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NAVAL AVIAITON SCHOOLS COMMAND
PENSACOLA, FLORIDA



REPORT OF TEST RESULTS

REPORT NO. NASC/TR-2007/1

INITIAL, COCKPIT ANTHROPOMETRIC ASSESSMENT OF U.S. NAVY T-6 LIFE SUPPORT EQUIPMENT.

by

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14. ABSTRACT Flight students were selected nearest Joint Primary Aviation Training System, Sitting Height, Buttock-Knee Length, and Thumb-Tip Reach. Each was outfitted with Navy proposed student configuration of life support gear and evaluated in both cockpits. Proposed student life support configuration did not restrict or interfere with direct forward reaches. The T-6 may not fully accommodate the full spectrum of anthropometric cases. Small and overall small could not reach normal and emergency landing gear and parking brake handle or forward left stick, even unlocked; overall small lowered the seat down from full up. Tall, overall large, and long limbed couldn't simultaneously achieve a safe ejection posture and overhead clearance with full internal FOV, especially in the aft cockpit. Manufacture spec.s for reach are not equal to MIL-STD-1333B. Small, and over small aircrew weren't accommodated. Taller and long legged aircrew couldn't achieve maximal internal FOV, remain below the canopy breaker, and zero thigh-seat gap simultaneously. Design Eye Point should be determined. The oxygen regulator should be relocated centrally or lower and left.					
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ABSTRACT

The purpose of this study was to conduct an initial anthropometric cockpit assessment of proposed modifications to T-6 aircrew survival equipment in order to identify potential restrictions or interference with cockpit functions. The participants represented each Joint Primary Aviation Training System (JPATS) anthropometric Cases, 1 through 7.

Methods. Seven flight students at Naval Aviation Schools Command were selected as Test Cases JPATS anthropometric dimensions by nearest Sitting Height (SH), Buttock-Knee Length (BKL), and Thumb-Tip Reach (TTR). Each Test Case was outfitted with Navy engineering change proposal student configuration of life support gear. Each subject's accommodation was evaluated in both cockpits: internal field of view (FOV), external over the nose (OTN) vision, reach to controls, overhead clearance, and safe ejection posture. Insufficient reach capabilities were measured to landing gear handle, emergency landing gear handle, parking brake handle, and some lower central main instrument panel switches with locked harness, with and without stretching shoulder and arm muscles against the restraint, and in two cases, unlocked harness at full payout. Inability to affect forward left control stick was also measured.

Major findings. Proposed student life support gear configuration was compatible for anthropometric Test Cases 1 through 7. But during simultaneous multivariate dimension interaction for normal and emergency functionality and immediate ejection safety, the T-6A didn't fully (safely) accommodate the full spectrum of anthropometric cases.

Results. Test Case 1, small, was not able to reach landing gear, emergency landing gear, and parking brake handles, or affect forward left stick, even with unlocked harness. Test Case 7, overall small, was taller in SH than JPATS Case 7 and was not able to reach landing gear, emergency landing gear and parking brake while stretching against locked harness, despite adjusting the seat down from full up. Test Case 4 tall, 5 overall large, and 6 long limbed, could not simultaneously achieve a completely safe ejection posture, path, overhead clearance, with full internal FOV, especially in the aft cockpit.

Conclusions. The Design Eye Point has not been determined. Prime Item Product Functionality Specifications are not equal to MIL-STD-1333B definitions of accommodations. Proposed student life support gear configuration does not worsen current anthropometric accommodation and straight forward cockpit functionality. But, the following anthropometrical dimension interactions present safety of flight hazards not known previously. Small (SEH), and over small (SEH and TTR) aircrew are not fully accommodated, with regard to function hand reach at minimal OTN vision seat heights. Taller (SH, and SEH) as well as longer legged (BKL) aircrew cannot safely position the seat for maximal internal FOV, remain below the canopy breaker, and achieve zero thigh to seat gap, simultaneously, as would be safest in the case of immediate ejection. This hazard was primarily in the aft seat where the canopy was closer to the occupant's helmet due curvature, and the canopy breaker is shorter than in the front seat.

Recommendations. NAVAIRSYSCOM should perform a larger and formal anthropometric study, and include more subjects representing JPATS Case extremes, 1, 7 and 8. Optimal accommodation conditions to be evaluated should be the following, simultaneously without seat adjustment:

maximum external FOV, better than minimal OTN vision, ejection overhead clearance (ensuring canopy breaker penetration prior to helmet contact), ejection path clearance (lower leg and foot with canopy bow), no gap between thigh and seat pan, and knee joint off the seat pan. Oxygen equipment should be located on the left side for Navy standardization, consistency with T-45, AV-8, FA-18 series and EA-6B aircraft. Minimally, the CRU-60/P should be attached on the right side to the parachute or survival vest with a pocket, and/or relocated to a more central location with a pocket.

TABLE OF CONTENTS

Abstract.....	iii
Table of Contents.....	iv
Table of Figures.....	iv
Table of Tables.....	iv
Introduction.....	1
Title.....	1
Purpose.....	1
Background.....	1
Previous Studies.....	2
Test Protocol.....	3
Participants.....	5
Human Subject Protection.....	5
Population.....	5
Test Procedures.....	6
Methods.....	6
Results.....	11
Characteristics of Participants.....	11
Cockpit Assessments, Crew Accommodation Evaluations (Fit Checks).....	11
Discussions.....	14
Cockpit Accommodation Inferences.....	14
Compared/Contrasted to Other Studies.....	17
Limitations of This Study.....	18
Conclusions.....	22
Recommendations.....	24
References.....	28
Appendixes.....	29
Appendix A Proposed Student ALSS Configuration	29
Appendix B Participant Information Sheet.....	30
Appendix C Naval Aviation Anthropometric Compatibility Assessment	31
Appendix D Sample Anthropometric Cockpit Evaluation Go-By.....	32
Appendix E Cockpit Instrumentation Panel Schematics.....	38

TABLE OF FIGURES

Figure 1 Proposed Student ALSS Configuration	1
Figure 2 Minimum OTN Visibility	3
Figure 3 Sight Picture Technique	9
Figure 4 Canopy Clearance Technique.....	12

TABLE OF TABLES

Table 1 Test Case Dimensions.....	7
Table 2 Aircraft DEP and NSRP.....	19

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Introduction

Title Initial, Cockpit Anthropometric Assessment of U.S. Navy T-6 Life Support Equipment.

Purpose

To conduct an initial cockpit assessment of proposed Navy modifications to T-6 aircrew survival equipment (see Figure 1 photo and Appendix A for contents) in order to identify potential restrictions, limitations, interference of cockpit functions for safety of flight for the specified anthropometric range of operators. The proposed seat pan/kit was not used for this study.

Figure 1 Proposed Student ALSS Configuration



Background

Joint Primary Aviation Training Systems (JPATS) included a cost effective aircraft and one design requirement to accommodate a wide anthropometrical range of operators. The initial specification for the JPATS aircraft cockpit was to provide a set of anthropometric dimensions for which a small pilot would not have to stretch and for which a large pilot would fit in (1). The working group used data from the Department of the Army, Anthropometric Survey 1988, ANSUR 88 (1). “Cull{ed} from it {ANSUR was} a sample {population} which represented those females with the potential to become pilots if the {USAF} anthropometric restrictions to enter flight training were not in place” (1). Air Force Instruction, AFI 48-123, lists flight training entry requirements (height, weight, and sitting height) that are different for males than for females. Neither US Navy policy requirements nor technical accommodation recommendations specify different anthropometric standards for sex; the Navy standards are based on system - operator functionality and safety without regard to physiological differences of size and/or strength. The final joint aircrew population expected to accommodate was matched demographically to the racial composition of 1992 college graduates who met USAF height-weight tables. The result was 580 females and 1302 males (1), from whom the multivariate JPATS anthropometric cases were created.

Dr. John Deutch, the U.S. Under Secretary for Acquisitions, directed the primary aircraft trainer program to accommodate at least 80% of the eligible females defined by the JPATS population (1).

Multivariate Case 1 was added to the JPATS specification: “sitting height was reduced to 32.8 inches and arm and leg reaches were reduced by {approximately} 1.0 inch from the previously defined smallest JPATS person” (1). That previously smallest JPATS person may now be termed Case 2, small build, short limbs. Multivariate Case 7 was created in response to U.S. Congressional interest that “proposed to accommodate 95% of both males and females (1). This requirement was eventually reduced to a goal (desired but not required)” (1) also shown in the appendix A matrix of the Operational Requirements Document, ORD (2). Interestingly, the reduction of Case 7 accommodation requirement down to a design accommodation goal is not specified in the Hawker Beechcraft Company (HBC) Prime Item Product Function Specification, PIPFS (3).

From over 160 human dimensions measured during ANSUR 88, nine primary dimensions were chosen in order to statistically derive seven JPATS Anthropometric Cases representing the extreme multivariate proportions of expected aircrew. The JPATS anthropometric Cases are Case 1 Small, Case 2 Medium Build with Short Limbs, Case 3 Medium Build with Long Limbs, Case 4 Tall Sitting Height with Short Limbs, Case 5 Overall Large, Case 6 Longest Limbs, and Case 7 Overall Small (4). See Table 1 for JPATS Cases. The following dimensions comprise the multivariate construction of the JPATS Cases: Sitting Height (SH), Sitting Eye Height (SEH) also known as eye height, Buttock-Knee Length (BKL), Thumb Tip Reach extended (TTR), Sitting Knee Height (SKH) also known as knee height, Sitting Shoulder Height (SSH) also known as acromial or acromion height, Shoulder Breadth (SB), Chest Depth (CD), and Thigh Circumference (TC), (4).

Additional anthropometric dimensions exist for JPATS Cases: Forearm-Forearm Breadth seated, Hip Breadth seated, Shoulder-Elbow Length arm flexed, Elbow-Fingertip Length arm flexed, Buttock Popliteal fosa Length (BPL) leg flexed, Popliteal Height sitting, Boot size, Thigh clearance, Chest Circumference, and Waist Circumference (4).

Buttock Leg Length also known as Functional Leg Length is not specified for JPATS Cases. BLL can be calculated from other dimensions, since a statistical correlation, linear regression coefficient exists, e.g. $BKL \times 1.75$ (5), $SKH + BKL$ or BPL (6).

US Navy regulations (7) only requires three of the JPATS primary dimensions to be measured (SH, BKL and TTR), and one is derived (SEH), based upon a 0.92 linear correlation from post hoc analysis of ANSUR 88 (5).

US Air Force T-6 (PT-6 and PT-9)¹ anthropometric accommodation assessment results (5, 6) were used by Naval Air Systems Command (NAVAIRSYCOM) to create (8) the technical recommendations for accommodation policy (7) for T-6A aircrew selection by restriction codes (9).

Lessons learned from operating T-6A at Training Air Wing SIX (TW-6) led to proposed survival items modifications to Aviation Life Support Equipment (ALSE), also known as Aviation Life

¹ JPATS Anthropometric Review - PT9 and JPATS Anthropometric Review - PT6 are unpublished cockpit evaluation reports from Greg Zehner's trips to Raytheon Air Corporation, Wichita, Kansas, June and September 1999 for PT9, and December 1998 for PT6. PT6 and 9 are production aircraft different than each other and different than the mock up evaluated in reference 1. These reports were probably used to sing-off procurement accommodation requirements. Contact JPATS Program Office at WP AFB or AFRL/HECP for these unpublished documents.

Support Systems (ALSS). See Figure 1 for proposed student ALSS configuration photo and see Appendix A for list of contents. Chief of Naval Air Training (CNATRA) supports the ALSS and seat kit modifications as part of the Technical Interchange Meeting (TIM) Engineering Change Proposal (ECP) to be included in the TW-6 T-6A Navy upgrade and for the Navy T-6AUP to be implemented at TW-5 and TW-4.

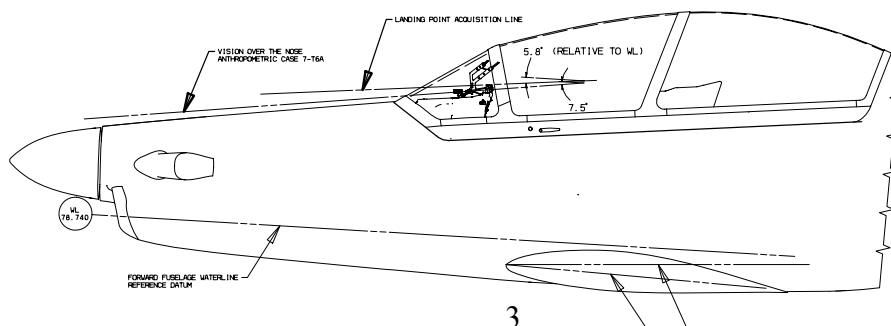
Previous Studies

Documentation of similar studies previously conducted was not found prior to cockpit fit checks. There are few published Human Systems Integration (HSI) studies using a preproduction mock up or a production T-6A Texan II with humans closely representing each of the 7 JPATS anthropometric Cases that verify or validate functional aircrew compatibility accommodation requirements or goals. This study may only be the second of its kind as an overall functional assessment of a T-6A anthropometric accommodation, but the first within the Navy. It may be the first production T-6A in Navy flight training.

