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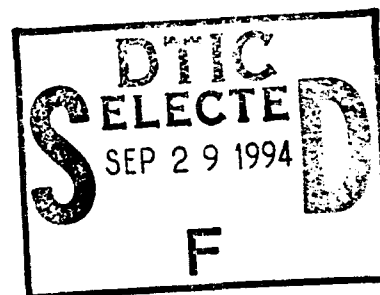


Preliminary Analysis of Army Aircrew Requirements for
Joint Surveillance Target Attack Radar System (JSTARS):
Human Performance Requirements and Job Demands

Beverly G. Knapp

ARL-MR-178

August 1994



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13. ABSTRACT (Maximum 200 words) In response to a request from Training and Doctrine Command (TRADOC) Systems Manager for the Joint Surveillance Target Attack Radar System (JSTARS), the U.S. Army Research Institute Field Office, now the Human Research and Engineering Directorate (HRED) of the U.S. Army Research Laboratory, located at Fort Huachuca, Arizona, conducted an analysis of Army aircrew positions aboard the JSTARS E-8 aircraft. The objective was to determine skills and abilities requirements, task demands, and implications of training and selection. The analytical approach included using the job comparison and analysis tool (JCAT) by experts who had flown on JSTARS in Operation Desert Storm. Data from these analyses indicate a significant cognitive (mental) demand for the three Army aircrew positions, a need for auditory attention ability at a midlevel experience range, and a strong emphasis on oral and written interpersonal communication skills. Findings suggest that these positions must be filled by experience personnel.					
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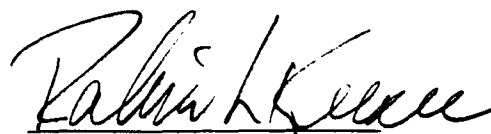
Preliminary Analysis of Army Aircrew Requirements for Joint Surveillance Target Attack Radar System (JSTARS): Human Performance Requirements and Job Demands

Beverly G. Knapp

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The Human Research and Engineering Directorate of the U.S. Army Research Laboratory was organized on 1 October 1992. This report was completed before the organizational change. The U.S. Army Research Institute reference in this report is now part of the U.S. Army Human Research and Engineering Directorate.

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Directorate Executive

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PRELIMINARY ANALYSIS OF ARMY AIRCREW REQUIREMENTS FOR JSTARS:
HUMAN PERFORMANCE REQUIREMENTS AND JOB DEMANDS

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PRELIMINARY ANALYSIS OF ARMY AIRCREW REQUIREMENTS FOR JSTARS: HUMAN PERFORMANCE REQUIREMENTS AND JOB DEMANDS

EXECUTIVE SUMMARY

Requirement:

In 1991, the TRADOC Systems Manager-Joint Surveillance Target Attack Radar System (JSTARS) requested the US Army Research Institute-Ft. Huachuca Field Unit (now part of the Human Engineering and Research Directorate, US Army Research Laboratory) to conduct a behavioral performance requirements analysis for Army aircrew on JSTARS. This was in response to questions raised regarding the appropriate senior and junior levels of expertise required for Army personnel on-board the JSTARS E-8 aircraft.

Procedure:

The analytical approach consisted of a combination of systematic job assessment techniques and open-ended interviews to extract skills and abilities requirements, cognitive task demands, and temporal ratings of mission functions. A key data collection instrument was the Job Comparison and Analysis Tool (JCAT) which allows specification of ability and skill clusters in cognitive, perceptual, and psychomotor areas. Data were collected using subject matter experts who were part of the Desert Storm operation.

Findings:

Data from the various job assessment analyses indicate a significant cognitive demand for the three Army positions aboard the E-8, particularly for the Deputy Mission Crew Commander. Skills and abilities clusters were at mid-level experience range for communication, conceptual, reasoning, speed-loaded, and auditory elements. A strong emphasis was noted for interpersonal and written communication skills.

Utilization of Findings:

The findings reported in this research note serve as input to the overall database of personnel issues and requirements for the JSTARS system, projected for test and deployment in 1995. Specifications for training and experience level of aircrew positions are critical to the formulation of operations concepts and doctrine currently being used.

PRELIMINARY ANALYSIS OF ARMY AIRCREW REQUIREMENTS FOR JSTARS: HUMAN PERFORMANCE REQUIREMENTS AND JOB DEMANDS

Introduction

JSTARS (Joint Surveillance Target Attack Radar System) is a battlefield management system that detects, locates, identifies, tracks, and targets hostile ground forces and force movements. JSTARS aircraft can also monitor slow moving fixed wing and rotary wing aircraft. The overall mission is to provide information to counter enemy movement through effective battle management and targeting.

JSTARS consists of three subsystems: an airborne platform, a radar sensor system, and a ground station module (GSM). As its name implies, JSTARS is a joint service operation. The aircraft system is maintained and operated by Air Force personnel, an airborne operations crew is composed of Air Force and Army personnel, and the GSMs are manned and maintained separately by the owning service on the ground.

