I guess like you said that's not the popular way to get ….

your technology is expanding that don't have that specially trained guy to take off and landing. Like the one box you saw there the we are the close up behind him got the two operators which you the guys that off in the middle. You can see on that table. There the box that the guy would pick up. And when they're taking off and going down range will take off with him standing out. Looking at the aircraft at that rate it doesn't really and gets it airborne checks. You know we started it down range will get out of his usual range he useless now he converts back to where he sitting in front of that console. And flying this system from the console. And now with a system called the turn and pioneer had the same sort of a kind of set up that they could launch and go down range on that.
More for an hour once you started going down range to develop you go on a semi portable in the back of the gator or back in another control station.

[00:32:18] **So we talked about this before and you've helped identify some of those people. But when multiple people are in the control station and seeing through these pictures we've got a good example of the different types of people. Could you do a quick rundown of the I guess the names of the functions or the I guess the titles of the people that would be in the control room.**

[00:32:44] Sure. And then it varies, on a small system less people. But in some of these some of these position might be held by one person. But you know so you can have a pilot. He's with he's going wave point to wave point. You're going to have a payload operator. So he's controlling whether you know he might be controlling a camera, radar, listening device. You are going to have what we call a mission commander could he can be the pilot he the third person. And then on some of the large systems today for the higher end systems you have you of to maintainer that is available to help troubleshoot anything that starts going wrong losing more. So with the equipment in the in the control station rather than the aircraft having flown.

So those are the four main types of people you have in and around the control room whether it's fixed or semi portable

Right. Some of those positions could be filled by more than one person.

And that's something that would be more common when they are fully mobile like out and about with a backpack that you have less people but they do form perform multiple functions.

Right. We make do like these small backpack systems like the army but they can for the smaller staff. Might have a two-man team. You know and one guy who just helping the guy set up. And he's the maintenance guy if you will for support guy and the pilot he just launches the aircraft. Or the other guy will launch the aircraft and he flies it over the hill or over this small town they're about to come in and the camera might even be fixed on the aircraft. Where he points the aircraft definitely where he wants to look and he's looking at his head on screen see the aircraft actually the pilot and the pilot operator. And the other guy is the you know the technical support. You get at them and then they get a group 2 stuff to ski and eagles and the systems of that size. So I thought things like that and you have a pilot. You have. A payload operator. And then you have some of the tactical officer. Tactical action officer to tell them to what to do. Scan eagle actually had one of a different spot that came into play. They had a position for intelligence he would be like intelligence petty officer. That would start to interpret the information. And make actions on it. He would be sitting there and say hey this thing just looks that way here. I need another shot of that. To the different devices or on a different angle. You know it maybe we were looking at the ship once. We caught the you to make passes to get more information This is I work right now. We have one pilot one tackle. Two payload operators. And there's usually a tech. So in the early stages to make sure everything keeps running. That just for the team and on station.

So those people are available during the entire flight?

Not on this one because it's aircraft air flight of 24 hours. We've got limitations on how many hours actually fly in an aircraft that manned aircraft carried over to unmanned aircraft as well. So what ends up happening with this particular system. While the aircrafts on station other crews police will come in and replace these guys. The aircraft just keeps flying. And that's a paradigm shift for people operating systems because usually take an aircraft up and bring it home. This gave the crew this on station they don't deal with the takeoff or landing. They might not even be they might be on that aircraft the whole time or another example they might join the aircraft that the aircraft get in close it's a low fuel state. And the replacement shows up so they now jump from one aircraft to the other.

And that is somebody else's responsibility to bring the first one back?

Right. We you know in our scenario we have actually two of the pilots because technically we could operate at a distance down range where we do have one aircraft traveling to it and one aircraft traveling back. So you have that crew with the payload operators only with the on station aircraft to get where that is. And you kind of pilot transition from.

How long do the shifts usually last?

We have an eight-hour block. They'll get in they'll be in the aircraft in about six hours. A lot of hours brief an hour the briefing the six-hour period in a straight solid six hours of piloting the aircraft.

Last couple of questions for this fixed and then we'll wrap up the time with you some more questions. So. Really quick what do you like most about the fixed control stations you currently use like the physical aspects of the controls or the system itself?