Air Force Research Laboratory (AFRL) at Wright-Patterson (WP) Air Force Base (AFB) and Sytronics, Inc. evaluated the USAF cockpit inventory for anthropometric accommodation of USAF population and USAF pilot and navigator populations and JPATS population (1, 5). External field of view was determined by a panel of {pilot} experts at Air Education and Training Command (6). Worst case flight operation scenario was generated for external visibility, field of view (FOV), over the nose (OTN): visual acquisition of the landing area at 500 feet above ground level (AGL) 2 nautical miles away, while flying a no flap approach to landing on a 3.5 degree glide slope without stretching or tilting the head up and back to see OTN (2, 5). The pilot's downward visual angle relative to aircraft waterline was determined to be 7.5 degrees (2, 5). See Figure 2. At this downward vision angle, the pilot had to have eyes positioned to visually acquire the T-6A's propeller nose cone spinner. How much of, or which part(s) of, the spinner was not specified. Figure 3 shows a front pilot's site picture which approximates OTN vision. Figure 3 is a specific site picture technique for another purpose, internal visibility of instrumentation, discussed later.

This univariate condition of pilot eye position was not known to be at the aircraft Design Eye Point (DEP), and was not correlated to other dimensions and conditions in a multivariate manner, i.e. where arm and leg reaches, safe ejection body posture, and clearances are simultaneously desired for optimal mission accomplishment and flight safety as required by military standards of crew station/cockpit design (11). From the determined OTN operational requirement, the minimal SEH at seat full up was 25.0 inches (6). Univariately, the maximum SH at seat full down in order to remain below canopy breaker was 41.5 inches, accounting for average HGU-55/P helmet size and thickness (of shell, styrene, and liner; 1.5 inches). Figure 4 demonstrates aircrew canopy clearance

Figure 2 Minimum OTN Visibility



technique (14). Univariately, maximum BKL was found to be 27.9 inches to avoid striking the instrument panel during ejection. Other results relative to this study are presented and discussed.

One technical report (10) for Universal Water Activated {parachute} Release System (UWARS) fit checks assessed the technical feasibility and operational HSI compatibility potential of changing to UWARS from the current Salt Water Activate Release System. This UWARS study did not have the DEP information, so a work around was used: test subject SEH was measured and compared to JPATS Cases; case were grouped together as small (1 and 7), Medium (2 and 3), and large (4, 5 and 6); each group's average SEH was calculated; and average seat bucket height was determined for front and aft crew stations for each group of subjects. Presumably each subject sat in the aircraft and adjusted the seat height to a personally desirable position, but not the DEP since it was unknown. This procedure may be critically flawed and invalidate the UWARS fit checks and studies using similar methodology, e.g. HBC PIPFS (3) zones reach checks for specified items.

NAVAIRSYSCOM conducted anthropometric accommodation studies in many aircraft and standardized a methodology (5): the Department of Defense Standard Aircrew Population, which became the JPATS Cases (multivariate dimension representatives), military standards for crew station geometry (12), DEP (11), and handbooks were used (5, 13). Flight and time-critical emergency controls were identified beyond the military standard generally implied cockpit items, and DEP located from design drawing, was used to evaluate FOV and minimal OTN visibility. Computer-aided design drawings and a FaroArm™ were used to measure and model reach and clearance distances of cockpits. Accommodations were assessed from multiple seat position trials, including full up, full down, and two intermediate heights. Seat height for DEP was not specified. Zone 1, 2, and 3 reach conditions to controls and pedals and clearances were in accordance with military standard accommodation verification (11). External FOV was measured from subject's ectocanthus for various seat heights (eye heights), compared to aircraft DEP, and dimensioning the distance between the two. Minimum SEH and SEH+TTR, as well as minimum and maximum SH, TTR, and BKL were determined for many USN cockpits, but not a T-6. These newer multivariate inter-actions methods and tools resulted in new restriction codes (8, 12). External FOV was functionally defined as ability to obtain design eye point; functional arm reach as operation of critical flight and time-critical emergency controls; functional leg reach as operation of pedals; cockpit volume clearances, including ejection clearances not striking objects unintention-ally; and overhead clearance as space below canopy or canopy breaker (13). Clearances were measured with head stationary and upright, as in an alert flying posture or as in a Frankfurt plane not specified. Lower leg clearance was measured from shin line and lower instrument edge of main panel. Ejection clearance was measured from knee to any obstruction. Reach to pedals was measured from a position where full control was achieved. Arm reach was measured for control stick full range of motion and others as Zone 2 conditions. Vertical FOV was evaluated by determining whether the subject could establish a horizontal vision line through the known DEP. New restriction charts included three bivariate critical dimension relationships of aviator survivability: SEH+TTR for ability to attain DEP and reach to controls; SEH+BKL for ability to attain DEP and operate foot controls; and SH+BKL for ability to clear escape path and operate controls without compensatory movements.

This T-6A study attempted to incorporate NAVAIR methodologies for reach and seat positions, some USAF methodologies for vision and clearances, as well as the authors' biomechanic, kinesiology, ergonomic, human factor, and flight experiences.

Test Protocol

Participants

Were not randomly selected; they were selected by best fit determined by independently gathered, limited anthropometric dimensional data and participation availability.

Human Subject Protection

Naval Aviation Schools Command (NAVAVSCOLSCOM, simply NASC) is not a designated research, test, or evaluation command, institute, or laboratory, and does not have an Institutional Review Board (IRB) within the chain of command. Due to time constraints, a protocol was not formalized for and Navy Surgeon General guidance was not obtained prior to conducting cockpit evaluations. Local IRB has yet to be determined for adhering to SECNAVINST 3900.39, Human Research Protection Program, but the intentions were. The author has conducted online human protection assurance training and certification and IRB approved human subject research. The author provided verbal and written study information. Verbal informed consent was provided by participants; documents were not signed. See Appendix B for sample study information provided to subjects. Subjects of this study were not harmed mentally or physically.

Population

The reference population was young adults from the United States of America who meet service specific aviation selection criteria. Eligibility criterion for the experimental population was near JPATS Case representation. Those willing and able then comprised the study population, also known as participants. Participants as well as the dynamic populations they came from, exhibit the healthy worker bias. This selection bias is acceptable since it is directly relevant to the operational group of aircrew flying the T-6A and near future series T-6s.

Anthropometric policies restrict personnel applying to Naval Aviation by stature, weight, and then by the number of training pipelines available - must be at least two (7), which is determined by SEH, TTR, SEH+TTR interaction, BKL, and SH for training and fleet aircraft (9). After pre-commissioning academic, medical/physical (including anthropometric), examination and screening, potential Naval Aviators and Naval Flight Officers are commissioned with an aeronautically designation. As flight students these personnel wait to commence Aviation Preflight Indoctrination (API) at NASC, Naval Air Station (NAS) Pensacola, Florida – an academic ground school and survival training program preparatory for Primary Flight Training in Naval Aviation Training Commands or Undergraduate primary Flight Training at Vance AFB. Various US service personnel as well as international military training officers attend API.

Test Procedures

Methods

Flight students were measured at NASC by the contracted CACI, Inc. Anthropometric Specialist, i.e. measuring technician, trained in traditional anthropometric measurement procedures by Anthrotech Inc. using a GPM-101 Anthropometer. The contracted measuring specialist independently provides standardization of anthropometric measurements; consistently precise and repeatable measurements improve accuracy (reduced intra-rater variability), and the sole source data eliminate inter-rater variability.

The Naval Aviation Anthropometric Compatibility Assessment (NAACA) was used to select JPATS anthropometric Case 1 - 7 representatives for the experimental population. See Appendix C for more information about NAACA. Three hundred and seventy-eight (378) flight students' anthropometric data were in NAACA. Since only three primary JPATS human dimensions are directly measured for the USN (7), a data pull of SH, BKL and TTR, associated last names, and command assigned to, was generated, and exported to Microsoft Excel. The selection time period of NAACA entries was from 01 May to 15 July 2007. These data fields were sorted for JPATS case matching priorities in the following order: SH, BKL, and TTR. The data was reviewed independently by two NASC anthropometric program personnel (author and an assistant) who found JPATS anthropometric case near matches. These near Case representatives were compiled and collaborated upon for best/nearest fit to JPATS Case, and prioritized in case of participant non-availability. There were no exact matches of human subjects to a JPATS anthropometric Case. See Table 1 for Test Case classification, and distance above or below JPATS anthropometric Case definitions. HT, WT, and Age were pulled from NAACA prior to cockpit evaluations. SEH (non-calculated), SKH, SSH, SB, CD, and TC were measured after cockpit evaluations.

Thirty-eight flight students were selected as close approximations of a JPATS anthropometric Case and were recalled for this study. Fourteen responded, and 13 were willing and able to participate both days. None of the participants exceeded body weight for height or body fat composition for respective service standards for health and fitness. All participants were aeromedically cleared for flight duties.

On 23 July, 2007, the test participants were provided one flyers coverall and one set of standard black flyers boots by NAS Pensacola, Aviation Supply Center, Flight Gear Issue at Sherman Field.

Attendees of the proposed T-6 ALSS modifications working group meeting were briefed by the lead researcher about anthropometric accommodation and cockpit assessments, just a few hours before conducting the cockpit fit checks, on 23 July 2007. See appendix D for anthropometric evaluation go by – a product of compiled references, standards, guidelines, previous fit check lists and experiences.

Author briefed subjects again about their voluntary participation and asked for last minute reservations. One subject was only available for the first day. He was allowed to depart, but he stayed in hopes of participating.

Participants group were provided an ejection seat safety brief by the TW-6 Aeromedical Safety Officer (AMSO).

Table 1 Test Case Dimensions

	Small	JPATS 1	Above (+) min Below (-) max	Medium Build Short Limbs	JPATS 2	Above (+) min Below (-) max	Medium Build Long Limbs	JPATS 3	Above (+) min Below (-) max	Tail SH Short Limbs	JPATS 4	Above (+) min Below (-) max	Overall Large	JPATS 5	Above (+) min Below (-) max	Longest Limbs	JPATS 6	Above (+) min Below (-) max	Overall Small	JPATS 7	Above (+) min Below (-) max
Test Case	1			2			3			4			5			6			7		
SH	33.65	32.8	+0.85	35.60	35.5	-0.1	34.45	38.5	-0.5	38.75	40.0	+0.25	39.92	40.0	-0.08	38.23	31.0	+0.23	32.70	31.1	+1.7
SEH calc	29.15	28.0	+1.15	30.8	30.7	+0.1	29.65	30.2	-0.55	33.95	33.4	+0.55	35.12	35.0	+0.12	33.43	26.8	+0.53	28.2	26.8	+1.4
Measured (direct)	29.06	28.0	+1.06	31.46	30.7	+0.76	29.82	30.2	-0.38	33.96	33.4	+0.56	35.45	35.0	+0.45	33.82	26.8	+0.92	28.05	26.8	+1.25
BKL	20.55	21.3	-0.8	21.65	21.3	-0.35	25.55	22.7	-1.0	24.00	27.4	+0.13	24.90	27.4	-2.5	25.63	20.8	-2.27	21.90	20.8	+1.1
TTR	30.77	27.0	+3.77	29.65	27.6	+2.05	34.88	29.7	+0.98	32.13	35.6	+2.43	34.43	35.6	-1.17	36.79	26.1	+0.79	28.88	26.1	2.78
SKH	17.76	18.7	-0.94	20.41	19.1	-1.31	21.69	20.6	-1.61	21.71	24.7	+1.11	24.25	24.7	-0.45	22.44	18.1	-2.36	19.76	18.1	+1.66
SSH	20.91	20.6	+0.31	22.89	22.7	-0.19	22.66	25.2	+0.06	26.18	26.9	+0.98	26.59	26.9	-0.31	25.35	19.5	+0.35	20.85	19.5	+1.35
SB	15.41	14.7 min 18.1 max	+0.71 -2.69	17.5	16.4 min 20.6 max	+1.1 -3.1	19.61	16.8 min 21.7 max	+3.41 -1.59	19.53	16.9 min 22.6 max	+2.73 -2.71	19.28	16.9 min 22.6 max	2.38 3.32	21.3	14.2 min 18.0 max	+4.5 -1.2	16.16	14.2 min 18.0 max	+1.96 -6.64
CD	8.43	7.4 min 10.9 max	+1.03 -2.47	9.88	6.9 min 10.6 max	+2.98 -0.72	10.26	7.1 min 11.0 max	+3.06 -1.04	9.61	7.3 min 12.1 max	+2.51 -1.39	8.88	7.3 min 12.1 max	1.58 3.22	11.54	7.2 min 10.2 max	+4.14 -0.66	8.84	7.24 min 10.2 max	+1.60 +1.36
TC	20.3	18.5 min 25.0 max	+1.8 -4.7	23.62	17.1 min 25.0 max	+6.52 -1.38	25.3	17.6 min 26.3 max	+5.1 -2.3	23.68	18.6 min 29.2 max	+6.08 -2.62	22.83	18.6 min 29.2 max	+4.23 -6.37	25.79	17.8 min 25.2 max	+6.69 -3.91	20.51	17.8 min 25.2 max	+2.71 -4.69
HT	61.85			65.40			69.65			72.90			76.56			74.65			62.20		
WT (lbs)	106.95			154.50			195.50			181.95			192.50			219.55			112.90		
Age	22			21			23			23			23			23			22		

SEH calculated via SH - 4.8 for males or 4.5 for females (4, 8)

A smaller N of just one of each JPATS anthropometric Case representative, plus one additional small person, was chosen for quality and time constraints versus quantity and degraded cockpit evaluations. The 8th subject did not participate.

A plastic 48 inch ruler/level was placed in the front cockpit on the floor board (waterline unknown) as far aft as possible at an unknown fuselage point, alongside the ejection seat so the top of the seat frame bucket could be measured vertically, perpendicular to the floorboard. The base of the ruler/level was wide enough to allow it to stand perpendicular to the floor board. Seat heights at the stops were measured: the top stop of seat height adjustment travel / highest seat height was 31 and 11/16 inches, and the bottom stop of seat height adjustment travel / lowest seat height was 25 and 2/16 inches. A small quick clamp was used as an adjustable, temporarily securable, perpendicular pointer. Cockpit space constraints made this measuring method imprecise. The length of the quick clamp made temporary securing to the ruler/level impractical, e.g. the clamp was not squeezed. So the author held the clamp longitudinally perpendicular to and adjacent to ruler/level. Cockpit side rail also induce parallax measuring error.