Despite very limited assets and a prototype developmental configuration, JSTARS proved to be of significant value during Operation Desert Storm (ODS). That it did not achieve full potential in support of ground component commanders, will to a great extent be ameliorated by attainment of the objective system (Kleiner, 1991). In the interim, one issue of immediate operational concern for the objective system is the determination of the human performance requirements for Army aircrew aboard JSTARS. This is the focus of the investigation reported here.

Objective

In response to a request from the TSM-JSTARS (TRADOC Systems Manager), the Army Research Institute Field Unit at Fort Huachuca, AZ, conducted an analysis of Army aircrew positions aboard JSTARS in order to address the following questions:

What are the skills and abilities requirements for the JSTARS Army aircrew positions?

How demanding are the tasks of the Army aircrew?

What are the implications of skills, abilities, and job demands for personnel, on experience and training level requirements?

The objective of this effort was to derive answers to the above questions using available recent documentation and subject matter expertise available from the ODS JSTARS experience.

Method

The analytical approach consisted of several phases:

Review recently available documentation on aircrew positions and tasks and convert to underlying behavioral performance requirements.

Interview available key personnel with ODS experience and derive lessons learned related to aircrew positions.

Collect Job Comparison and Analysis Tool (JCAT) data from key personnel.

Collect mental and temporal demand data from key personnel.

Combine obtained data into comparison matrices for interpretation.

Documentation Sources and Key Personnel

Sources of data for JSTARS aircrew portions were, the JSTARS Mission Crew Functional Analysis (Grumman, 1988), JSTARS position assessments (SAIC, 1989), and ODS flight crew checklists (1991). Using these as a base, lists of high level functions were prepared, and presented to key personnel for consensus on thorough representation of critical Army aircrew tasks.¹

The high-level functions which all agreed represented the full range of actual or potential tasks in a JSTARS mission were:

- Mission Planning and Pre-Brief
- Brief
- Pre-Flight and Run Up
- Outbound
- On-Station
- Off Station, Debrief, and Post-Mission

These formed the basis for structuring tasks in the JCAT job assessment phase of data collection, and evaluating tasks for mental and temporal demand.

¹Personnel consulted were: COL Martin Kleiner and LTC Larry Corn (TSM-JSTARS); LTC Robert Jost (US Army Intelligence Center, MIDAS Division); MAJ Mike Widener, CW2 Jim Borgman (Joint STARS Joint Test Force); Mr. Jim Miller (PRC), and MAJ Shawn Griffith (JTF-Langley AFB).

Job Comparison and Analysis Tool (JCAT)

JCAT is a prototype research method for the assessment of skill and ability demands of new or existing jobs. The JCAT was developed as a modification of the MARS (Manual for the Ability Requirements Scale) based on over 25 years of research by Fleishman and Associates. A key to developing this method was the establishment of an abilities and skills taxonomy which would be comprehensive for jobs in applied domains, and therefore suitable for military use. The most suitable taxonomy was that developed by Fleishman and Quaintance (1984), and consists of 50 defined, measurable skills and abilities dimensions. In creating JCAT from MARS, the ARI research unit (now part of the Human Engineering and Research Directorate, US Army Research Laboratory) adapted MARS to the specifics of military job assessment needs. Table 1 presents the JCAT skills and abilities.

The JCAT (Muckler, Seven, & Akman, 1990; Akman et al., 1991) consists of a paper and pencil booklet with a series of flow charts, rating scales, and matrices of mission functions, which allow the elicitation of abilities and skills related to any given job under consideration, without the JCAT user having to possess knowledge of the underlying meaning and behavioral components of the 50 abilities and skills. This tool was administered to individuals, (from those key personnel listed above) who had actual flight experience in ODS, and had formulated a sense of the position demands, as well as demands to be expected in the objective system.

Five positions were assessed using JCAT, the two Army positions flown in ODS, and the three positions projected for the objective JSTARS. A typical JCAT "run" consisted of instructing the JCAT user to envision the position under consideration, and complete the JCAT answer form following the JCAT booklet. Thus each JSTARS expert went through several JCAT runs independently for each position. The positions assessed were:

- GLO (Ground Liaison Officer - ODS)
- AST (Aerial Surveillance Technician - ODS)
- DMCC (Deputy Mission Crew Commander - Objective System)
- AST (Aerial Surveillance Technician - Objective System)
- TSS (Target Surveillance Supervisor - Objective System)

Cognitive and Temporal Demand Data

From the six high level mission functions, task lists were developed through key personnel consensus and review of the Grumman and ODS flight crew checklists. These task lists are not necessarily the final or approved versions since the concept of operations may not be firm; however, they were agreed to exemplify and cover the scope of all potential duties that might be encountered by the Army aircrew. Two task lists were used: for