Capability in a fixed environment you have the ability to connect to better command control linkage. A Like I'm in a building so I can easily pass through a large dish KA or KU band antenna which is a broadband capability that more power and. Satellite linkage. To use is stronger link less likely to lose it. If I'm in a smaller system that's moving around probably not having that. I might have a UAS satellite (40:16) that I might have a narrow time radio. Well they do go through satellite but there are narrow band systems. So their capabilities are much more reduced like I think I can fly them off a narrow band but I can't bring sensor information back out. So the ability to connect to stronger support.

So I guess that would be if I were to ask you what you don't like about the more mobile systems that would be that would be is that lack of connectivity or options.

Yeah it is because the thing you have to relate it to that same time you talk about this. Is what is my mission. You know they say that that two-man squad for the army they just want to look over the next hill. He couldn't care less if he didn't have satellite linkage. True. So for him that's great He wants to be a lightweight and variety.

What would you say is the thing you like the least about fixed control stations you have worked in?

Size. Many generally you go back now you've got a building people will make a big. Also having you have people coming by too.

And that's on the fixed ones?

Yeah. Yeah. And if your mobile its harder for them to find out where you're at.

So you get a lot more visitors when everybody knows where the control station is?

Yeah.

OK all right I'll jump over to Mobile and go 15 more minutes. You got to get back to what you're doing. So thinking about the controls conversation we had earlier we kind of got a good feel for your general take on it but out of all the controls you've used whether they're touch screen or you know control sticks that type of thing. What we're the ones that you prefer using the most.

I think if you're if you're talking beyond the horizon phase of any flight from not visually sighted something. Right. I think it tended to be to use a mouse or waypoint or. System like that where I can make quick change is off of the mouse click and execute. Your ability to use sticks when out of the line site to get a new thing which is often called a pilot induced isolation being over control that things is happening. I've been a little late to see your reaction to what happened. But probably maybe now the mouse and keyboard is actually for the bigger stuff especially the small stuff made it go toward more to say x-box or toggle type capability.

And what you call that pilot oscillation?

Yeah. And printers have a problem quite often. But because there's a bit of a delay no matter how much satellite when you show you the satellite you can get up to a six second delay. So now if you make a control input approach for landing. if it goes into effect six seconds later and then you realize oh I over did that too much now I need to make another counter correction. You know when you're trying to go up and down and now you're trying to get it what you get out. Of control and put out of it you know to make that thinks they can support you. Where you're now you constantly fluttering down. That’s pilot induced oscillation, the predators had that happen a lot because they still do a manned controlled landing verses an automated landing.

What about displays when you're fully mobile and even thinking about you know being out and about with a back. Are you ever using more than the one display? Or do you have multiple displays because you have multiple people out there with you helping you pilot?

I would I would look at I have one person as the pilot person doing payload. On have two displays one for each guy to do his job. I think that helps rather than trying to pilot off of one another and looking off each other. You know it goes back to stand for the pilot and trying to get the aircraft airborne. Driver is trying to work the sensor and it may not be in the same direction. And you know he may be flying by any pilot training with him have it on his own screen.

Is that a scenario for more of a type 1 and 2 where the pilot is probably standing and moving and somewhat mobile whereas the payload operator could either be walking along with the pilot or with own screen stationary somewhere.

The payload is probably got his own screen and sitting down. He didn't need to walk around to see it, could have a spot on desk maybe even a tablet to write down. It's more of the smaller stuff. Middle stuff is still the same. The fire scout, the payload operator, and the pilot have their own screens. If I'm on the payroll operator I'm working as a fire scout. I get a 360-degree sensor. So I look behind the aircraft for the left of the aircraft. That doesn’t help the pilot is all he's actually in this case, he has a map and he's called waypoint or an override and direction the aircraft you know X Y or Z. It helps that those guys have their screens fairly close together to look. I would say they need their own screens. It’s difficult trying to incorporate both task into one.

The guy that is out and about if he's got a screen on it. If you don't you're talking a smaller size. So now you're talking maybe it's small little screen that sits on top of the control. And that might be a three-inch screen. Know three to four inch screen he's just looking outside and seeing as it goes. The other guy might have just as much a three or four inch feet but at least he can. Concentrate on other aspects of it.

From the results of survey glare and noise level were the most common issues in the mobile control stations.

I have to glare as my top one that I've worry about them being able to see the screen. You know that two-man squad they're walking down the middle of nowhere might not get under a tree or not or they get some shade over that guy.

Do yall have any equipment that you typically keep with is to try to you know diminish the issues with glare?