Author discussed a lack of known T-6A DEP information with HBC egress engineer, Doug Kizzar. He and Matt Conrad provided pages 10 and 11 of UWARS test report (10) which explained how the unknown DEP was approximated by Neutral Seat Reference Point (NSRP). Author provided a NAVAIRSYSCOM/ NAWCADPAX AIR 4.6 Anthropometric Team spreadsheet which showed the blank fields for the priority 1 DEP and NSRP for the T-6A, as of 2000. See Table 2. Based on the definition of NSRP (11), iterated in Appendix D, and on the methods of UWARS technical report (10), seat travel along the ejection seat guide rails was marked by the HBC representative. Black

china marker was used on each ejection seat fixed frame, forward and aft crew stations, in order to denote maximum seat height, and minimum seat height, adjustment end/stop points.

The front seat travel distance in this study was 6 and 9/16 inches. The front seat travel distance in the UWARS TR (10) was 7.0 inches, as measured with a short, metal measurement strip secured to the seat guide rail, and a metal pointer secured to the top of the seat frame bucket.

Due to time constraints of this study, and the reasonably assumed more precise measuring method of the UWARS TR, these researchers choose to use the UWARS TR method for seat travel distance of 7.0 inches. This given distance of seat travel was divided by two to derive the NSRP, $7.0 \text{ inches} \div 2 = 3.5 \text{ inches}$. This calculated half travel point of the seat was measured with a digital caliper along the fixed seat guide rail from the lowest seat bucket position and marked between the min and max seat height marks, as the NSRP for this study.

On the second day, 24 July 2007, TW-6 AMSO measured with the digital caliper the ejection seat frame bucket top travel of the same (by BUNO) aircraft used 23 July. The NSRP was marked at 3.65 inches above full down for the aft seat, and 3.35 inches above full down for the front seat.

Each subject donned the proposed student ALSS configuration. See Figure 1 for photo and see Appendix A for contents. Each participant secured him/herself into an available crew station of the Training Squadron FOUR provided T-6A. Assistance was provided by TW-6 and TW-5 AMSOs. For efficient time use, both cockpit/crew stations were evaluated simultaneously; one participant and one AMSO each. Subjects were evaluated in each crew station. Ground power was provided so the Martin Baker Mk. US16LA ejection seat could be adjusted, raised and lowered; the participant could have required external OTN as shown in Figure 2 schematic and internal cockpit vision of all (3, 14) illuminated displays and instruments as shown in Figure 3.

Bottled water was provided to participants in order to prevent deleterious dehydration effects. Normal hydration of the test subject was desired. Since inter-vertebral disks are viscous tissues, it is reasonable to assume that disk hydration level can change human standing and sitting height dimensions (scientific literature references TBD). Thus, this likely result confounder, hydration level, was controlled for. Gravity result confounding was controlled for by a fairly short duration of subject participation, less than 1 hour total in the static aircraft.

The T-6A weight and balance were not calculated with subjects in crew stations and secondary researches onboard the left wing root. Thus aircraft pitch on deck was not determined. External vision, over the nose (OTN) and downward was estimated by subject acquiring shoes of a person walking backwards away from but directly in line with and in front of the aircraft's nose nearest point visible on the deck. This method has been used in previous fit checks in T-44, C-12, and S-3B. The distance was stepped by feet, toe-heel. The feet used were nearly 12 inches, sufficient for estimation in this study. Propeller spinner visibility was not used in this study, but post cockpit evaluations with participants demonstrated by default that they saw the spinner; participant recall did not specify a lack of spinner within their FOV. Since the T-6A DEP is undetermined, internal vision was assessed by subject remarking on how much of the main instrument panel instruments or displays were visible. An AMSO reported which portions of the instrument panel or displays were not visible to the participant, or reported the top

of the participant's internal FOV. A seasoned Instructor Pilot (IP) with over 600 T-6A flight hours provided a common instructor technique for student seat height adjustment. The JPATS T-6A familiarization phase student guide formalizes this method See Figure 3 for technique sight picture. The T-6A flight manual states that aircrew should adjust the seat so all instruments and displays are visible (14). IP seat height adjustment technique is to adjust the seat height so as to align the near edge of the anti-glare shield/lower edge of the central warning system, master warning annunciator mounting panel, so as to just see the top of the electronic Attitude Direction Indicator (ADI) display. In his opinion most pilots maximize their external vision while allowing sufficient internal vision of all forward displays, instruments, switches, knobs, and handles with nearly no head movement adjustments. Another technique is to align with and see the blue light above the ADI. Yet another technique is to align and see the top left corner of the ADI, specifically the bright/dim switch button, indicator bar, adjacent to the display. Previous CNATRA cockpit fit checks required seeing the top carrot of the ADI. See Appendix D for this study's assessment checklists items.

Figure 3 Sight Picture Technique



Reach to controls, switches, knob, buttons, etc. of instruments and displays on the main and on both of the side panels were evaluated. The shoulder harness inertial reel of the upper restraint system was locked for Zone 1 (no stretching of arm or shoulder forward), and Zone 2 (stretching of arm or shoulder forward) controls. See Appendix D for list of controls in each Zone. Other reach capabilities were assessed with the shoulder harness inertial reel of the upper restraint system unlocked, e.g. for reaching normal canopy closing handle/lever. Closed canopy release handle miss distance was not measured since both crew stations were occupied by participants, AMSOs were unable to measure when the canopy was closed. The seasoned IP mentioned a need for the student in the front crew station to reach and operate the following: 1) Emergency Landing Gear Handle; 2) Landing Gear Downlock Override button; 3) Parking Brake Handle for emergency brakes; 4) Emergency Canopy Release Handle; 5) UHF STBY knobs located on the lower portion of the center main instrument panel; and 6) PMU switch.

Miss distance was measured with the digital caliper from the subject's TTR position to the handle, lever, switch, or button. The thumb was along extended arm axis with first finger curled around so thumb tip and finger tip pads meet similar to measuring procedures of reference (7).

Cross cockpit reach with a locked harness and both stretching and not stretching against a locked

inertial reel, fully retracted upper restraint harness was explored to assess proposed ALSS configuration's increased bulk and bulk location interference with cross cockpit reaches. These cross cockpit reach evaluations were just of curiosity, not of any contractual or operational requirement. See Appendix E for cockpit schematics (14).

Ejection injury potential was evaluated by placing the subject at or as near as possible to proper ejection body positioning/posture. With the canopy open, the 48 inch ruler/level was placed atop either the helmet and or canopy breaker, whichever was higher. The bubble was centered and the distance below or above the other point was measured using the digital caliper. Rudder pedal positions were noted. Thigh gap was measured using the digital caliper, which proved to be difficult, thus estimated when a gap existed. Seat height was adjusted by the subject to achieve no thigh gap. Rudder pedal position, internal and external vision, and canopy and canopy breaker clearances were all noted for this 0 thigh gap position. The published method for ensuring canopy clearance is for the aircrew to place a vertical fist between helmet and canopy (14).

Proper body posture for ejection is the following. 1) helmet aft against and within the lateral borders of the head box, 2) chin up, approximately 10 degrees, 3) back straight and pressed aft against seat back, 4) buttocks aft, against the seat back, 5) legs extended, 6) heels on the floor or on the rudder pedals, if at the controls, 7) thighs flush against the seat within the lateral boundaries of the seat pan or side restraints, 8) arms and elbow inward, close to the body, 9) hands in an approved grasp position on the ejection handle. These items are presented in The Bureau of Medicine and Surgery Department of the Navy's U.S. Naval Flight Surgeons' Manual, 3rd edition, Washington, DC, 1991; initial *Ejection Seat Training*, Lesson Topic 3.2 of Advanced Continuation Training for Aircrew Selected for Tactical Jets (N6), Course Identification Number B-9E-1231, Naval aviation Survival Training Institute, Naval Aviation Survival Training Program (NASTP), Pensacola, FL, November, 2001; annual egress currency (15); and quadrennial refresher NASTP training. This proper body position reduces injury potential. Normal flying posture should position the pilot very near the DEP (head not likely against the head box and chin upward), but still have military standard Zone 1 reach capability, and be ready for an immediate ejection (no thigh gap, no cockpit or canopy strike hazards), if necessary, without delaying ejection to adjust seat and ruder pedals.

Results

Characteristics of Participants

Two females (small and overall small) participated and both were Student Naval Flight Officers (SNFO), USN. Four male (1 longest limbs, and three tall SH with short limbs) Marine Student Naval Aviators (SNA, aka student pilots) participated. The remaining participants were male, Navy SNAs, except one who was a Navy SNFO. Table 1 includes demographics ranges of height from 61.85" to 76.56", weight from 106.95 lbs to 219.55 lbs, and ages from 21 to 23 years old.

Cockpit Assessments, Crew Accommodation Evaluations (Fit Checks)

The first participant was a Case 1, small. She initially positioned the aft seat full up and the rudder pedals full aft, for maximal external visibility, minimal lower cockpit reach, and minimal canopy and canopy breaker proximity. Her miss distance for the landing gear handle was 2.72 inches. Clearances from cockpit and canopy structures were sufficient, and ejection body position was safe: no thigh gap for potential seat slap; and her knee joint was off the forward edge of the seat. Proposed ALSS configuration did not present any interference with her cockpit functionality. No other aft seat positions were assessed for ALSS or other cockpit functionality and compatibility since those seat heights would have worsened her external visibility but improved her cockpit reaches. In the forward seat she positioned the height full up and rudders full aft. Her nearest forward OTN external visibility was 52 feet. Her miss distances were 3.6 inches to the landing gear handle, 1.05 inches to the parking {emergency} brake handle, and 2.2 inches to the PMU switch. In the NSRP her miss distance to the emergency landing gear handle was 2.1 inches. No other seat heights were assessed. Clearance, escape path and position were not hazardous, and ALSS did not create interference problems. Zone 1, 2 and 3 reach assessments were conducted, but only Zone 1 miss distances were measured and recorded. Zone 2 reduced miss distances, but only Zone 3, unlocking the harness, allowed Test Case 1 to reach and minimally operate items; reach was still insufficient to simulate raising the gear.

The second participant was a Case 7, overall small. She initially positioned her aft seat at full up and rudder pedals full aft. She could not reach while stretching, the Power Control Lever (PCL) cut off gate, a military standard zone 2 condition control; or reach without stretching the landing gear handle, possibly a zone 1 condition control by military standard, but a zone 2 by PIPFS; and could not reach far enough to affect full forward control stick, a military zone 1 condition control, but a PIPFS zone 2. She could reach and operate the canopy closing handle (Zone 3). In the NSRP and full down seat heights, her aft cockpit reach functionality improved to the extent that she could reach the above mentioned items and still reach and operate canopy closing handle. Clearance, escape path and position were not hazardous, and ALSS did not create interference problems. In the front cockpit her seat was positioned 1.61 inches down from full up where she could align the top of the instrument panel anti-glare shield edge with the top of the ADI (IP technique). Her nearest forward OTN external visibility was 55 feet. Her miss distance to the landing gear handle was 3.72 inches, to the normal landing gear handle was 3.88 inches, 2.5 inches to the PMU switch, greater than 6 inches to the UHF standby switch, and she had to lower the seat height 2.65 inches down from full up in order to see the blue light. Clearance, escape path and position were not hazardous, and ALSS did not create interference problems. Thigh gaps were not found in any seat position.

The third participant was a Case 6, longest limbs. He initially adjusted the aft seat height for IP technique position (aligned the top of the ADI to be just visible below anti-glare shield) and rudder pedals full forward. At this seat height (not recorded) there was a 2.01 inch distal thigh gap above the seat. The aft seat was raised (height not recorded) so his helmet was even with the aft seat canopy breaker. At this seat height (not recorded) a 0.8 inch thigh gap existed. Neither seat height (not recorded) was safe for ejection - dynamic overshoot, aka seat slap hazard - so the seat height (not recorded) was adjusted in order to achieve a zero thigh to seat gap. At this seat height (not recorded) his helmet was a fist breadth, width (across knuckles and thumb) per Flight Manual procedure (see Figure 4) from the canopy in the aft crew station, but 1.9 inches above the aft seat canopy breaker. In the front cockpit he initially positioned the seat at full down where his helmet was clear of the canopy and below the front seat canopy breaker. He could not see the blue light. At front seat full down, a 1.85 inch thigh gap existed, an unsafe ejection condition, so the front seat was raised to a height where no thigh gap existed (safe ejection condition). This was determined to be the front NSRP where his internal visibility was restricted by the anti-glare shield - he could not see much of the top instruments. No further seat positions were assessed since his internal vision would have been more restricted and his canopy and canopy breaker clearances would have been less reduced, compromising mission effectiveness, flight and ejection safety. The PIPFS 30 inch escape path clearance was confirmed as measured by the 48 inch ruler/level from back tangent forward to the instrument anti-glare shield; the seat was not raised beyond normal travel to measure canopy bow clearance. ALSS did not interfere with his cockpit functionality. Cockpit reaches were more than sufficient for function in all Zones. ALSS did not create interference problems.