Table 1

JCAT Skills and Abilities Taxonomy

A. COMMUNICATION SKILLS	1. Oral Comprehension	E. PERCEPTUAL ABILITIES	(VISION)	24. Near Vision
	2. Written Comprehension			25. Far Vision
	3. Oral Expression			26. Peripheral Vision
	4. Written Expression			27. Night Vision
B. CONCEPTUAL SKILLS	5. Selective Attention	(AUDITION)		28. Depth Perception
	6. Problem Sensitivity			29. Glare Sensitivity
	7. Pattern Recognition			30. Visual Color Discrimination
	8. Spatial Orientation			31. General Hearing
C. REASONING SKILLS	9. Visualization	F. PSYCHOMOTOR ABILITIES		32. Auditory Attention
	10. Memory			33. Sound Localization
	11. Originality			34. Rate Control
	12. Fluency of Ideas			35. Control Precision
D. SPEED-LOADED SKILLS	13. Category Flexibility	G. GROSS MOTOR ABILITIES		36. Multi-Limb Coordination
	14. Deductive Reasoning			37. Arm-Hand Steadiness
	15. Inductive Reasoning			38. Manual Dexterity
	16. Information Ordering			39. Finger Dexterity
E. SPEED-LOADED SKILLS	17. Mathematical Reasoning			40. Wrist-Finger Speed
	18. Number Facility			41. Speed of Limb Movement
	19. Reaction Time			42. Extent Flexibility
	20. Choice Reaction Time			43. Dynamic Flexibility
F. SPEED-LOADED SKILLS	21. Time Sharing			44. Gross Body Coordination
	22. Perceptual Speed and Accuracy			45. Gross Body Equilibrium
	23. Speed of Closure			46. Static Strength
				47. Explosive Strength
				48. Dynamic Strength
				49. Trunk Strength
				50. Stamina

the GLO and DMCC position - ODS checklist, 38 tasks; for the AST and TSS positions, a composite checklist was developed by the key personnel. (These lists are shown in Tables 5 and 6.)

A sorting instrument for cognitive and temporal demand was developed which consisted of five judgment blocks each. For the cognitive demand, the blocks were:

HIGHLY DEMANDING: Required maximum mental effort & expertise
VERY DEMANDING: Requires a lot of mental effort
MODERATELY DEMANDING: Takes average mental effort
MINIMALLY DEMANDING: Easy task; little mental effort
NOT DEMANDING: Unskilled task

For temporal demand, the blocks were:

EXTREMELY TIME CONSUMING
VERY TIME CONSUMING
MODERATELY TIME CONSUMING
TOOK LITTLE TIME
NEGLECTIBLE TIME DEMAND

For each position being considered, individuals sorted the tasks into one of the five blocks by placing task number into the appropriate block. Thus a total of 10 judgments were made, one for each position on both mental and temporal demands. The GLO task list was used for both the GLO and DMCC, and the AST list accommodated the TSS positions. Experts were asked to make their judgments for each position as if these were the tasks that were required. Consensus was reached among these experts that these lists were suitable.

Data Collation and Analysis

Data collected from key personnel in the form of "lessons learned" and observations from ODS were tabled and subjected to content analysis. The derivation of mission functions and tasks were the basis of input for the JCAT, and demand sort procedures. Data from these procedures allow the determination and diagnosis of sources of human performance load. In these cases, databases were formed, and findings are presented as matrices which show average ratings, ranks, percentages, or frequencies in various categories. Given the preliminary nature of this initial analysis, and the relatively small number of participants, comparative statistics were not applied; rather, judgments regarding findings were from inspection of highly rated item clusters to derive clearly apparent trends.

Results

JCAT Findings

JCAT data form a database from which can be derived various profiles of the skills, experience, and abilities required of personnel to perform a job. The first level of consideration is, of the 50 skills and abilities represented in the JCAT taxonomy, what subset best represents the job (according to consensus)? A second level of analysis is, what level is required for each skill or ability selected (based on averages of ratings by individual raters)? The framework for understanding JCAT results is shown in Table 2. Of the 50 skills and abilities, these can be clustered in a number of ways, and a very prevalent grouping that has been used in related previous research is shown (Muckler, Seven, & Akman, 1990). On the left are a set of four cognitive skill and experience clusters - communication, conceptual, reasoning, and speed-loaded, with their corresponding skills listed. The skills and experience required to have high proficiency in these areas are highly cognitive in nature, and are most amenable to enhancement through training, both resident or formal, and on-the-job. On the right are four clusters encompassing perceptual-motor abilities: vision, audition, fine psychomotor, gross motor. These capabilities are primarily innate, and so are typically more manipulable by selection of persons or in some cases, low-level, repetitive practice drills. Definitions and discussions elaborating the eight skill and ability clusters are found in Appendix A.