Usually like that Picasso that you could see in the photograph that things fall out and there's panels that fold up to kind of come out away from that big screen to provide some shade. The Pioneer had that control thing and he had the ability to close the door. And it all phases well. But other than that they guys walk around and just looking for putting themselves in the shade. Sometimes it turns them away from the aircraft.

What about when they're out about more than that. I guess this may be just more of a category one or two.

when you're your guy walking around is always in need of smaller cavalry.

For when you when you want them to. Did you ever have to use a backpack an all-around equipment?

Really I mean we just had that simple thing of launching that. Kidding around the area and stayed in the rough area where you had what we call visual line of sight. We see the system in some ways I think I have put up a canopy, and have gotten under those. And what one guy did in a lot of times of day working in an area just said an air space in that area. And. Everyone else just stays out of the line of sight.

So that the need to keep equipment like physically on your person for a long duration is fairly minimal given the type of aircraft you're flying in that environment?

Again a smaller one and lower range and lower endurance too. When we were having our guys that are flying the pioneer turned kind of a Bluetooth type system if they were going to be real practice they would have had it strapped with wrap around their neck and take some of the weight off. But even with all that they might get out of have a one-hour period they may get to a point three or point 2 about 10 15 minutes. So he might operate 10 to 15 minutes

If there's an issue with the plane when you are flying when you're using a keyboard and mouse do you ever have to take over and if you do are there control sticks or something to fly the plane? How does that work?

Yes, we can, talk with the FAA like they are launching. I've got. A plan route, gps wave point to gps wave point. And if I push the button the aircraft took off it follows all around to come back. I've never had an issue where I've have to go override. That's usually when ATC comes back or payload operator want you to make another run. So what I what you do when you're flying a lot like. This like you described going on override is like flying by autopilot. So. It would be like if I want to make it and come out the heading into go into the wave point. Air traffic control told me I need you to go ahead to 2-7-0. I go in and go okay 2-7-0 execute and the aircraft turns to 2-7-0. And then rolls out it stays there. If I want to change the altitude, then punch in and out in and apply that move into that in and out. So you can override it and you do it, it's not an uncommon thing. But it's a lot like you're not doing all the physical lower the collective lower the power setting and just the pedal the path of the changing torque. And I'm going to put the nose over to make it come down into the lap. Not doing anything that just say I want you to go to a new heading and new altitude and the aircraft will do those actions. I've found.

In the fixed control stations are there certain types of seats they use?

Whatever comfortable one you can steal. They try to this is a comfortable one. That you know have a lumbar support here with the ones we have here. They put a lot of effort into it. Thankfully they got lumbar support. Ability to rock back and change height, lot of the arm rest, in your head rest can positioning can change. Another one. We just grabbed a chair off the ship and brought it into the room. You know we put we put up our equipment and then and everything else is what you got. And I think that when you saw the ones in the picture that I sent is fold out, tailgate chairs. Yeah there's like there's a concert or something like that.

Were there any questions that you felt I needed to ask you that I didn't need ask any topics I don't and didn't.

I don't think that there is one perfect answer because you've got to look at the size of the system and the mission. What works for small will never work with the big stuff and vice versa.

11.3.8 Interview #8

So you mentioned it had been about 10yrs or so since you had flown remote?

Yeah about 10 years, so I flew for about 3-3.5 years about 750 hrs.

What type of aircraft did you fly?

Uh, Predator and briefly I stood up the MQ9 Reaper capability. It was not a full up one though. It was about 2500lbs lighter than what the production models are.

Do you know about how much the controls for those types of aircrafts have changed since you've used it?

No.

So you were using it before they made some ergonomic changes to make it more comfortable?

Yeah

So most of what you operated was from a fixed control station, is that right?

Yes, fixed location trailers. The predators were originally in deployable trailers but they were fixed at different locations. I operated them in a training environment, I operated them in Pakistan, and at another classified location.

What was the typical setup within the trailer for the control station? What equipment did you typically have in there?

Side by side seating with stations for folks to sit behind you and do any kind of any kind of radar work or mission control, they could listen in in the back of the trailer. Two big screens in front of you, vertically stacked and smaller down on the keyboard area two smaller MSD like, but they were not actually MSDs. They were two small displays. The keyboard, stick and rudder, throttle. And then we supplemented it with, in our stations, especially in further mission type stuff with a couple of additional screens. One keeping track of performance data, engine performance, flows, because we were trying to maximum, absolutely eek out every split second of one station time, so on the left side we had that. On the middle we had a couple displays to help out with communications, with other government agencies, other portions of missions information flowing onto those screens. And then the mission commander inside, could also throw up on one of the other screen that was in the middle, pictures or various chat kind of things going on.