Figure 4 Canopy Clearance



The forth participant was a Case 5, overall large. He adjusted the aft seat initially at the IP technique position (aligned the top of the ADI to be just visible below the anti-glare shield), and the rudder pedals full forward. He repositioned/lowered the seat to see the blue light. At this seat height (not recorded), a 1.22 inch thigh gap existed (unsafe), his helmet was 0.87 inches above the rear seat canopy breaker (potentially unsafe), but his helmet was below the canopy (potentially safe). So, his seat height was raised to achieve no thigh gap. At this seat height, NSRP, his helmet to canopy clearance was estimated at only 1.0 inch. In the front cockpit he initially positioned the seat full down and rudder pedals full forward. He could see the top of the ADI under the anti-glare shield, but a 1.71 inch thigh gap existed (unsafe). So, the seat was raised in order to eliminate the thigh gap, the seat was measured at 4.21 inches below full up. He could now only see the middle

portion of the brightness/dimness indicator of the ADI. His helmet was below the canopy as well as the front seat canopy breaker. Other clearance, were sufficient and cockpit reaches were more than sufficient for function in all Zones. ALSS did not create interference problems in either crew stations.

The fifth participant was a Case 4, tall SH with short limbs. He initially adjusted the aft seat at the IP technique position (aligned the top of the ADI to be just visible below the anti-glare shield), and the rudder pedals full forward. At this seat position, 0.71 inches below NSRP, a 0.65 inch thigh gap existed (unsafe per NASTP and ref. 15), and his helmet was 1.0 inch above the aft seat canopy breaker (potentially unsafe per refs 5,6,13). So, the aft seat was raised to eliminate the thigh gap. At this seat height (not recorded) he could not see the top $\frac{1}{4}$ of the ADI, his helmet was 2.7 inches above the aft seat canopy breaker (potentially unsafe), and a flat fist, i.e. knuckle height, below the canopy (potentially safe). In the front cockpit the seat height was positioned in order to see the top of the ADI, rudder pedals near full forward. His nearest forward over the nose external vision was estimated at 16 feet. His helmet was below the front seat canopy breaker (safe) and below the canopy (safe), but a 1.1 inch thigh gap existed (unsafe). So, the seat was raised to eliminate the thigh gap. At 0.45 inches above NSRP, there was zero thigh gap. Helmet was below front seat canopy breaker (distance not recorded) and below the canopy, but he could not see the top $\frac{1}{4}$ of the ADI. Cockpit reaches were sufficient and ALSS did not interfere in either cockpit.

The sixth participant was a Case 3, medium build with long limbs. In the aft cockpit he adjusted the seat at the IP technique position (aligned the top of the ADI to be just visible below the anti-glare shield); rudder position was not recorded. At 1.12 inches below full up there was no thigh gap. His helmet was 0.95 inches above the aft seat canopy breaker (potentially unsafe), but below the canopy (potentially safe). Full control stick range of motion was confirmed. He could not reach, even stretching, cross-cockpit controls with a locked harness. In the front cockpit, the seat height was adjusted to the IP technique position. Seat height was measured at 0.47 inches above NSRP. There was no thigh gap (safe). His nearest forward OTN external visibility was measured at 13 feet. He had full control stick range of motion with a locked, retracted harness. He could not reach, even stretching, cross-cockpit with a locked harness: right arm left to the emergency landing gear handle, or left arm right to the parking brake handle (miss distances not recorded). Canopy, canopy breaker, and other front cockpit strike clearances were sufficient from hazards (safe).

The seventh participant was a Case 2, medium build with short limbs. In the aft cockpit he adjusted the seat at the IP technique position (aligned the top of the ADI to be just visible below the anti-glare shield); rudder pedal position was not recorded. At 1.47 below full up there was no thigh gap (safe), but his helmet was 0.73 inches above the aft seat canopy breaker (potentially unsafe). Full control stick range of motion was confirmed. But he could not reach, even stretching, cross-cockpit controls with a locked harness. In the front cockpit, he adjusted the seat IP technique position, 1.35 above NSRP. His nearest forward OTN external visibility was measured at 11 feet. His helmet was below the front seat canopy breaker and canopy. He had full control stick range of motion with a locked, retracted harness. He could not reach, even stretching, cross-cockpit, right arm to the left (specific points and associated miss distances not recorded).

Discussions

Cockpit Accommodation Inferences

Test Case 1 was not a great match to JPATS Case 1, but she was the nearest match available. Test Case 1 was the first subject in the cockpits and IP technique for seat adjustment was not yet known; the IP arrived after Test Case 1 departed. Test Case 1, authors, and equipment have not been available since then in order to reevaluate her at less than seat full up.

Since Test Case 1 was small, the primary concern during cockpit functional assessment was external vision. Reach was secondary to, dependent of, maximum external FOV. Thus, only full up seat height was assessed; an early, yet vital, mistake. Lower seat heights should have been assessed as planned, but these improvements would have been at the expense of a farther away external FOV and OTN visibility distance, which would pose a problem in the take off, landing, low altitude, formation, or air-to-air flight phases.

Test Case 1's TTR was longer than JPATS Case 1 by 3.77 inches, but she missed reaching the landing gear handle by 3.6 inches. The remaining miss distance of 0.14 inches may have been because Test Case 1's SSH was 0.31 inches taller than JPATS Case 1 SSH. The excess of TTR should have compensated for the higher shoulder pivot point, slight excess of SSH, and enabled reaching the parking/emergency brake handle, but there was still a 1.05 inch miss distance. Both of these items were assessed with a locked shoulder harness inertial reel without stretching. If IP technique of seat height adjustment, or DEP was known and attained, reaches would likely have improved. A small person not able to reach some controls, may be a reason why the landing gear and parking brake handles were not listed in PIPFS (3) as Zone 1 requirements, as implied by Mil-Std-1333B (11), and therefore not procedurally required to be reached after locking harness (13). Zone 2, stretching against locked inertial harness reduced the miss distances, but did not provide enough functionality for flight safety. Only unlocking the harness allowed Test Case 1 to reach and simulate lowering landing gear, but full shoulder strap pay-out still didn't enable her to simulate raising the landing handle, from full up seat height, which is a potential flight hazard during a wave off/missed approach. See recommendations for possible TTR modifications to restrictions in reference (9).

Test Case 1's BKL was 0.8 inches shorter than JPATS Case 1. Her BKL was 0.45 inches short of the minimum required and restricted flying the T-6A (9). This restriction is presumed to prevent the knee joint being on/over the ejection seat pan which would create a gap between the distal thigh and the seat (dynamic overshoot injury, seat slap) and or allowing the knee joint to act as a fulcrum and extending the leg which might allow the lower leg or foot to strike the instrument panel or canopy bow during ejection, catapult phase where the seat moves up the guide rails. Test Case 1's potential BKL related hazard did not create a thigh gap or extend the lower leg, since the knee joint was off the seat pan. If her BPL was measured, it would likely have been equal to or longer than the Mk 16USLA seat pan. Additionally, the T-6A shin well provides tremendous clearance from leg or foot striking the instrument panel, which is complimented by the lower leg restraints/garters. See recommendations for possible BKL modifications to reference (9).

Test Case 7 was also not a great match to JPATS Case 7, due to Naval Aviation restrictions (6, 8). Test Case 7 was overall small, so again full up seat height was the initial point, since external OTN

visibility and reach were the primary concerns. Test Case 7 tried multiple seat positions not studied for Test Case 1. Test Case 7's SH, SEH and TTR were shorter than Test Case 1's, but above JPATS Case 7's. Test Case 7 was functionally accommodated in the aft station by less than full up seat heights. When Test Case 7, the second participant was in the front seat, and the 3rd participant was already in the aft seat, Test Case 1 had already departed.

Test Case 7 had reach difficulties similar to Test Case 1 in the front cockpit, even with the seat 1.61 inches down from full up, a lower seat position than for Test Case 1. Test Case 7's miss distance to the landing gear handle with locked shoulder harness inertial reel and not stretching was 0.12 inches more than that of Test Case 1. This unexpected result may be accounted for by the lower SSH, by 0.06 inches, and much shorter TTR, by 1.11 inches. Test Case 7's external FOV, and OTN visibility were similar to Test Case 1's despite the 0.92 inch shorter SEH, and 1.61 inch lowers seat height position. Reaches were not, but should have been, reassessed when Test Case 7's seat height was adjusted at IP technique position; another 1.04 inches lower to 2.65 inches from full up, which was only 0.85 inches above NSRP. Less miss distances for reaches would have been measured, i.e. improved reach capabilities expected.

Test Case 3 was medium build, long limbs. His SH was near the middle of the range to be accommodated, 3.45 inches above the minimum and only 0.5 inches below JPATS Case 3. Test Case 3 was a good JPATS Case 3 match. Yet Test Case 3's helmet was 0.95 inches above the aft canopy breaker, with the seat at IP technique position, 1.12 inches below full up. Test Case 3's SEH was only 0.38 below JPATS Case 3. Although the helmet was sufficiently below the canopy (14), helmet above canopy breaker is considered an unacceptable hazard (1, 5, 6, 9, 11, 13). One and one-half inch has been a subjective tolerance from previous fit checks. It is reasonable to assume that the +Gz during ejection, seat catapult phase, will cause the intervertebral disks to compress, thus shortening overall vertebral column height, i.e. SH. Published quantification has not been seen yet by this author, but slump and submarining have been observed during in ejection seat testing. Test Case 3's BKL was 1 inch shorter than JPATS Case 3 but didn't pose any ejection hazards, thigh gap or cockpit strikes. Test Case 3's TTR was second longest of the Test Cases, and 1 inch longer than JPATS Case 3's. No locked shoulder harness inertial reel without stretching functional reach problems were found for Test Case 3. Over-reach was not estimated for Test Case 3. So, Mil-Std-1333B criteria of Zone 1 reach for an exact JPATS Case 3 remains unknown, but likely achieved. See recommendations regarding SH/helmet-canopy breaker and BKL/thigh gap. In the front cockpit at IP technique for seat adjustment Test Case 3 was fully accommodated: did not have straight reach problems and did not have ejection hazards. Test Case 3 was the first subject to have cross cockpit reach assessed.

Test Case 2 was medium build, short limbs. Test Case 2's SH was only 0.1 inch shorter than JPATS Case 2's, but 1.15 inches taller than Test Case 3's SH. Test Case 2 had similar helmet above canopy breaker hazards as discussed above. Test Case 2's distance above aft canopy breaker was 0.73 inches which was 0.22 inches lower than Test Case 3's height above canopy breaker. This hazard occurred at a seat height 1.47 below full up, which was only 0.35 inches lower than the seat height for Test Case 3. Body or head position may account for some minimal difference but not the full 0.8 inch discrepancy. The average thickness of the HGU-55/P was 1.5 inches (6), but variation does exist (differences in helmet liners). Since both subjects were assessed during the same time period, they did not wear the same helmet, which may account for some helmet above canopy

breaker distance between Test Case 2 and 3. In the front cockpit at IP technique for seat adjustment, Test Case 2 was fully accommodated: he did not have straight forward reach problems and did not have ejection hazards. Test Case 2 was the second and last subject assessed for cross cockpit reaches.

Test Case 6 had the longest limbs of all subjects. SH was 1.77 inches below the maximum to be accommodated (3, 8). Test Case 6's SH was only 0.23 inches above JPATS Case 6, and TTR was only 0.79 above; thus a good JPATS representative for upper body and limbs. But Test Case 6's BKL was 2.27 inches and SKH was 2.36 inches shorter than JPATS Case 6's; thus under representing the lower limb JPATS long limb case. In the aft cockpit, the combined effect of Test Case 6's SH+BKL generated the very large 2.01 inch thigh to seat gap, despite the rudders being full forward. This unexpected thigh gap must have been skewed by SH since BKL was shorter than JPATS Case 6. This hazardous condition occurred at IP technique seat adjustment. Since Test Case's SH was 1.77 inches below maximum, that allowed the seat to be raised to a point where the top of the helmet did not exceed the aft canopy breaker height, but a thigh gap still posed an ejection injury hazard. To eliminate the thigh gap the seat had to be raised so high that the top of the helmet was 1.9 inches above the aft canopy breaker, unacceptable to AETC and NAVAIRSYSCOM (5, 6). This allowed for a fist amount of clearance, just meeting the operational canopy clearance (14). In the front, Test Case 6 attained a safe ejection posture and seat height. Front cockpit canopy curvature provided more clearance than in the aft cockpit, and the taller canopy breaker on the front seat allowed for more seat height adjustment so as to eliminate any thigh gap. But this safer ejection condition was at the expense of slightly reduced internal vision. Although not optimal, this condition was easily corrected by slight slouching forward the trunk, neck, and head - presumed to be a prevalent compensation for taller aircrew. Engineering solution is preferred. Despite Test Case 6's SH, and TTR exceeding those of a true JPATS Case 6, no control stick interference occurred. It was suspected that longer legs would create obstructions to stick range of motion (6). Test Case 6's TC was 3.91 inches less than the JPATS Case 6 maximum, and his CD was 1.2 inches thinner than the JPATS Case 6 maximum. Both of which may explain the added bulk and location did not create any ALSS to control stick interferences.

Test Case 4 had tall SH and short limbs. Test Case 4's SH was 0.25 inches above JPATS Case 4's, but 1.17 shorter than Test Case 5's SH. Test Case 4's SEH was 0.56 inches above JPATS Case 4's, but 1.49 inches shorter than Test Case 5's SEH. Test Case 4's BKL was only 0.13 inches above JPATS Case 4, a close approximation; although his SKH and SSH were a bit higher than JPATS Case 4. Test Case 4's TTR was much longer than JPATS Case 4's, but only 0.9 inches shorter than Test Case 5's TTR. Test Case 4 was not as short limbed as desired, in regards to TTR and SKH. Cockpit reach was not problematic for Test Case 4, as expected. But aft cockpit ejection safety was problematic due to Test Case 4's somewhat longer SKH than JPATS Case 4. Implied was a longer Buttock Leg Length since the rudder pedals were full forward and still allowed for a thigh to seat gap. Eliminating that thigh gap compromised internal vision and drastically reduced helmet to canopy clearance below operationally acceptable limits (14). The top of the helmet was well above the canopy breaker; again unacceptable for AETC and NAVAIRSYSCOM (4, 5). Test Case 4 was better accommodated in the front cockpit in regards to his JPATS Case 4 tall SH, even with slightly longer SKH and BKL than JPATS Case 4. This greater front cockpit accommodation was again due to front canopy curvature being higher above the seat than in the aft cockpit, which provided

greater canopy clearance. More clearance allows for a taller canopy breaker. Taller canopy breaker enables for greater seat height adjustment upward in order to eliminate the thigh gap created by longer legs, or a leg component. But again, eliminating thigh to seat gap by a raised seat reduced internal vision. Despite Test Case 4's SH, BKL and TTR exceeding those of a true JPATS Case 4, no control stick interference occurred. Based on ref. (6) it was suspected that longer legs would create obstructions to stick range of motion. Test Case 6's TC was 2.62 inches less than the JPATS Case 4 maximum. Test Case 4's CD was 1.39 inches thinner than the JPATS Case 4 maximum. Both of which may explain the added bulk and location did not create any ALSS to control stick interferences.