Table 3 shows the results of JCAT "runs" for each position, by cluster. The numerical values in each cell are the average of ratings provided by all key personnel on the skills or abilities of that cluster. Total average values could range from a low of 0 to a high of 7. As an example, for the GLO position, the communication skills present the highest personnel demand (5.83), and gross motor ability is very modest (1.86). (Skill and ability levels generally fall into three categories: high, mid, or low, with values of 6-7, 4-6, and 0-4, respectively. These ranges were derived from the behavioral anchors on the actual rating scales.) This means that, a GLO would need to have training and experience at a high mid-level for communication skill, but gross motor tasks are not a primary aspect of the job. Following this logic, it can be seen that the GLO presents demands for a mid-level, experienced person in all of the cognitive areas; the DMCC (GLO equivalent for the objective system) has demands that are even higher. Perceptual motor abilities demands are much less critical, except for auditory; the trend is still upward for all clusters between what was required in ODS vice the objective system. In all cases, the objective system is more demanding.

Table 2

JCAT Skills, Experience, and Perceptual-Motor Abilities Clusters

COGNITIVE SKILL & EXPERIENCE CLUSTERS		PERCEPTUAL-MOTOR ABILITY CLUSTERS	
COMMUNICATION	CONCEPTUAL	VISION	AUDITION
Oral Comprehension Written Comprehension Oral Expression Written Expression	Memorization Problem Sensitivity Originality Fluency of Ideas Flexibility of Closure Selective Attention Spatial Orientation Visualization	Near Vision Far Vision Night Vision Visual Color Discrimination Peripheral Vision Depth Perception Glare Sensivity	General Hearing Auditory Attention Sound Localization
REASONING	SPEED-LOADED	PSYCHOMOTOR	GROSS MOTOR
Inductive Reasoning Category Flexibility Deductive Reasoning Information Ordering Mathematical Reasoning Number Facility	Time Sharing Speed of Closure Perceptual Speed & Accuracy Reaction Time Choice Reaction Time	Control Precision Rate Control Wrist-Finger Speed Finger Dexterity Manual Dexterity Arm-Hand Steadiness Multi-Limb Coordination	Extent Flexibility Dynamic Flexibility Speed of Limb Movement Gross Body Equilibrium Gross Body Coordination Static Strength Explosive Strength Dynamic Strength Trunk Strength Stamina
GREATER SKILL & EXPERIENCE RESULTS FROM EXTENSIVE TRAINING & JOB EXPOSURE		HIGHER LEVELS OF ABILITIES ARE A FUNCTION OF INNATE CAPABILITIES & LOW-LEVEL PRACTICE DRILLS	

Table 3

Cognitive and Perceptual-Motor Personnel Demands for JSTARS Army Aircrew Using JCAT

POSITION

COGNITIVE SKILL & EXPERIENCE CLUSTERS (TRAINING-EXPERIENCE)	POSITION				
	GLO Operation Desert Storm	DMCC Objective System	AST Operation Desert Storm	AST Objective System	TSS Objective System
COMMUNICATION (4)*	5.83**	6.12	4.66	5.25	3.62
CONCEPTUAL (8)	4.66	4.68	4.91	4.87	4.95
REASONING (6)	4.19	4.66	5.16	4.91	4.72
SPEED-LOADED (5)	4.43	4.50	4.26	5.10	4.70
PERCEPTUAL MOTOR ABILITY CLUSTERS (SELECTION & PRACTICE)					
VISION (7)	2.38	3.35	3.04	4.00	3.04
AUDITION (3)	4.44	5.16	4.33	5.16	4.44
PSYCHOMOTOR (7)	2.19	3.14	2.85	4.00	2.57
GROSS MOTOR (10)	1.86	2.75	1.83	2.85	1.90

*NUMBERS IN PARENTHESES REFER TO NUMBERS OF SKILLS OR ABILITIES IN EACH CLUSTER.

**NUMBERS IN EACH CELL REPRESENT THE AVERAGE OF RATINGS ON A 0-7 SCALE.

SKILL/EXPERIENCE LEVELS

0-4 ENTRY-LEVEL
4-6 MID-LEVEL
6-7 HIGH-LEVEL

ABILITY LEVELS

0-4 LOW
4-6 MEDIUM
6-7 HIGH

GLO - Ground Liaison Officer

DMCC - Deputy Mission Crew Commander

TSS - Target Surveillance Supervisor

AST - Aerial Surveillance Technician

The junior level positions AST (ODS) and AST (Objective System) show a similar pattern to the senior level DMCC position, in that cognitive skills and experience are the primary driver of the job. However, the trend toward greater demand is not consistent from ODS to the objective system except in the perceptual-motor clusters. Presumably, in differentiating the ODS experience from what is likely to be experienced in objective system operations, the breakout from two Army jobs to three will off-load some cognitive demand and disperse these types of duties. This is not the case for the DMCC position, which shows a consistent upward trend for all clusters, including the cognitive. Also of note for the junior positions is that the auditory ability requirement is also much higher than either the visual or fine/gross motor.

A visual representation of position differences can also be displayed as bar graphs or JCAT strip charts (see Figures 1 and 2). Each display shows the demand levels by cluster and JSTARS position, and the contrast between cognitive vice perceptual-motor demand; the cognitive being mid-level, and the perceptual-motor low level in all cases except auditory.