Ok, so you had a typical desk with a keyboard and control stick for the controls. And then you had varying display layout combinations.

Yeah, well the standard predator setup was the stack big screens that were over your head, the two small ones down in front of the keyboard. That was it. We had to modify it with those additional, I think it was about 3 screens from what I remember. Two mission control screens in the middle and one where we kept track of various engine, fuel flows, and other things to try to maximize... TITs, just to maximize mission accomplishment stuff.

Ok, so would that bring the total displays to 7 or 8?

Yeah, I would say 7 displays. Potentially 8.

Ok, when you were the pilot, you weren't using all 7 or 8 displays. You were focusing on a few primary displays and the other people with you on the mission were looking at the other displays?

Yeah, so usually in the ground control station we had two of us inside, and then people outside in the mission commanders kind of, we had an operations cell with all kinds of fusion stuff going on. And they would send information over headset, or to the screens because some of the folks were located in different portions of the world. So those screens, as the pilot in command and executing and authorities and different things, I would look at those screen also for authorities, what was happening, mission type data, what people might want to be seeing, or verifying positive id of targets and things like that.

Did you always have other people in the control station with you helping you with the flight?

No. Usually, it was the pilot, because we tried to keep it pretty sanitary, I'll get to that in a second. Most of the time, pilot and sensor. Sometimes we would bring in a, especially on a difficult mission where we were potentially doing some close air support, forward air control type support doing talkons. Sometimes we would bring in a second pilot to focus on the talk on portion. Doing the management of other aircraft. It can also just be done by the pilot, depending on complexity, number of guys on the ground, just kind of managing it, and availability of pilots.

What all positions for other people would you have? Not necessarily all in the same flight.

It'd almost be like in a normal flight deck the jumpsuit kind of role. We would bring in a chair and you could sit in between the two and work. We also had a dry erase board usually sitting up high and left over the top of the pilot kind of next to the pilot probably one also on the sensor side the sensor might use. That is where we did a lot of writing down information for mission, forward air control, and things like that. Where you stacks were, whose hitting what target, nine lines, all those more kind of military type functions.

Did you ever use the desk surface to write notes or take information down, or was there enough room?

No, not that I remember. There wasn't very much room for all of that. I might have written on my lap, but I can't recall really. Maybe little notes and things but for the most part no. I think we used those boards typically.

Talking about the controls, were the controls you mentioned, the keyboard and stick, was that standard across all the different aircraft you flew?

Um, you mean manned and unmanned?

Just for the unmanned.

Uh, yes. Although, the reaper had some modifications to it because it had flaps. It had some slightly different throttle settings and things like that. So there was an adjustment made from the basic predator ground control station to a reaper station, at least in the early days. You had a couple of mechanical configuration changes that you would make. And software was loaded a little differently.

Did you ever have a mouse or a trackball with it as well?

I'm trying to recall if we had that or not. I'm thinking we must have, because we would position cursors and set up our points... I just can't, it is like your right hand, do you have a pointer finger... I'm assuming yes but it wasn't something I thought much about. I didn't fly with a mouse; I flew with a stick. We would use it to fill in boxes or select things on the map, things like that.

Did you ever have any foot controls that you recall?

Yes, rudders and breaks.

And that was for the unmanned?

Yes.

Was it done that way because it resembles more that of a manned aircraft, like if you were physically flying it... was it meant to kind of layout....

Yeah, right. Yes, the left right rudders, especially when landing the predator, it is very difficult and very susceptible to wind, so any cross wind you really had to kick in rudders on landing. Although, when I was evaluating other UAS systems after I got out of the Predator, specifics I can't really discuss. They had developed a methodology with the hand controller to be your rudders. You just kind of rotate clockwise or counter clockwise on the hand controller and you had your rudder function. When I flew that, I really liked that. But I didn't do a lot of flying. I was just going around to see what the different kind of black world, grey world programs that the other contractors were bringing in to report to Chief of Staff of the Airforce. And that functionality though seemed really nice. I only got to fly it that one time, so I guess I can't really discuss it much beyond that.

What you said is helpful because it kind of mirrors what we've started to come across. So some of the feedback from the FAA was there was a lot of questions about why pedal control wasn't mentioned. And then when we start to interview people we start to find kind of like what you said, pedals were really there to help mirror the cockpit layout for people who had been pilots to more easily transition. But the general sentiment that you shared, through software you can kind of remove the need to use pedals at all because you can get more accurate control either automated in the aircraft itself or via some type of hand control like you mentioned.