Test Case 5 was the closest to overall large. Test Case 5's SH only 0.08 inches from the JPATS maximum, but SEH was 0.45 inches above JPATS Case 5 SEH. He was a good JPATS Case 5 representative. He was shorter limbed than JPATS Case 5 (BKL, SKH, and TTR), but Test Case 5 was not able to achieve a safe ejection posture in the aft cockpit. Again, probably due to the lower clearance from seat to canopy in the aft station than in the front cockpit (6), also the shorter canopy breaker height limited seat height adjustment range for tall SH. A raised seat eliminated the seat slap hazard potential, but again reduced internal vision, as expected and put his helmet above the aft canopy breaker – AETC and NAVARISYSCOM unacceptable (5, 6, 9). In the front cockpit Test Case 5 was accommodated with regard to ejection safety, but at the greatest internal vision reduction of all subjects. This was not a surprise since Test Case 5's SH and SEH were very close to maximums (2, 9). Test Case 5 was not large in girth: CD was 3.22 thinner, and TC was 6.37 inches less than those for JPATS Case 5. Thus, ALSS did not interfere with control stick range of motion.

Compared/Contrasted to Other Studies

The following mean miss distances to controls while stretching against a locked shoulder harness inertial reel, relative to mean SSH of 21.5 inches were previously determined (6) as follows: Gear Handle 4.0" forward and 3.4" aft cockpit; Control Stick Full Left 3.7" forward and 2.9" aft cockpit; Parking Brake 3.3" forward cockpit; and Emergency Gear Handle: 1.9" forward cockpit. Test Case 1 and 7 miss distances were less than the averages published by Zehner (6). Test Case 1's SSH was 0.59 inches shorter, and Test Case 7's SSH was 0.65 shorter. Thus, both of their miss distances were reasonably expected; near published.

Zehner determined T-6A minimum SEH was 25.0 inches with seat full up without regard to or requiring Zone 1 or Zone 2 reach capability; maximum SH was 41.5 inches; and maximum BKL was 29.0 inches for front canopy bow clearance and 30.0 inches for aft canopy bow clearance, and 27.9 inches for lower instrument panel clearance (6). SEH was a determining factor with Combo Leg (BKL and KSH) for full rudder throw with toe brake application, and with SSH for reaches (6). Seat height adjustment to SEH ratios were also determined to describe their interactions and presumably provide information for operational consideration. For every inch the seat can be lowered from full up, the minimum span required for forward left control stick can be reduced by 0.5 inches.

Test Cases 1 and 7 initially had the seat positioned at full up for maximum external visibility where lots of miss distances were noted for reach Zone 1-3 items and conditions. At least minimum SEH at seat full up, minimum required span for T-6A forward left stick was previously determined to be

60.1 inches (6). Case 7's span was 45.04 inches, 15.06 inches below a functional minimum, which explains her inability to effect forward left stick, as expected for her overall small size. As long as SEH is greater than 25.0 inches, for every 1.0 inch the seat can be lowered from full up the required span for forward left stick can be reduced by 0.5 inches (6). So predictably, adjusting the seat down 1.5 inches from full up for Test Case 7 would have enabled forward left stick, with the right arm. This study somewhat validate this correlation, but overshot the downward seat adjustment by 1.15 inches. Had the seat been lowered by 2.03 inches for Test Case 1, she would have been able to affect full forward stick and possibly reach other controls, not evaluated for her. Predictive dimensional interactive adjustments for other reaches (6) were not published, so other comparisons between studies were not done, e.g. for left hand to landing gear.

Limitations of This Study

True JPATS Case representation was not available; no exact matches on any dimension(s). Active duty naval flight students were not at the extreme JPATS anthropometric Case SH. US Navy aviation policy negates program eligibility for the extreme JPATS Case SH by 1.0 inch. Navy minimum eligible SH is 32.0 inches, and maximum eligible SH is less than 41.00 inches, e.g. 40.999 inches (9). T-6A maximum SH is 41.9 inches for the front seat, and 41.5 inches for the aft seat (6). JPATS anthropometric Case 7 with SH = 31.0 inches and JPATS Case 8 (from Joint Strike Fighter) with SH = 41.0 inches were beyond the minimum and maximum eligible for all Navy type/model/series aircraft with known/determined restrictions (9), although a SH = 41.0 inches is eligible for Air Education and Training Command USAF JPATS T-6A flight program training (1, 6).

Not all JPATS anthropometric Case dimensions for this study's participants were known before selection. No participants had visibly large arm, chest, abdominal, buttock, or thigh circumferences or depths to interfere with control stick full range of motion. No participants were older than 23.

This study did not have a flight clearance for proposed ALSS configuration and, thusly, did not conduct in flight cockpit functional assessments of anthropometrics. Minimum payout and locked shoulder harness in a +1 Gz, on deck, near level attitude, restricted the subjects as far away from lower cockpit items controls as possible, but during flight dynamics of less than +1 Gz, unknown restraint slack is experienced and allows the occupant some limited travel even farther away from lower cockpit items.

Proposed ALSS has more bulk than current configuration, and therefore was expected to restrict or interfere with functional reaches. It did not; and, no more so than in other cockpits using the PCU-56/P//CMU-36/P//LPU-36/P configuration, i.e. T-34C, T-45A/C, FA-18A-F (15), EA-6B, and AV-8B. The benefits of nearing a more standardized ALSS configuration from trainer to fleet aircraft, with more water and land survival items, out weighs the potential risks of PCU-56/CMU-36/LPU-36 interferences of the T-6A anthropometric accommodation ranges.

Placement of the CRU-60 on the right side of the aircrew emulates the current T-6A ALSS configuration (14) due to the placement of the aircraft oxygen hose. No test Case participant had previous military ALSS experience. Therefore, they were unaware that CRU-60/P location on the right side of the body might interfere with some cockpit reaches; specifically a snag hazard during cross body reach and was, e.g. right arm to the left for full left and forward control stick.

This interference was not evident until the TW-5 AMSO, with over 1,000 T-45 instructor hours and previous PCU-56/SV-2/LPU-28 and PCU-56/CMU-36/LPU-36 flight experience, donned the proposed instructor and the proposed student ALSS configuration in both front and aft crew stations. Operationally, the control stick is grasped by the right hand, even for left hand dominant aircrew; so right hand release and transfer of the control stick to the left hand, and then extending the right arm across the body and right hand to left side cockpit items such as landing gear handle is unlikely.²

The main instruments panel lower sections have cut outs. These shin wells seem to ingeniously provide more leg clearance during normal, egress, and escape/ejection than MIL-STD-1333B recommend, 1.5 inches. No participant of this study had any leg clearances issues at any rudder pedal placement. Since the ejection seat was not raised up the rails, leg clearance to canopy bow was not assessed, as it was in the USAF WP study (6).

Joint Services Specification Guidelines (4) are not referenced in the JPATS T-6A requirements, probably because the JSSG was being compiled and developed concurrently or post facto. But the JSSG 2010-3 (4) Crew Systems reference MIL-STD-850B (12) for DEP and MIL-STD-1333B (11) for Crew Station Geometry. Both documents have existed for many decades and provide specifics not incorporated in the JPATS T-6A. Other specification documents not referenced are MIL-S-18471 and MIL-A-81815 for ejection seats, and MIL-S-81771 for adjustable seats.

DEP is the single reference point for anthropometric accommodation. DEP is the midpoint of the DEL, the spectrum of the SEH to be accommodated (11, 12). Additionally, MIL-STD-1787C paragraph 3.2.3 defines DEP as “The aircraft cockpit reference point used to calculate internal and external vision angles and construct aircrew station geometry. It should be based on the sitting eye height of the 50th percentile aircrew member, allowing for posture, slouch, with the seat in the neutral seat position that permits the required internal and external vision. In some aircraft, pilots do not sit at the eye position in order to maximize external vision; therefore, correct positioning of the design eye is an important consideration in the cockpit development.” DEP is not yet known for the Hawker-Beechcraft T-6A Texan II. But DEP has been determined for the Beechcraft T-34C Mentor. NAVAIRSYSCOM relied upon USAF accommodation verification and validation (8). The USAF Wright-Patterson cockpit accommodation study reported the minimum and maximum critical anthropometric dimensions for many aircraft without using or determining DEP (6). An operationally relevant work-around was used on deck to assess external visibility flight requirements (2, 5): the propeller spinner was to be visible (6). This OTN spinner visibility condition was assessed from the subject’s chosen seat height position, assumedly with sufficient Zone 1 and Zone 2 reach conditions meet, but not from the DEP. Case 7 SEH was required to meet Zone 1 and Zone 2 items reaches as defined (4) which are not the same as defined elsewhere (10, 11).

² After the 23/24 July 2007 cockpit ALSS modification evaluations, discussions determined that the CRU-60/P interference was due to it not being attached to the PCU-56/P and/or the integrated PCU-56/P//CMU-36/P. While writing this technical report, TW-5 and TW-6 AMSOs with NAWCAD PAX resolved the snag hazards by using a CRU-103/P pocket for housing and attaching the CRU-60/P. A CRU-60/P pocket is the recommended and approved TIMS action for the Navy ALSS configuration.

DEP and DEL are important data to aircrew accommodation within a cockpit for functional fit checks as well as for ground and flight operations. For Human-Systems-Integration (HIS), also known as Human Factors Engineering in the U.S. and as Ergonomics in the U.K., optimal human-vehicle-mission performance in all mediums (formerly known as man-machine-mission-medium) is the goal. DEP is the standardized reference point which should be a position known by aircrew, where it is and how to achieve it, at least as a reference point from which to start seat location or postural deviations and/or return to.

Table 2 Aircraft DEP and NSRP

Priority	Aircraft	Crew Position	Design Eye Point (DEP)			Neutral Seat Reference Point NSRP		
			Fuselage Station (FS) inches	Waterline (WL) inches	Buttock Line (BL) inches	Fuselage Station (FS) inches	Waterline (WL) inches	Buttock Line (BL) inches
01	T-6A	Forward	?	?	0.00	?	?	0.00
01	T-6A	Aft	?	?	0.00	?	?	0.00
05	T-34C	Forward	87.65	125.60	0.00	93.75	94.60	0.00
05	T-34C	Aft	138.65	125.60	0.00	144.75	94.60	0.00

Aircrew do not sit in an “anthropometric sitting position” while flying in the airplane as they do during SEH measuring. Forward and downward head positioning or slouch whether physical or mentally fatigue, seat angle, or discomfort, or just poor posture, is difficult to measure in amount and degree of primary and secondary vertebral curvatures. Head tilt and neck/back slouch are additional multivariate interactions confounding a suspected eye position. Further difficulties accounting for slouch is that slouch reportedly changes throughout phases of flight, and adjusting seat heights is compensation method. Thus, any assumed posture and eye position not at DEP is a non-standard, subjective, variable, and relative position that should not be used for design or cockpit functional accommodation assessments, verification, or validation. An “alert” body posture for flight threat vigilance and mission success must be a sustainable posture and eye position, not degraded by fatigue. DEP, the maximal vision and reach origin, is the box of eye positions for the full range of the accommodated anthropometrics. A separate head forward, helmet not against the head box, “alert” eye position can be reverse engineered to become the ADEP, if different from the DEP. DEP does not mandate head full aft against the aircraft or seat head support. So DEP may functionally be ADEP.

For Heads Up Display (HUD) incorporation, aircraft DEP is essential. MIL-STD-1787C for HUDs, paragraph, 3.2.4, specifies a Design Eye Box which is “The three-dimensional area surrounding the design eye position which defines the area from which the HUD symbology performance parameters are defined.”

Reach assessments requirements were confusing and still contradictory. USAF WP accommodation assessment of the JPATS T-6A used cockpit controls/items for Zone 1 and 2 reach and operate conditions listed in the JPATS T-6A PIPFS were purportedly determined by AETC panel of experts (6). But these cockpit controls/items and reach for functional reach and actuation are not the same as those implied in MIL-STD-1333B (11) as well as those specified by NAVAIRSYSCOM (5).

MIL-STD-1333B (11) paragraph 4.5.1.2 defines the military standard of Zone 1 as “Restraint

Harness Locked - Functional Reach. This zone includes the area that can be functionally reached and actuated by any crewmember...when located at the appropriate DEP fully restrained and equipped without stretch of arm or shoulder muscles. Controls placed in this zone shall include those frequently used during operation of the aircraft in flight phases which require full restraint. This would include such flight phases as takeoff, landing, low altitude-high-speed flight, weapons delivery, and escape. This zone defines the maximal limit allowed for the placement of emergency (escape system) controls and establishes the forward most operation limit of primary flight and propulsion controls.” Zone 2 as “Restraint Harness Locked - Maximum Functional Reach. MIL-STD (11) Zone 2 has the same leading sentence as zone 1 above, but reach and actuation with “maximal stretch of shoulder and arm muscles....and then later ‘defines the maximum limit allowed for the placement of emergency controls other than escape controls.”