Job Demand Task Sorts

The task sorting process was conducted to aggregate tasks according to cognitive and temporal demands, as described above. Table 4 presents the results as percent of tasks placed in each demand block by JSTARS position. The two task lists used each consisted of 38 tasks; a distribution of each set of tasks by position indicates where the highest demand exists.

As already indicated by the JCAT data, the highest cognitive requirements are for the GLO and DMCC (senior level, officer position). In both positions, mental demand is approximately equal, with two-thirds (over 67%) of tasks either "very" or "highly" demanding. This is slightly less so for the junior level positions. The AST in Desert Storm had a higher set (58%) of cognitive demands than the objective level system estimates (AST - 45%; TSS - 53%); apparently, the level of mental work will be diffused down to about half of junior level tasks in the objective level system, but unchanged at the two-thirds level for the DMCC.

In examining the nature of the tasks that comprise these high cognitive demands, Table 5 presents the working task lists used for demand sorting for the DMCC and GLO, and Table 6 for the AST and TSS. Of the 38 DMCC tasks, 24 or approximately two-thirds were rated "very" or "highly" demanding. These are indicated by a single or double asterisk in the lists, followed by a code for cognitive (C) or perceptual-motor (P). Of the 24 demanding tasks, 23 are cognitive in nature. Similarly, for the AST and TSS (both positions rated using same task list), 17 (45%) tasks, were rated "very" or "highly" demanding; and over two-thirds of these are cognitive (C) in nature.

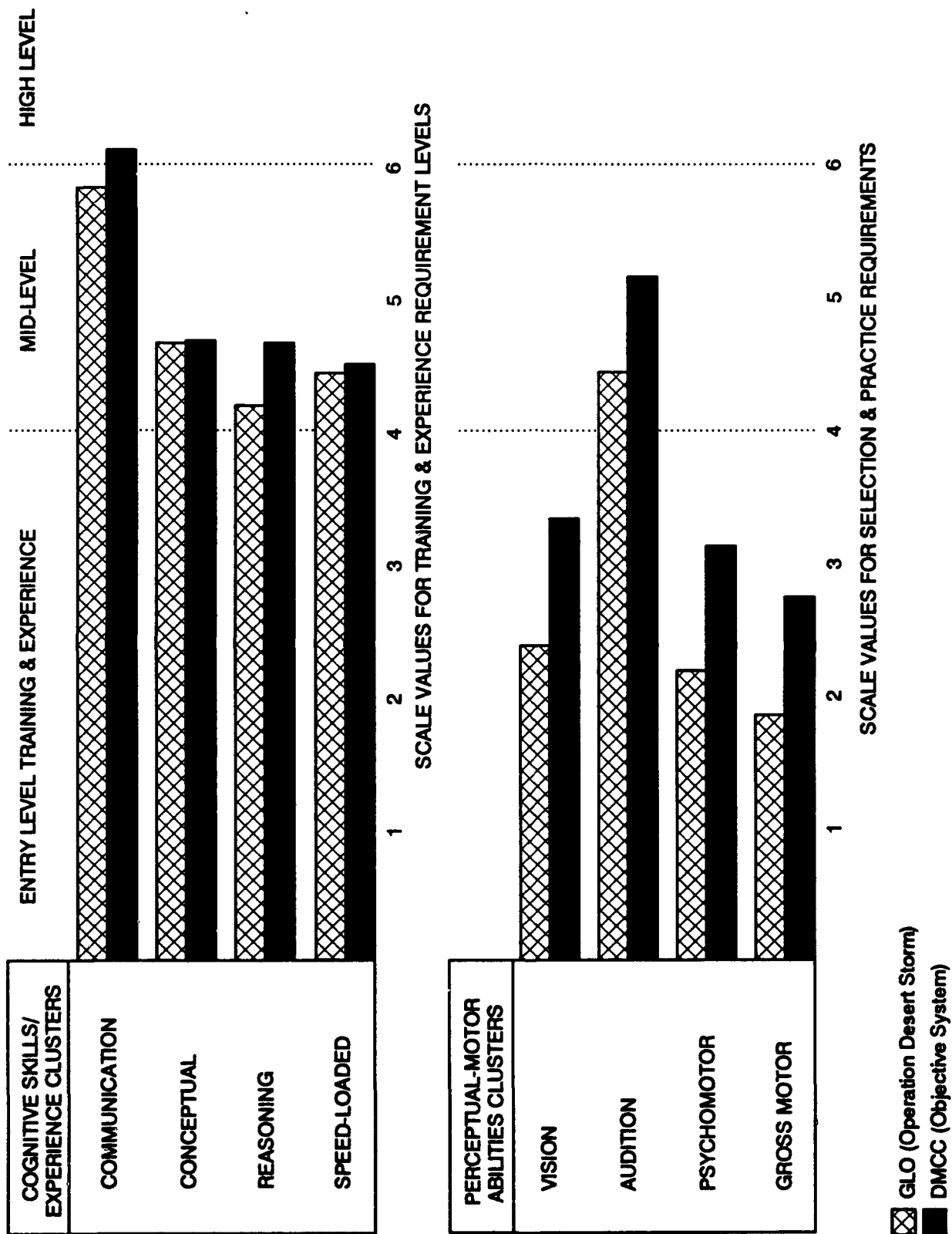


Figure 1. JCAT strip chart - GLO and DMCC.