So I don't remember how I did the breaking function on that. SO breaking, the breaking function for the manned aircraft, predator, and reaper, the top portions of your rudders are your breaks. And then you always have a parking break, which was done through software in the predator. That function, I can't remember on this other modified bird.... appeared to be more ergonomically designed, I can't remember what the breaking function was... how to break.

Was that a fairly common theme, to have a control station resemble a cockpit as close as possible? Or were...

Obviously it was really a piece of shit for assembling a cockpit because all the keyboard and menus and look heads down and all that crap. Over time, when we got more and more pilots into the aircraft, we had a lot of modifications to the screens so that we could basically fly instruments off of the display. Kind of the heads up display function. But the mechanics of the gear flaps, rudder, stick, was all still there to try to uh... it was an engineer reach out to the pilot to say hey yeah we are not forgetting that you guys want to fly with the stick and rudders. The engineers had set up a lot of stuff in the menu system that was not necessarily intuitive to a manned pilot or easy to get to, or ability to monitor wasn't very good.

Here is kind of the general theme from all the interviews and even the survey we did and it is very polarizing and kind of hints at why we are finding what we are finding. The general feedback from everybody is they know what they are used to using, they think it could be better but they don't know how to make it better simply because they use what they use. It is hard for them to envision.

That's right, until you actually experience something else it is hard to think about what could be better. For example, that rudder control, when I sat down on that hand stick I though "well that is interesting". When I started flying with it, it was like oh man that is intuitive, after I played with it for a little bit it was very easy for me to do. Now long term, would it have gotten my wrist tired, probably not because you don't do a whole lot of ruddering while you are flying except for landing phase. I liked it, but I wouldn't have discovered it on my own as a methodology to do things better. As a matter of fact, when you start talking ergonomics in the screens, we always complained about ok we would like to have everything on one or two screens so it is not all these different displays. But it was always difficult for people working with us to design that, to kind of work the next generation screen. Although the heads up display stuff became very useful and where north up arrows were to keep us oriented and things like that were incorporated fairly easily. Where we got that from, I'm not sure, maybe out of other guys. When I picked my team, I had a cross-breed of different fighters, different special forces kind of guys, aviators, bomber aviators, so I had a slew of people. And they, through their experience, may have said oh this is what we have on our A-10 that will keep track of that and it is like ok, let’s throw that over to general atomics and tell them we want a north up arrow so we know where north up is all the time. And then the guys who flew heads up displays with instrumentation, instrument approved huds, they put in their inputs on what we wanted to see on the huds. And then, but the thing we quickly also started seeing is we run into clutter problems. So what is the right amount. It like you have got to experience it first and play with it for a little while before you really know if you like it or don't like it because you get trained in one way to do things and that’s the way you always want to do it.

Reuben talking about manned pilots versus unmanned pilots opinons....

Right, and I can see that right because that is very much what they are comfortable for. When I jumped onto the gaming time games like the P-51 or landing something on a carrier or whatever just for my fun. Those controllers are a pain in the ass trying to figure them out and get used to them. Where say just give me a stick and rudder and I could have handled it much easier. But that is the way I was trained. But for them, if you are always using that and you get used to using all the little controls and all the little other kind of piccolo type things... It is just, ok that finger button does this and you get in the habit of that is what the finger button does and you move this one and it does that and the combination with this does that. It seems harder for me but when people do that all the time, I can see them getting used to it. Yeah, I can see that being a real challenge. Really, what I think it will ultimately take is testing.. potentially what it could take, you know I've done some ergonomic testing when it came to bringing in some different weapons to the airforce and we had bandwidth problems, so the way we displayed it, how we flew the bombs into targets. There were different methodologies, there was different proportionalities that they could put into how the bomb steered. And we didn't know what we liked best until they ran us through numerous iterations. So we learned how to do it and then we fly it that way for a while. And then they rated us on how well we did, and I don't know how well I did, but they knew. And then they would do another methodology. And then between the groups they mixed it up, which one you learned first and second because whatever you came off of they were finding something very similar to you. What you were used to is what you did best at and then when you tried to switch, it takes a learning period to get used to the switch. I think in the end you are going to have to learn the controller guys maybe flying controllers against the certain flying and problem associated with flying and compare it to guys who are doing stick and rudder and is that the best methodology. If you find no difference and potentially there really is no difference and there is these two different options. And I am sure the FAA wants someone to settle down on ok what is the layout so they can train. I see your polarization challenge because I have seen it my whole career. And when it is something new that pops up like we did with some of these flying bombs and things you try to guide them to targets. It was almost whichever way we learned first you did better because you had to do difference in adjustments to whatever the other methodologies that they had developed for flying it or displaying it or even how the bomb flew. You just kind of adapt to it and adjust.