T-6A PIPFS (3) Table 5A and AL-TR-1993-0054 (6) Table 5.1 define neutral positions of the control stick, rudder pedals and PCL as Zone 1. PIPFS (3) Table 5B and AL-TR-1993-0054 (6) Table 5.1 define full operational range of the control stick, rudder pedals, and PCL as Zone 2. These seem to be reversed, thus incorrect, when compared/contrasted to the MIL-STD (11). The maximum allowed placement for the control stick and the PCL, thus maximum range of motion while grasped, for the T-6A may not meet the guidelines shown in the MIL-STD-1333B figures (11). T-6A PCL placement may account for the miss distances found in this study for Test Cases 1 and 7 as well as previously reported (6).

PIPFS Zone 1 and 2 reach items and conditions may be more operationally relevant (3). The list was purportedly developed by AETC experts, assumed to be operators, e.g. pilots. The flight manual supports the assumption of operationally relevant control reaches: a locked shoulder harness is not required for take-offs, landings, or low altitude-high speed flight; no reach and actuate function is specified after harness locked just before ditching or crash landing, assuming the harness can and will be unlocked for egress. After ditching or crash landing the harness locking mechanism may fail in a locked position, thereby requiring reach and actuation to other cockpit items such as full rudder and toe brake, parking brake handle, securing the engine via PCL, and emergency ground egress controls (e.g. canopy release lever) – all erroneously listed in PIPFS as Zone 2 not Zone 1. A locked harness is only required for aerobatics. But during aerobatics OTN external visibility is important, and full rudder and full forward left stick (erroneously listed in PIPFS as Zone 2) are required for spin recovery, with shoulder harness locked, and possibly under less than +1 Gz. A shoulder harness locking mechanism may fail in a fully retracted and locked position during flight, thus making it necessary to reach and actuate the full operational control range movements of all flight, propulsion, landing, stopping, and possibly egress controls with that locked harness condition. Design requirements, e.g. placement of the throttles and stick, at the MIL-STD-1333B level would have met the safer functional requirements during worst case scenarios as well as operational requirements during aerobatic maneuvers (11).

T-6A PIPFS paragraph 4.3.3.7.3.1 specifies allowing proper body posture for ejection (3). Thigh gap tended to be problematic. The participant approximating Case 4, tall sitting height/short limbs, had a BKL 1.3 inches longer than a true Case 4. This longer BKL may account for his 0.65 / 1.10 inch thigh gap while seated at instructor pilot technique for visibility, front and aft cockpit respectively. But the rudder pedals were adjusted full forward. Adjusting seat position upward from NSRP to eliminate the thigh gap in the aft cockpit put his helmet 2.7 inches above the canopy

breaker, but fortunately remained below a closed canopy. He was a more operational population representative. Oddly, the same situation was created and mitigated for the participant approximating Case 5, overall large. His BKL was 2.5 inches shorter than a true Case 5. At instructor pilot technique for visibility seat placement, he had 1.22 inch thigh gap, and his helmet was 0.87 inches above the aft canopy breaker. Adjusting the seat to NSRP eliminated the thigh gap. In the front seat a 1.71 inch thigh gap was eliminated by lowering the seat 4.21 inches from the full up, 0.71 inches below NSRP. Both cases demonstrate the complexity of body dimensions, seat adjustments in just one plane and how they affect other accommodation, function, and safety; truly multivariate interactions are at work.

The curvature of the canopy improves the ejection safety of aircrew. Both crew stations had sufficient helmet to canopy distance for all Test Cases, on deck. This safety margin may not hold true while the aircraft is less than +1Gz. Canopy breakers are to strike the canopy first in order to eliminate helmet-canopy strikes prior to canopy breaker penetration of the canopy if the Canopy Fracture System (CFS) detonation were to fail. With regards to aircraft design fuselage station coordinates, the canopy breakers are located behind the occupant's helmet. The breaker provides an initial stress point. The distance from that stress point to the occupant's helmet is assumed to be short enough for sufficient propagation of fracture lines above the occupant's helmet and body, in order to reduce injuries from impacting the canopy (i.e. vertebral body compression fractures, and/or spinal cord impingements) and/or from shearing across the remaining shards (i.e. lacerations). Helmet heights exceeding the canopy breaker was and is unacceptable by AETC and NAVAIRSYSCOM (6, 9).

Conclusions

1. ORD (2) and PIPFS (3) disregarded, e.g. did not reference, MIL-STDs (11, 12), Joint Services Specifications Guides (4), other MIL-Specifications or DoD Handbooks with regard to DEP, crew systems, and crew station geometry. DEP and NSRP remain undetermined.
2. Assuming a standard mean differential between SH and SEH works half of the time (5,13). Calculating SEH this way validates that the approximation formula applies to the mean (50th percentile) SH of a standard distribution curve, but not to all individuals (the other 50%).
3. Seat height, travel distance and lower and upper stop points along the guide rails, may not be standardized between. Previously determined seat travel in UWARS TR (10) was not equal to those found in this study, or between front and aft crew stations ejection seats in this study. There may be intra-aircraft as well as inter-aircraft variation of seat travel distances and locations (min and max stops along the rails).
4. Using the propeller spinner, specific point unknown, as a marker to approximate the 7.5 degrees downward OTN visibility may be more precise than counting/measuring steps away from the aircraft that feet can be seen by the front seat occupant. But the -7.5 ° was created in flight by an unspecified SEH occupant at an unspecified seat position, presumably in conjunction with ORD (2)/PIPFS (3) Zone 1-3 reach items and conditions, but not at MIL-STD-850 DEP (12) and not at MIL-STD-1333 (11) reach and actuate Zone 1 control conditions.
5. The T-6A may not accommodate the entire population required per ORD (2), much less the Under Secretary of Acquisitions and U.S. Congressional mandate/intent (1), and those stated in the PIPFS (3) that it shall {does} accommodate Cases 1-7.
 - a. Not all Test Cases could simultaneously be seated high enough for the OTN external vision required, yet have full internal visibility of all forward displays, instruments, switches, buttons, knobs, handles, etc.; have full operational function/range of motion of the military standards normal flight and the NAVAIR time-critical emergency controls with a locked harness, stretching or not; have full rudder operational throw; have no gap between thigh and seat pan; have no cockpit strike hazards; and be below the canopy breaker.
 - b. Case 7 is alleged to be an accommodation goal, not a requirement, but this less stringent accommodation is not specified in the PIPFS. Thus, JPATS Case 7 is to be accommodated in the T-6A as well as in the T-6AUP, unless the T-6AUP ORD (2) and PIPFS (3) specified this accommodation exemption.
 - c. Test Cases 1 and 7 could not reach and actuate all cockpit controls under MIL-STD 1333B (11) Zone 1 or Zone 2, with seat full up. Test Cases 1 and 7 could not functionally reach and simulate raising landing gear handle. Test Case 7 could not achieve forward left stick. Reaches improved and miss distances decreased, by lower seat positions, but at the expense of OTN.
 - d. Full forward rudder pedal placement was not far enough forward for long legged Test Cases. Test Cases 3 - 6, where SH was greater than 35.6 inches and BKL was greater than 24 inches,

induced thigh gap, a hazardous ejection condition, thus violating PIPFS (3) paragraphs 3.3.7.1 and 4.3.3.7.3.1, "...allow proper body position before [for] {safe} ejection".

1) Long BKL, more specifically long BLL or Combo Leg, contributes to seat-slap hazard potential. Test Case 5's tall SH of 39.92 inches, which is less than the maximum of 41.5 inches (6) and maximum of 40.99 inches (9), placed the helmet above the canopy breaker in order to eliminate a thigh-set gap, dynamic overshoot/seat-slap ejection injury hazard.

6. Front cockpit seemed safer with regard to canopy clearance during ejection at or near +1Gz conditions, when contrasted to the aft cockpit.

a. Canopy curvature, height above the seat in the front cockpit is greater than the canopy height above the seat in the aft cockpit. This is visually obvious.

b. Additionally, the front seat canopy breaker is higher than that of the breaker on the aft seat, which contributes to greater SH accommodation in the front cockpit (SH up to 41.9 inches) than in the aft cockpit (SH up 41.5 inches) as previously determined with seat full down (AL-TR-1993-0054). Service and command policies require the helmet not to exceed canopy breaker's height until further evidence can quantify an allowable distance for each seat and crew station relative to canopy curvatures, in accordance with PIPFS paragraphs 3.3.7.1 and 4.3.3.7.3.1, "...allow proper body position before [for] {safe} ejection".

7. T-6A leg clearance, rudder pedal adjustment, and throttle location functionally accommodated Test Cases the 1-7. These conclusions were comparable to previous findings.

8. Proposed student ALSS configuration was not any worse than current configuration.

9. Placement of the CRU-60/P on the right side of the non-integrated PCU-56/P and survival vest CMU-36/P and/or on the right side of the parachute harness PCU-56/P integrated with CMU-36/P survival item pockets, was a snag hazard during right arm range of motion. In forward and left direction, it inhibited some non-required cross-cockpit reaches with locked inertial reel and harness restraint system (Zones 1 and 2). This snag hazard was due to non-attachment and has been resolved by use of an attaching pocket for the CRU-60/P. See foot note 2.

Recommendations

1. Directly measure SEH rather than applying a mean differential calculation, since SEH (5, 9) and DEP (4, 11, 12) are discriminating accommodation factors.
2. Directly measure BPL for ejection posture safety (5).
3. Determine if T-6A seat height travel distances are standardized between front and aft cockpits of same aircraft and between aircraft: e.g. determine if there is intra-aircraft and/or inter-aircraft seat travel distance variance (10).

4. Overhead Clearance. Determine maximum safe helmet height allowing canopy breaker penetration prior to helmet to canopy strike for both cockpits (3, 5, 6, 9, 11, 12, 14). This must be relative to closed canopy curvature above each seat, occupant helmet potential impact point and aft of that point where the canopy breakers penetrate. This information will be helpful for operations and fit checks. In other words, determine how far above the front seat canopy breaker may an occupant's helmet be? Same for aft seat. If these distances are determined then modify the below statements with those acceptable distances. If not, then provide the following statements for more informed aircrew risk decision making (acceptance and/or mitigation), safety hazard awareness.

a. Replace canopy clearance determination by aircrew's fist in the Flight Manual (14) and Student Guide with "Top of the helmet shall be at or below the canopy breaker. Without parallax, the Plane Captain or other crewmember should visually confirm helmet height not exceeding canopy breaker height. This seat height position should be noted and not exceeded prior to ejection." Add the following statements to the Controlled Ejection Emergency Procedures. "If time permits lower the seat to previously noted seat height position where the top of the helmet is below the canopy breaker." "Ensure thigh to seat gap is also eliminated prior to ejection." "Warning. Death or serious injury may result if helmet strikes the canopy prior to canopy breaker. Severe neck injury may result." "Warning. Severe leg injury may result from dynamic overshoot acceleration if a gap exists between thigh and seat." "Note. Less than +1Gz ejection seat testing with failed Canopy Fracture System has not been conducted."

5. Determine T-6A, and T-6AUP, DEP and NSRP from design drawings, blue print or computer based. Provide aircrew formal procedures to achieve DEP. Replace or validate the technique for visually aligning the edge of the main instrument panel anti-glare shield with the top portion of the ADI. Add this procedure to Student Guide and Flight Manual preflight procedures (14).

a. The portions of instrumentation or displayed information not seen by eyes positioned high in the cockpit for improved external visibility could be repeater displayed on a HUD.

1) HUD DEP should be at the aircraft DEP, as determined by engineering drawings. HUD should be visible from the full range of SEH while the occupant is in a safe ejection position and have necessary reaches. Cockpit verification should be done across Case 1-8 ranges of all dimensions, including thickness/circumferences. Additionally, the HUD Up Front Control Panel above the main instrument panel should be positioned so the lower edge does not obstruct a high

eye height internal visual line to the upper portions top row of instruments and displays, but aft enough to be reached and operated.

6. Conduct formal multivariate anthropometric accommodation assessment, verification/validation, of JPATS Cases 1-8 using DEL, DEP and NSRP. Ensure testers and subjects understand MIL-STD-850B (12), MIL-STD-1333B (11) concepts for functional importance and relevance, as well as their differences from JPATS/T-6A ORD (2) and PIPFS (3).

a. Evaluate anthropometric extremes of thickness, i.e. include subjects with large arm, chest, abdominal, buttock, or thigh circumferences in each Case. Include and/or represent the instructor pilot population. Select some subjects of each Case of older ages, i.e. 25 through 50.

b. Specify more or at least clarify Zone 1, 2, and 3 controls, handles, levers, switches, buttons, knobs, etc., including PCL cut-off gate, PMU, UHF STBY, and cross cockpit reaches. Eliminate disparity between MIL-STD-1333B (11), JPATS T-6A ORD (2) and PIPFS (3). ORD and PIPFS Zone 1 and Zone 2 reaches seem to be operationally irrelevant. Normal and emergency T-6A flight manual procedures following a locked inertial reel/shoulder harness do not require ORD or PIPFS Zone 1 or Zone 2 reaches (14), but the MIL-STD does.

c. Further assess and refine T-6A TTR minimum. The TTR minimums could be increased, probably by 2 inches, affecting Cases 1, 2, and 7. This amount would make the “new/replacement” Joint Service primary trainer the same as the “old” Navy primary trainer, the T-34C, and be consistent with follow-on training and fleet aircraft with regard to TTR requirements NAVAIRINST 3710.9 series (9). Modify control stick with a telescoping handle³. This will improve control stick through full range of motion capability for short arm (TTR) and/or tall (SH, SSH) aircrew.

d. Improve the aircrew reach and sitting height capabilities through cockpit ergonomic changes. Ejection testing would be needed to ensure seat/occupant system stability, due to the forward Center of Gravity shift of the occupant relative to the seat. Test data can be leveraged from other Martin Baker America (MBA), Naval Air Warfare Center (NAWC), and Wright-Patterson (WP) seat pad tests already conducted.