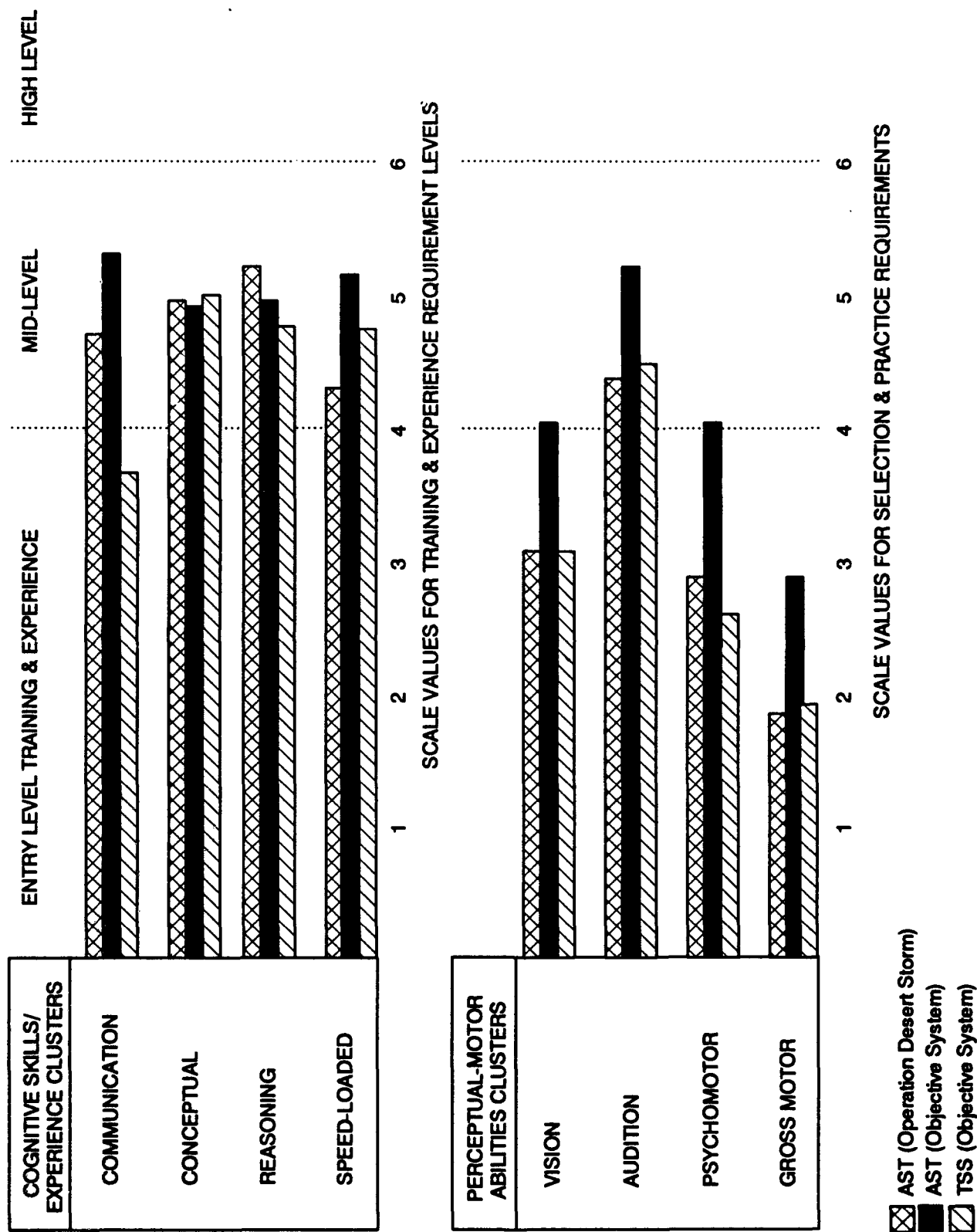


Figure 2. JCAT strip chart - AST-ODS, AST-OBJ, TSS.

Table 4

JSTARS Army Aircrew Tasks: How Demanding is This Job?