Saw same thing in the virtual reality stuff I worked in....

Just a couple other thoughts to consider. In the culture, one of the things the FAA is pretty hard over on and I don't know how much it can be adjusted is they do want people, this is not just based on performance, but when they are in the airspace they need to use aviation terminology, they want a culture of safety, you know like the way airmen think. It is not that I can pull this off, it is, that is not safe. We are going to mitigate the risks here and do something a little more conservative. Where if you go more towards techy, Silicon Valley it is like oh cool, look what I can do here. That is more of the test pilot mentality. That has a purpose but it is highly controlled type of thing. As you guys look at different configurations and flows, as long as it ultimately meets the minimum requirements of what the FAA wants that is good. But they do, you have to maintain that whole safety, anything without that safety, airmen concept are not going to be good.

Back to the control stations, how long were your typical missions? How long were you seated at the control station?

For the majority of my time, the aircraft was staying airborne for almost 24hrs. Probably more like 20hrs. A typical crew duty at that time, especially the early days until I could get more people into the squadron. So I assembled the first armed predator squadron reacting to everything in the world after 9/11. So we were a little unmanned. Our duty day was about 13 hours, 11 hours of crew rest, with about a half hour brief, half hour debrief. That was that extra hour so you are not really in the cockpit. We tried all kinds of different versions, about two hours on, hour off. We tried some longer periods. But we generally settled into about a 2hr, when I was doing it, 2hr to 4hr. Now my ops officer, when he took over another squadron, he went to longer times in the seat and he seemed to like that. We would fly typically two to three hours on and then, and sometimes even 4hrs on, hour off, but somebody would be a relief pilot while you went to the bathroom or something like that. Usually the mission commander was a qualified pilot and he would step into the cockpit and fly for a little while if the mission allowed. If it was heavy in the mission, we would have to bring someone in, get them smart on what is happening with the mission, just for a guy to go take a leak or something.

Would anyone ever stand while they were flying the aircraft or were they always seated?

No, always seated. That was the design of the system then. There really wasn't the option to stand. Any person that would stand would be that jump seat pilot who was working with other aircraft in a fluid air controller role.

For some configurations that were somewhat mobile, which sound like yours, yours was mobile until it needed to stay put for a while, it is kind of in the middle, its fixed yet movable.

Yeah, and I never flew it while it was moving around. It tended to be pretty fixed, it was designed mobile, but it tended to be pretty fixed.

For some of the people in the in between solution, in between being permanently fixed like at a facility and then the other extreme is the out and about when you have a backpack and you are out in the woods, yours fall kind of in the middle.

Yeah, because it was also limited in design to fit within that trailer, so that was a restricting space for it.

For some of the people with a similar configuration as yours, they mentioned glare and noise level were some of the more common issues with the control station. Now, it sounds like if you were in a trailer it was totally boxed out with no windows.

Yep, no issues.

What about noise level?

Also, where we were, no issues. Now people, if you didn't maintain a sanitized flight deck, people coming in there and start talking, now that was bad. Somebody coming into the place you would know it. Door opens, you would get some light into the place, although we did have some curtains that we could draw across when someone was back in the back. If they came in and started talking, it was in a small trailer, so you would hear them. Now how much it interfered depended on how long and how loud and complexity of the mission. Now obviously if something was going on complex, stay the hell out of my GCS unless you are an intel guy bringing me pictures or things.

That is something we should note with a trailer control station.

That is a good point. So yeah, if the FAA, you know a sanitized cockpit is very important. Now in the commercial world, there is a different requirement for security they have the locked cockpit but there is something in between there on maintaining.... I've worked with border patrol, they have a sanitized cockpit, you have to ask permission to come in. We were using that a little bit towards my end, if you wanted to come in you had to get permission to come into the back of the GCS. Now they could just walk in, but they were supposed to get permission.

What was the amount of space like? I am picturing the standard trailer that you would pull behind a truck, space would be much more limited in this mobile/fixed control station versus one at an actual facility. Was it extremely cramped or did they fit the equipment in there to give you enough room to move around?