1) Incorporate an adjustable back rest similar to the post production SJU-17A, Naval Aviation Common Ejection System (NACES) Pre-Planned-Product Improvement (P³I) capability, block one upgrade. See FA-18 (15) and T-45 flight manuals.

2) Allow for ergonomically prescribed personal seat (buttock and/or back) pads as done at TW-5 for TH-57 aircrew, as well as for rotary wing and fixed wing ejection seat United Kingdom aircrew⁴.

³ The Lockheed S-3B has telescoping control sticks for emergency flight control systems procedures. The adjustable height provides a longer lever arm for more mechanical advantage to move flight control surfaces when hydraulic system pressure assist is not available. See S-3B NATOPS Flight Manual, NAVAIR A1-S3NFM-001.

⁴ Since 1973, British aircrew with lower backache have been personally issued Institute of Aviation Medicine Type Aircrew Lumbar Supports “which has proven of considerable benefit in reducing the incidence of backache or eliminating it altogether.” Winfield. *Aircrew Lumbar Supports: An Update*. Aviation, Space and Environmental Medicine. Vol. 70, No. 4. Apr 1997.

Either method can position the occupant forward and improve both reach and OTN external FOV for the smaller (short SH, SHE, SSH) and/or short upper (TTR) and lower (BKP, SKH, BLL) limbed aircrew, without drastically reducing internal vision.

3) Modify or replace the ejection seat to allow four-way adjustment (fore, aft, up, down).

e. Further assess and refine T-6A BKL minimum. Rudder travel aft in the T-6A is sufficient for small, and short lower limbed aircrew,;therefore, the BKL minimum could be reduced by 0.5 or up to 1.0 inch. Buttock-Popliteal Length (BPL) equivalent to the ejection seat pan length should be the appropriate dimension for determining minimum safe leg length so as not to have the knee joint over the seat pan, creating a distal thigh (popliteal fossa) to seat gap, or extending of the lower leg (shank). Ejection testing would be needed to ensure occupant lower limb safety (i.e. no seat slap, or instrument panel strike, other cockpit strikes, or canopy bow strikes). Test data can be leveraged from other MBA, NAWC, and WP seat tests already conducted.

7. Reassess accommodation of Test Case 1 using IP technique for seat height adjustment, NSRP, where full functional reach is attainable, and full down front and aft cockpits, and determine external FOV OTN for front station.

a. Determine Test Case 1's fit assessments not equivalent to test methods used for Test Case 7. Specifically determine Test Case 1's accommodation with the seat less than full up, and miss distance to canopy opening handle without stretching against a locked shoulder harness inertial reel.

8. Accommodate longer legged aircrew. Move the rudder pedal forward stop point farther forward. Forward placement will reduce or eliminate thigh-seat gap during no rudder deflection, i.e. proper ejection posture, condition without having to adjust the seat, i.e. unprepared, immediate, urgent ejection situation.

9. Accommodate shorter legged aircrew. Move the rudder pedal aft stop point farther aft. Aft placement will improve full rudder throw for shorter legged aircrew with associated short SH, SEH, and SSH, who have to position the seat higher for improved external vision, especially OTN.

10. Study T-6A accommodation by using a Link Model multivariate analysis: eye height/position, shoulder height/pivot point, elbow, wrist, finger tip, buttock/hip, knee, and ankle pivot points, MIL-STD-1333B (11). Physical models and/or computer modeling this way could even determine DEL, thus DEP from the given dimensional ranges required for anthropometrical accommodation, even for the future Case 7 and Case 8 accommodation.

11. All occupants shall be able to reach all operational controls, reach all controls required with a locked harness inertial reel, not have any internal visual obstructions, have at least the minimally required OTN and external FOV for all missions/flight phases, and proper ejection body posture, all without having to adjust the seat or rudder pedals.

12. Relocate the human mounted oxygen regulator to a more central or left side area. This would standardize oxygen equipment location across Naval aircraft platforms, even consistent with Chemical-Biological-Radiological Defense flight gear configuration where the oxygen canisters,

pusher fan, regulator, selection/connector valve, and aircraft hose connection are located. The CMU-36, which is a Tri-Service survival vest, for other Naval aircraft (e.g. T-4, FA-18, EA-6B, Av-8B) as well as on the integrated torso/survival pockets (Navy specific) have the regulators on the left side since the ejection seat pan emergency oxygen (SJU series) and aircraft oxygen supply connectors are on the left side. Snag hazard discovered on 23 Jul 2007 has been resolved. See foot note 2.

13. Conduct tests in flight for operational functionality and safety of proposed Navy ALSS T-6 configurations above and below +1Gz for entire anthropometric Case spectrum.

14. Include T-6A ALSS configuration section into flight equipment configuration manual, NAVAIR 13-1-6.7-1.

15. Continue with proposed Navy ALSS configurations for both student and IP, with CRU-60/P pocket.

16. Recommendation for this study:

a. Reprioritize dimensions for JPATS Case matching in a manner more functional. SEH (it all starts with DEP for vision and reach), then SSH and TTR (for arm reaches), then SH (for overhead clearance: canopy {curvature} and canopy breaker), then BLL (for pedal reach and thigh-seat gap), then BPL (for knee joint position), SKH (for thigh-seat gap and pedal reach). This may help for further ad hoc analysis of this study's data as well as set a better precedent for future accommodation studies. Note: JPATS Case descriptive nomenclature priorities of body size by HT{SH}/build, and then by limb length {TTR and BKL}.

b. Re-evaluate Test Case 1 in both cockpits at various seat heights using same methods for Test Case 7 in the front cockpit and all other Test Cases in both cockpits: seat height adjustment technique for vision.

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Appendix A

T-6A Aviation Life Support System Configurations
Technical Interchange Meeting (TIM) #1

Current Student ALSS	Proposed Student ALSS	Proposed Instructor Pilot ALSS
HGU-53/P and HGU-55/P Flyer's Helmet	HGU-68/P Flyer's Helmet	HGU-68/P Flyer's Helmet
U-93A/U Communication Plug and Communications Cord (Oxygen Mask to Helmet Junction)	Communications Cord (Oxygen Mask to Helmet Junction)	Communications Cord (Oxygen Mask to Helmet Junction)
Neutral Lens Tracked Visor or Neutral Lens Bungee Visor (Both Trimmed for the MBU-12/P Oxygen Mask)	Neutral Lens Tracked Visor or Neutral Lens Bungee Visor (Both Trimmed for the MBU-23(V)9/P Oxygen Mask)	Neutral Lens Tracked Visor or Neutral Lens Bungee Visor (Both Trimmed for the MBU-23(V)9/P Oxygen Mask)
MBU-12/P Oxygen Mask	MBU-23(V)9/P Oxygen Mask Assembly	MBU-23(V)9/P Oxygen Mask Assembly
CRU-60/P Oxygen Connector	CRU-60/P Oxygen Connector	CRU-60/P Oxygen Connector
	CRU-60/P Mounting Plate Assembly with CRU-60/P Cover Pocket (Attached to the CMU-36/P AIRSAVE Survival Vest Via a Webbing Panel)	CRU-60/P Mounting Plate Assembly with CRU-60/P Cover Pocket (Attached to the Integrated PCU-56/P Torso Harness)
Male UWARS Upper Fitting [2 Each]	Male JWARS Navy Buckle Sub-Assembly - OR- Male Navy Generation 1 Upper Koch Fitting [2 Each]	Male Joint Water Activated Release System (JWARS) Navy Buckle Sub-Assembly -OR- Male Navy Generation 1 Upper Koch Fitting [2 Each]
Male Lower Fitting [2 Each]	Male Navy Generation 1 Lower Mini-Koch Fitting [2 Each]	Male Navy Generation 1 Lower Mini-Koch Fitting [2 Each]
PCU-15A/P and PCU-16A/P with Oxygen Connector Mounting Bracket	Non-Integrated PCU-56/P Torso Harness	Integrated PCU-56/P Torso Harness with Survival Items:
	CMU-36/P AIRSAVE Survival Vest with Survival Items:	
LPU-9/P Automatic Life Preserver	LPU-36/P Low Profile Flotation Collar -OR- LPU-23/P Flotation Collar Variant	LPU-36/P Low Profile Flotation Collar -OR- LPU-23/P Flotation Collar Variant
	AN/PRC-90-2 or AN/PRC-149 Survival Radio	AN/PRC-90-2 or AN/PRC-149 Survival Radio
	Mini Maglite AA Flashlight	Mini Maglite AA Flashlight
	MC-1 Hook and Snap Blade Knife -OR- Hook Blade Knife and Survival Knife and Sheath	MC-1 Hook and Snap Blade Knife
	MK-124 Mod 0 Marine Smoke and Illumination Signal	MK-124 Mod 0 Marine Smoke and Illumination Signal
	MK-79 Mod 2 Personnel Distress Signal Kit (Pencil Flares)	MK-79 Mod 2 Personnel Distress Signal Kit (Pencil Flares)
	Four-Ounce Emergency Drinking Water Supply Bottle	Four-Ounce Emergency Drinking Water Supply Bottle
	Four-Ounce Drinking Water Bag [2 Each]	
	2" X 3" Emergency Signaling Mirror	2" X 3" Emergency Signaling Mirror
	SDU-39/N Distress Marker Light	SDU-39/N Distress Marker Light
	Classic Fox 40 Signaling Whistle	Classic Fox 40 Signaling Whistle
	Sea Dye Marker	Sea Dye Marker (Stowage Method TBD)
	Magnetic Wrist Compass	
	Ground/Air Emergency Code Card	
	Cyalume S.O.S. Light (Green)	
	Leatherman Wave Survival Tool	
	SRU-31/P Packet 2 – General:	
	Instruction Card	
	Fire Starter	
	Wrist Compass	
	One-Quart Water Bag	
	Surgical Razor	
	Fishing Kit	

	Camouflage Face Paint [1 Black Tube and 1 Brown Tube]	
	Flexible Saw	
	Tourniquet	
CWU-27/P Flyer's Summer Coveralls	CWU-27/P Flyer's Summer Coveralls	CWU-27/P Flyer's Summer Coveralls
GS/FRP-2 Flyer's Gloves	GS/FRP-2 Flyer's Gloves	GS/FRP-2 Flyer's Gloves
CSU-13B/P Anti-G Garment	CSU-13B/P Anti-G Garment	CSU-13B/P Anti-G Garment
A-A-59530 Aircrew Safety Boots	A-A-59530 Aircrew Safety Boots	A-A-59530 Aircrew Safety Boots

Proposed Mk. US16LB Ejection Seat Navy Survival Kit Unit Items
[2 Each] Female JWARS Release Assembly -OR- Female Navy Generation 1 Upper Koch Fitting with the Seawater Activated Release System (SEAWARS)
Female Navy Generation 1 Lower Mini-Koch Fitting [2 Each]
Four-Ounce Drinking Water Bag [2 Each]
Nylon Cord (MIL-C-5040 Type 1) [50 Feet]
MK-124 Mod 0 Marine Smoke and Illumination Signal
Bailing Sponge, Type 2, Class 2
Cyalume S.O.S. Light (Green)
Orange Signal Panel Blanket with Instructions
AN/URT-140 Radio Beacon Set
Single-Ply, Orange LRU-23/P Life Raft with a FLU-6/P Inflation Device
SRU-31/P Packet 1 – Medical:
Instruction Card
Toilet Soap
Gauze Bandage (2 Inch X 6 Yards)
Surgical Tape (1/2 Inch X 10 Yards)
Camouflaged Compress Bandage (4 X 4 Inches)
Adhesive Bandage (3/4 Inches X 3 Inches) [6 Each]
Sunsect Sunscreen and Insect Repellent (0.3-Fluid-Ounce Packets) [3 Each]
Iodine Water Purification Tablets [50 Tab Bottle] -OR- Chlorine Water Purification Tablets [10 Tab Strip]
Anti-Chap Lipstick Tube
Adhesive Surgical Skin Closures (1/4 Inch X 3 Inch) [12 Each]
Rescue/Signal/Medical Instruction Panel from NAVAIR 13-1-6.5 Manual
Moleskin Surgical Adhesive Tape (4 X 5 Inches)
Blistex Burn Cream (1/8 Ounce) [2 Each]

- The CRU-60/P cover will also prevent the aircrew's forearm from rubbing the top of the CRU-60/P oxygen connector when the aircraft's flight control stick is moved.
- NAVAIR 13-1-6.3-2 Update – Navy-specific PSP configuration
- Additional standard and emergency oxygen hose disconnect tests might have to be performed if the CRU-60/P is placed on the lower right hand side of the torso harness and survival vest. This mounting location introduces a small amount of additional slack in the hoses, and additional disconnect tests might have to be performed to verify that the additional slack does not degrade hose separation from the CRU-60/P during the ejection. Additional windblast and ejection testing will be required if the CRU-60 oxygen regulator is located more centrally or on the right hand side, and if replaced by CRU-103.
- AN/PRC-90-2 radios may be replaced with AN/PRC-149 radios.
- The T-6 Avionics Upgrade Program (AUP) aircraft will have Navy-specific Naval Air Training and Operating Procedures Standardization (NATOPS) Flight Manuals.
- TW-5 T-34 aircrew do not wear anti-exposure coveralls, so the expansion panel for the CMU-36/P AIRSAVE will not be required for the Navy ALSS configuration for TW-5 T-6AUP aircrew. IPs with large chest and/or abdominal circumferences who already have water immersion/anti-exposure CWU clothing will not likely wear it if student if not afforded to students. Since CNATRA is not required and does not issue anti-exposure clothing to flight students the risk is managed by operationally placed flight limitations.
- The Navy T-6AUP anthropomorphic accommodation study with TMS ALSS configurations will be performed in January 2008 at Hawker Beechcraft Company, Wichita, Kansas.