COGNITIVE DEMAND	GLO <38 TASKS>	DMCC <38 TASKS>	AST (ODS) <38 TASKS>		AST (OBJ) <38 TASKS>	TSS <38 TASKS>
HIGHLY DEMANDING	22%	22%	16%	12%		12%
VERY DEMANDING	45%	46%	42%	33%		41%
MODERATELY DEMANDING	19%	19%	22%	20%		28%
MINIMALLY DEMANDING	11%	11%	13%	21%		13%
NOT DEMANDING	3%	2%	7%	14%		6%
TEMPORAL DEMAND						
EXTREMELY TIME CONSUMING	---	---	3%	3%		3%
VERY TIME CONSUMING	5%	5%	5%	3%		13%
MODERATELY TIME CONSUMING	37%	37%	32%	21%		26%
TAKES LITTLE TIME	37%	37%	42%	52%		45%
NEGIGIBLE TIME DEMAND	21%	21%	18%	21%		23%

Table 5

Task List: GLO and DMCC Positions with Cognitive and Perceptual-Motor Codes

GLO/DMCC	AIRCREW AID	E-8A
MISSION PLANNING CELL *1. Break out Air Taking Order (ATO) (C) - Check special instructions (SPINS) - Established priorities - Pre-planned requests - Map requirements ■ Pull and mark maps as required ■ Ensure map scale is standardized ■ Plot SARS ■ Plot sector searches **2. Review Ground Situation (C) - Friendly - Enemy *3. GSM Status (C) - Green/Amber/Red - Locations - Supported Unit 4. Army communications Plan - GSM frequencies ■ Primary ■ Alternate ■ GS failure (G2/ALO/CTOC) - Non-GSM Units (Request/Report) ■ Primary ■ Alternate ■ Call sign		

**** Highly Demanding**

*** Very Demanding**

PRIMARY Behavioral Component

Cognitive (C)

Perceptual-Motor (P)

GLO	AIRCREW AID	E-8A
GLO POSITION DUTIES PRE-BRIEF 1. Review pass on book *2. Check GSM status (C) 3. Review communications - Call signs - Freqs **4. Review Air Tasking Order (ATO) for Army specific tasking (C) **5. Review Special Instructions (SPINS) (C) **6. Review mission objectives with Air Coordination Element (ACE) (C) **7. Review mission priorities with ACE (C) 8. Perform personal equipment checks: - Uniform, chemical equipment - Identification tags - Headset, flight helmet - Mission documents ■ Comms card ■ Radar Service Request (SAR) sheets ■ MAPS ■ CEOI A RUN UP 9. Secure LPU (enroute to seat) 10. Perform Personal Equipment Checks: - Secure personal equipment (on right side of seat) - Check seat, shoulder harness, lap belt - Check LPU (secure on back of seat) - Check oxygen mask (PRICE check) 11. Check Crew Member Terminal (CMT) - Ensure intercom is set as needed ■ Receive (R) and transmit (T) are set as required ■ GLO monitors mission net (PR2) and ground net (PR6) ■ Army AST operator monitors AST net (PR4) and ground net (PR6) - Ensure radio net is set as needed ■ Recommend that GLO and Army AST operator monitor on the GSM radio net		

GLO	AIRCREW AID	E-8A
GLO POSITION DUTIES 12. Conduct Commo Check - Check with Communications Work Station Officer - Check with Army AST operator on ground intercom net - Answer commo "roll call" when prompted by Radar Management Officer (RMO) - Contact ground station modules (GSMs) ■ Check on secure (green) and non-secure (red) 13. Check Aerial Surveillance Technician (AST) - Review preplanned RSR/EPs - Build preplanned RSR/EPs *14. Support comms/data line status to ACE and advise the Air Surveillance Officer (ASO) that the Army AST is mission ready (C) CLIMB OUT 15. Radio silence until airborne, then reestablish GSM/AC commo net (IAW SOP for EMCON) *16. Report transition and altitude to GSMs (C) *17. Report on track (C) 18. Verify status of GSMs and SCDL *19. Report operational status to ACE and reassign on-board tasking as required (C) ON TRACK **20. Review timelines with ASO (C) 21. Report turns and waypoints as needed with GSMs 22. Communicate with GSM and help AST record voice RSRs *23. Communicate with GSMs/G2s or alternate contacts for passing of sensor reports (C) **24. Monitor preplanned RSRs and prioritize requests (C) **25. Deconflict jobs with ASO (C) **26. Deconflict jobs with ACS (C) *27. Disapprove RSRs which violate mission objectives (C) **28. Contact users (Division Artillery, Attack Helicopters) as required to pass sensor reports (C) 29. Communicate AC primary mission equipment (PME) status to GSMs		

GLO	AIRCREW AID	E-8A
GLO POSITION DUTIES POST MISSION **30. Keep track of radar operations. Record "up and down" times, record problems, record recommended solutions (C) **31. Relieve Army AST as necessary (P) **32. Attend mission post flight briefing (C) **33. Contact GSMs point of contact (POC), face-to-face or voice to debrief mission results (c) *34. Write mission results, problems and solutions in Army "Pass On Book," located in mission operations (C)		

Table 6

Task List: AST and TSS Positions with Cognitive and Perceptual-Motor Codes

Aerial Surveillance Technician Checklist (38 Tasks)