Yeah it did. I will try to describe it, but I can't remember exact sizes. Remember I am also coming out of a fighter cockpit so I am used to being.... So you walk in the, I say the length of it was 8-10yds so about 24ft maybe, 25ft, maybe 30ft long. As you walk in the back door, there was two doors, there is one right by the pilots section, and there was one in the very back. IF you walked in the back door, there were a set of desks, so probably two stations, potentially 3 if I remember correctly in the back. Where you could get on headsets and listen, do some kind of work with the crew if necessary and function from inside that GCS. Although, we found very little need for that, because we had mission control. Sometimes on very sensitive missions I would move out when there was specific targeting things going on and I'm coordinating with other government agencies and the white house, or the commander, the geographical commander. I would sit out there because I could headset talk with the pilots, you know give them a heads up and at times not want anyone else to hear what the flight conversations were. So I would sit there, so there were actually two or three seats that you could sit alone and you had a desk there and you could work. But that was mission command work. There was a station that was rarely used while I was flying that would use our SAR radar when the airplane was configured with SAR that you had a station there to manage that but nothing was ever done. Then you had two front seats with enough room, plenty of room in between, we could walk in between the two seats to sit down on the outbore of the seats there was no room to move around that I can recall. And there was some room behind the seats to stand, so there was no problem with standing and then you could sit between the two seats. So the width of about a chair was the room between the two seats.

So if it wasn't too confined, and glare and noise were not issues, were there any other problems that seemed to be an issue that I hadn't mentioned?

Well, again, I am coming from the context of a fighter background sitting in an ejection seat. So you know staying comfortable in those seats for a long period of time and sitting in those seats for a long period of time was always an issue. Now a days it is harder than when I was younger but sitting there the whole time you get a little tired so you do need to get out of there and get relief from everything to just going to the bathroom to just taking a quick little walk around. Overall, the seats to me were fairly comfortable but I again I had to fly across oceans, oceanic trips, 16-20hrs sitting in an ejection seat. So anything is better than that and that was my experience until I flew UAVs.

So they did make an effort to find comfortable seating?

Yes, there were arms, it had flip up/down arms so easy in and out, now they weren't real adjustable but you could sit with your hands on the armrests and take some of the burden off there with reaching arms and carpal tunnel and stuff like that. There was some attempt at that.

Were the chairs fixed to the floor?

Yes, they were. the two main ones were. How much movement was in them.. I can't remember if they were adjustable up and down, forward and aft a little bit. I remember the recline was adjustable, so I am thinking there was a little bit of forward and aft adjustment because the rudder pedals and different lengths that was never a problem. And I don't believe it was a rudder pedal adjustment, I think the chairs moved a little bit.

Do you remember if the chair was closer to seating in a vehicle or more like an office style chair?

It was more like a vehicle. Fairly, luxurious for a cockpit like chair. Even though the padding may wear out. If I recall correctly, I do seem to remember them swapping out those chairs every now and then too to keep us in some comfort. But this was the early days of the program so it was probably more available to do that kind of thing. We were a high visibility program, I had contract representatives with us all the time both from the general atomics standpoint, the communications standpoints, so those "something" were there to respond to any issues that we had that effected the missions at all. And they were quick to respond. I was not in normal operations, we were really, we had missions that couldn't fail and everybody was watching us all the time. By everybody hardly anybody, hardly anybody, but the highest levels of government were keeping track of us. So we got what we wanted without really asking. If you though man this seat is starting to get uncomfortable, probably what would happen within the next week is we would get a new chair and we probably wouldn't even know that they swapped it out.

Given the layout, there was never any need for you to have to carry anything. All the equipment was in the trailer so they parked the trailer, you showed up, go in and fly?

Right.

What did you like most about the control station configurations that you used?

Probably again, you get used to what you are flying. But what I noticed that I liked the most when it occurred was the two main screen that were in front were configurable and I could adjust them a bit. And then when we had the instrumentation on that single screen that I looked to right in front of me, up top was a tracker, kind of a moving map of where the airplane was and all of that. Those two screens lined up, I was in love with that, and then when they added all of the instrumentation like the heads up display that wasn't over cluttered, that made life much easier. I sit there and look straight up and ahead and as far as flying the airplane, seeing where it is going, managing my flight, also having the ability to get to my lost link profile and seeing all that in one place or actually it was two main screens, was huge. And then I had on one of my screens the heads up display you could put what the sensor is looking at through whatever sensor he is using and I could have that right there on my heads up display and manage the mission too. All that being limited to two screens right in my field of view while I'm sitting here at a 30-degree angle leaning back and I'm watching, my hand on the stick, a lot of the time we would hand fly because we were following somebody or trying to stay out/ stay into the sun so no one could see us, or try to keep down wind so noise wouldn't get in the area so we are very, much more hands on than what was typically done with UAVs at the time, and even now. What I didn't like, was all these menus.