Appendix B

Subject Information Sheet

23 Jul 2007

Naval Aviation Schools Command anthropometric support for Training Air Wing SIX flight gear modification T-6A functional cockpit evaluations.

The following personnel have anthropometric dimensions near Joint Primary Aviation Training System population cases 1-7. Proximity to a JPATS Case is only approximate by Sitting Height, by Buttock-Knee Length, and then by Thumb Tip Reach. Other JPATS case dimensions' proximity have not been determined. You get to sit and play in a T-6A (as directed) – good deal.

Who: List of name, service, rank, and JPATS anthropometric Case for Recall (participant recruiting)

Names are blanked for this paper to personal identification information

Name	Case	Name	Case	Name	Case
USN ENS	1 or 7	USN ENS	3-	USMC 2 nd Lt	3+
USN ENS	1	USN ENS	2++	USMC 2 nd Lt	2+
USN ENS	1 or 7+	USN ENS	6-	USMC 2 nd Lt	2+
USN ENS	7+	USN ENS	6-	USMC 2 nd Lt	6-
USN ENS	3+	USN ENS	6-	USMC 2 nd Lt	6-
USN ENS	3+	USN ENS	6+	USMC 2 nd Lt	6-
USN ENS	2+	USN ENS	6	USMC 2 nd Lt	4++
USN ENS	2+	USN ENS	6-	USMC 2 nd Lt	6-
USN ENS	2+	USN ENS	5-	USMC 2 nd Lt	4+
USN ENS	5-	Volunteer USN ENS	4-	USMC 2 nd Lt	6-
USAF2 nd Lt	6-	Volunteer USN ENS	6+	USMC 2 nd Lt	4+
USN ENS	4+	Volunteer USN ENS	4+	USMC 2 nd Lt	4+
USN ENS	5--	Volunteer USN ENS	Avg Joe	USMC 2 nd Lt	5-
USN ENS	3-	Volunteer USN ENS	3-		
USN ENS	3-				

Where: 1) Sherman Field Flight Gear Issue, Customer Service, Bldg 3581
 2) Training Air Wing SIX hangar, Sherman Field, NAS Pensacola, FL
 Gear fittings on the (you the) test cases will be conducted in the T-6A pilot paraloft located on the ground floor, south side of hangar 1853.
 Cockpit functional evaluations (fit checks) will be conducted using a T-6A parked in hangar 1853.

When: 1) 25 July 2007, Wednesday, 10:00-11:00, then eat lunch
 2) 25 July 2007, Wednesday, 12:00 – 16:00 ejection seat brief and cockpit checks
 26 July 2007, Thursday, 07:45 – 11:30 cockpit checks

Uniform: Flight Suits. If you don't have one yet, stop by Flight Gear Issue Wed AM to receive your 1st issue of one flight suit and one pair of flight boots if they have your size from the nearly new stuff. – good deal.

POC: LT Timothy J. Ringo, MSC, USN, Aeromedical Safety Officer (AMSO)
 Comm: 850-452-3997, DSN 922-3997; LT Hunt, NASC AMSO, 452-3241

Copy to: Each person listed

Appendix C

Naval Aviation Anthropometric Compatibility Assessment (NAACA)

NAACA is a software program which uses an Oracle database. NAACA was created by NETPDTC for NAVSCOLSCOM screening of (potential) flight students. NAACA is a database: It stores subject biographical and anthropometric dimension measurements. Aggregate data pulls for statistical research may be conducted by the program manager.

NAACA Assesses Compatibility: Once data is entered, the subject's can be evaluated for determination of potential cockpit compatibility. Type/Model/Series Aircraft restrictions are determined for each critical dimension, and for training pipeline(s) to fleet aircraft restrictions. Additionally, subject's body weight is determined below or above certified or qualified safe weight ranges for aircraft seats and/or escape systems. Aviators shall not be assigned or allowed to fly in an aircrew seat for which a restriction exists (7).

NAACA Screens Aviation Applicants: Service specific aeronautical designation criteria are screened. Minimally, applicant height is determined for eligibility; weight is also screened. Some other dimensions are screened as an additional check for another service entry and participation in Naval Aviation. Naval Aviation requires a minimum of 2 training pipeline to fleet aircraft eligibility (7), which is also screened. Alternate compatible pipeline and/or aircraft are determined for informed decision making at the accession point.

NAACA is based upon known specific aircraft crewmember station dimensions (9). Not all aircraft and not all crewmember stations have determined restrictions. But NAVAIRSYSCOM anthropometric restrictions are scientifically based and validated, as well as operationally verified predictive tools to improve human-systems-integration for optimal aircraft operation and reduce potential mishaps and injury.

Appendix D

Sample Anthropometric Cockpit Evaluation Go By

Baseline The T-6A cockpit anthropometric evaluations relied upon theoretical space and volume principals, experiential knowledge, and previous fit check procedures and objectives as well as potential ALSS interference with control range of motion, reach restrictions, or escape compromises.

Seat Positions	FOV E I		Over head Clearance	Canopy Breaker Clearance	Functional Reach		Rudder Positions Fwd Mid Aft			Leg Clearance Shank-Inst. Panel	Ejection Clearance	Thigh Gap
					Zone 1	Zone 2						
Full Up												
Design Eye Plane/Point												
Top of ADI		√										
NSRP												
Full Down												
												0

SH clearance/head box

SEH DEP

TTR reach flight and non-flight controls

SEH+TTR DEP & reach controls

SEH+BKL DEP & operate foot controls

SH head clearance

SH+BKL clear escape path & operate controls w/out compensatory movements

Flight Controls, front & aft cockpits:

Throttle is Zone 1 per MIL-STD-1333B, but Zone 2 PIPFS

PCL full range is Zone 1 PIPFS

Fuel Cut-Off

Stick, Rudder Pedals and PCL in neutral position are Zone 1 PIPFS

Stick - full throw or circle w/out ALSS interference is Zone 1 PIPFS and Zone 1 w/ $\geq 1.5''$ clearance per MIL-STD-1333B

Canopy & Escape Sys, normal and emergency Zone 1 pr PIPFS

Emergency ground egress control is Zone 2 PIPFS

Inertial lock manual selector is Zone1 per PIPFS

Rudder Pedals Zone 2 per PIPFS

Landing Gear - normal and emergency (allows hydraulic s for emergency brakes) Zone not specified - should be Zone 1

Landing Gear Override Switch and Gear Handle is a simultaneous.

Flaps, NWS, HOTAS, Toe Brakes, Trim & Speed brakes are Zone 2 per PIPFS

(Emergency) Parking Brake handle

Other Controls:

Battery switch, Air conditioning switch, Master Caution switch light

Light switches: anti-collision, position, & cockpit

Radios – primary and UHF standby control knobs, in center console
NavAids, Vents, and PMU switch
Seat height adjusting switch, Hot/Cold Microphone, Heaters, pitot, de/anti-ice
Aft Controls: circle repeats above

Zone 1 controls are primary (frequently used) flight controls & time critical emergency controls (i.e. during take-off & landing phases, LAT, ACM, escape,...)

Aircrew has head, back, & butt against seat back (along back tangent).

Harness is locked. No arm/shoulder stretching against restraints.

Zone 2 controls are primary flight controls & time critical emergency controls (NAVAIR places E-handle here, but MIL-STD-1333B escape controls are Zone 1)

Aircrew has head, back, & butt against seat back (along back tangent).

Harness is locked. Arm/shoulder stretching against restraints is permitted.

Miss distances are measured. Overreach measurements are estimated.

Rudder pedal reach.

Pedal position/location is measured initially at farthest forward adjustment position/location for which full rudder throw is possible.

Pedal position/location is measured finally at farthest aft adjustment position/location for which full rudder throw is possible.

Full brake or at least sufficient braking application to stop landing roll-out (prevent over-run, off-roading) should be measured also.

Full rudder throws are w/out locking knee or rotating hips.

Brake application at extreme rudder throws w/out locking knee or rotating hips.

Clearances:

Overhead, highest point to overhead is measured; fist height (presumably four knuckles vertically) is specified in T-6A NATOPS Flight Manual.

Head or helmet (not thickness of Zeta-Liner or # of TPL and helmet size and type) to canopy, front & aft stations.

Head or helmet (same as above wrt helmet configuration) above or below canopy breakers, front 1.5" & aft seats 2.5" (FA-18B/D AMSO & tech rep estimate for spinal compaction).

Escape path:

Knee to instrument panel, lower & upper glare shield; and canopy bow.

Lower leg (shank/shin) & foot/toes clearance from the same as above.

Thigh gap is noted for each seat position, should be 0.00" - no gap. Popliteal Ht sitting range is 12.4" – 21.3" PIPFS

Leg, to lower instrument panel edge for all seat positions and rudder throws - should have ≥ 1.5 inches per MIL-STD-1333B

Knee joint off seat pan. Buttock-Popliteal Length, 16.5" – 23.2" PIPFS.

Leg garter clear of snags.

PIPFS: 30" forward min clearance line parallel to ejection path & measured perpendicularly to the seat back (this is the back tangent); and +/-13" lateral from seat centerline. Max radii of forward corners of envelope shall be 6".

Control Stick:

Thigh Circumference range is 17.1" – 29.7" PIPFS

Thigh Thickness range is 4.7" – 8.1" PIPFS

Design Eye Position/point along a plane/line (waterline and fuselage marks not available)

Measured up from floorboard waterline to aircrew's right ectocanthus.

HUD eye tube estimate &/or correlation (verification /validation).

DEP is midpoint of DELine, which is a segment of the over the nose visual line connecting 2 points which represents the predicted eye positions of the extremes of the aircrew population (JPATS SEH range).

EFOV:

Landing site picture, & glide slope indicators shall be visible from DEP, as well as taxi (fwd dist of $\geq 65'$ (T-44 checklist) & parking visibility needs.

PIPFS: 2nm at 500 feet AGL visibility of landing aim point worst case AOA

Over the Nose Vis shall be 7.5° downward referenced to a/c waterline front cockpit,
accommodates worst case – does it accommodate JPATS Case 7 SEH w/ Zone 1 & 2 reach;
OTN aft cockpit of 2.5° up, head against head tangent/head box.

MIL-STD-850B: 300" x 11,600' runway on 3° glide slope at 1, ½, & ¼ mile (nautical).

Lateral &/or downward EFOV from DEP:

0° azimuth	10° up & 11° down	aft aircrew
20	20	5 down
30	25	
90	40	
135	20	

IFOV:

PIPFS: All instrumentation and displays shall be visible (i.e. readable) from DEP.

IP technique: Top of ADI, or blue light.

Neutral Seat Reference Position is with the seat in the nominal mid-position of seat adjustment range.

Control Grip Reference Point is the point at which the aircrew 2nd finger (middle digit) is in contact with the forward or downward face of any grip type control (i.e. throttle).

Efficient, Safe, and Comfortable aircrew operational position is the goal to allow effective cockpit/mission function and to reduce fatigue, discomfort, escape path interference, obstructions to vision, to reach, and to actuation of critical controls (MIL-STD-1333B).

Potential Life Support Equipment Interferences:

Control stick envelope, Anti-G suit inflation/inflated

Anti-G suit plug-in & hoses

Oxygen hose plug-in & excessive bending stress at seat

Emergency oxygen on/off lever

Oxygen mask &/or hose

Upper & Lower restraint straps & hardware

LPFC, Helmet edge roll & /or visor

Eventual HUD operation and possible (Panoramic) NVG

Survival pocket bulk &/or location with arm reach or throttling back, landing gear, canopy, & ejection handles as well as & other switches, levers, & knobs

Urinary collection operations, Hydration

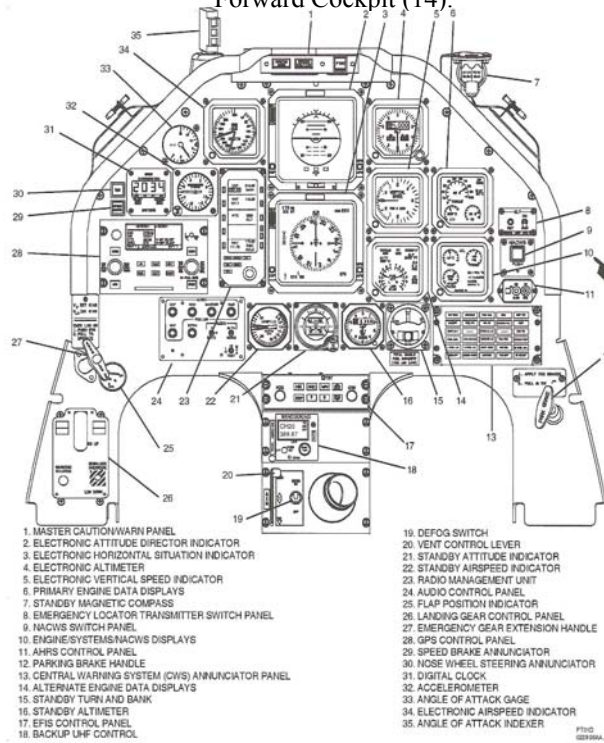
Cockpit FOD retrieval

Escape path strike envelope, Proper ejection body position preparation, Rudder throw

Appendix E

Cockpit Instrument Panel Schematics

Forward Cockpit (14).



Aft Cockpit (14).