Was there any physical aspect of the control station you didn't like? The way the chair was seated, desk height, the controls in general, anything about your physical use while piloting an unmanned aircraft. Was there something you recalled that you didn't like or would have changed?

Yeah, I get back to the media system. I flew in fighters where I had multifunctional displays MSDS and I could bring things up on those displays in different modes through different toggles. That would have been a much better use of that space in front of me in having a little bit of desk space versus everything just being all these keyboards in front of me. I didn't like that a whole lot. I had to hand peck on a keyboard setup in front of me to bear down into different menus. I had tiny little screens to look at on those menus. Sometimes there was like a 0-1 for on and off. That was all ergonomically terrible. The chair I had some flexibility to look up on those screen but what I could put on them and have it cluttered up or not cluttered up. The specific map and detail in that might. Am I using a TPC type map very close in or am I using a JMC, different airspaces could be displayed on that map for the tracker and then down below on my heads up display functionality I could put the nose camera. So like I am just regular flying. I could put the sensors IR camera, so I am watching mission which could be looking off to the side and back so it takes a little bit of getting used to you know. If you are looking the wrong way while flying ahead kind of thing. But that never bothered me with the heads up display information. I like that, it was prominent, they were the biggest displays there so it was the most prominent displays. the lower display of the two was the HUD so you could always have that right in your eye sight.

Is there anything else about the physical control station that I did not ask about? Or is there any question or topic area that you think I missed that we need to be focusing on?

Clutter, de-clutter you've mentioned before in your stuff. That was a huge challenge and what we did because of software... the ability to adjust overlays we thought would be awesome. Like having weather laid out on the screen and being able to track for a little while for lost link because when we lose the link we want to be able to send the routing of the UAV back maybe away from the weather. It was something possible. That was too far, too difficult to do while we were there. So then you are trying to correlate a separate picture one of the screens you'd bring out to track some weather and figure out ok the weather is roughly here and correlate... So that whole layering of information and being able to do different layers in this kind of situation with a larger UAS is useful for longer type missions. You can put different aerospace up there, and you can leave it. Or you get into even more restricted areas, you know pick and choose what layering you want would be very helpful. We ended up getting around that with many, like the 7 or 8 screens to get around that. I would correlated, so when I do a lost link I'm looking up now so the big screen is in front of me, the top one was where the aircraft was tracking and I could click on my lost link profile and see where it was. But then I would have to look down on another screen where I would bring up the weather trying to get an idea of what the weather was or the weather man would come in to give me a weather brief and he'd bring it up for me. And then I would have to look on a totally other screen, maybe not even in the same size and correlate where is that weather on my tracker where I've got the lost link ok and how is it flowing and I need to redo my lost link profile differently. That was multiple screens, potentially different scales to deal with for example weather. We figured out work arounds for airspace. We just programmed them into the computers like routing or orbits and things like that to make it so that we had visible airspace on the thing. I'm sure some of that has changed since then. But that was a layer we had to artificially create. The more of that we can have the better but with clutter and stuff it is always better to be able to turn off like do I really need to watch the weather all the time. Some people may like it but others may not. Do I need to be concerned about the airspace below 5000 when I'm flying around at 20000, probably not? So the ability to layer and adjust is... more complex type airspace and missions is definitely a positive.

So the recommendation could be to reduce the number of displays but in order to diminish the need for the number of displays we could include the concept of layering. And the ability to clutter or de-clutter based on the layers you want.

Right. It takes away from having to waste grey space. I was an instructor too and an evaluator, once you put your hand on that stick you lose about half your brain power, and then you add talking, that's probably almost another 50%. The easier it is to limit your calculations and air-man and trying to correlate between this display and that display is a good thing. For standards for different phases of flight that you could adjust, like takeoff has this overlay and landing has this overlay and general in-route flight has this standard. And then you can adjust it to Reuben's en-route structure which you like to see. You don't have to play around with it and reconfigure it every time you are in flight.