MISSION PLANNING (MP)

- *1. Receive orders, taskings, and requirements. (C)
2. Identify Army taskings and requirements by priority.
- **3. Analysis of area of operations and flight requirements. (C)
- **4. Establish surveillance plan and coordinate flight priorities and requirements with ASO. (C)
- **5. Coordinate and create target and weapons allocations list. (C)
6. Coordinate Communications Plan of the Day (CPOD).
7. Prepare mission profile and disseminate to GSM section.
- *8. Brief Army requirements and assets during prebrief; finalize joint coordination of surveillance requirements. (C)

MISSION BRIEFING (MB)

1. Check-in and receive flight equipment issue.
2. Receive mission and classified flight materials.
3. Receive briefing.
- **4. Final coordination of mission requirements. (C)
5. Transit to aircraft.

PREFLIGHT (PF)

1. Perform preflight inspections (aircraft T/O checklists).
- *2. Perform preflight safety of flight duties assigned. (P)
- *3. Initiate console operations. (P)
- *4. Conduct communications checks (ICS/voice radio). (P)
5. Final crew report and taxi.

TAKEOFF AND TRANSIT TO STATION PROCEDURES - OUTBOUND (OB)

- *1. Perform safety of flight duties assigned. (P)
2. Complete console initialization and task setup.
3. Initiate SCDL operations.
- **4. Establish communications with supported elements. (C)
5. Complete aircraft checklists for takeoff and transit to station.

ON-STATION PROCEDURES (OS)

- *1. Perform safety of flight duties assigned. (P)
- 2. Initiate system tasks and complete operational checks.
- *3. Report on-station to supported elements (per GLO). (C)
- **4. Conduct operational tasks assigned; execute surveillance, targeting or attack control assignments. (C)

OFF-STATION AND DESCENT PROCEDURES - INBOUND (IB)

- 1. Perform safety of flight duties assigned.
- 2. Report off-station to supported elements (per GLO).
- 3. System and console set for decent and landing (per T/O checklist).
- 4. Secure classified and mission materials.

LANDING AND POST MISSION PROCEDURES (PM)

- 1. Perform safety of flight duties assigned.
- 2. Secure and clear aircraft.
- 3. Report to debrief.
- **4. Conduct post mission analysis. (C)
- **5. Outstanding tasks identified. (C)
- *6. Flight equipment and materials secured. (P)
- 7. Report flight operations for next mission assignment.

**Highly Demanding
*Very Demanding

PRIMARY Behavioral Component
Cognitive (C)
Perceptual-Motor (P)

Although GLO and DMCC tasks are primarily cognitively challenging, the time demands for any one task, as shown at the bottom of Table 4, are moderate. This indicates high mental load and a requirement to perform on tasks rapidly, meaning cognitive skills such as data assimilation, communications, and reasoning must be precise and rapid. These types of skills are enhanced and refined mainly as a result of job experience. The junior positions are similar in time demand but slightly more widely dispersed; this indicates that certain tasks will consume more time even though most will not.

Detailed Analysis of Crew Demands

Since both the JCAT and the task sort procedures have revealed that there is a significant cognitive demand present within the requirements for aircrew personnel, a more detailed analysis of the data was indicated. This analysis was to pinpoint or "diagnose" the specific skills and abilities comprising the demand, and to identify where in the mission flow cycle they occur. JCAT data are particularly well suited for this type of diagnostic analysis.

GLO and DMCC Positions. As previously described, JCAT data were collected to derive skills and abilities requirements using a flow chart and rating procedure for overall job demand as well as for demand within individual job functions. (The functions are Mission Planning, Brief, Pre-Flight, Outbound, On-Station, Off-Station, and Post Mission/Debrief). A matrix of the six functions with the eight skills and abilities clusters for the GLO and DMCC positions is shown in Table 7. The cell values represent the average rating from all experts on the 0-7 scale. As above, the demand categories for scale values are: 0-4, low level; 4-6, mid-level; and 6-7, high level.

From inspection of the GLO and DMCC matrix, a number of findings are drawn. First, all six functions place a greater skill and ability demand on the DMCC than the GLO (all values for DMCC slightly higher). Second, the most critical, or demanding function is "On-Station," since five of eight clusters require mid-level expertise (all skill clusters plus auditory ability). The remaining functions, in order of decreasing skill and ability demand, are: Mission Planning, Outbound, Post Mission/Debrief, Brief, and Pre-Flight. Third, the communication cluster is required in the mid-range to perform all functions for the DMCC position, particularly for Mission Planning, Brief, and Post-Mission/Debrief. Fourth, auditory ability is required at a mid range for Pre-Flight, Outbound, as well as On-Station.

Further decomposition of the five skills-abilities clusters required at mid-level was conducted to ascertain the specific skills or abilities most responsible for the mid-level values. The most intense load is for the On-Station function, and the rank

Table 7

Skill and Ability Demands for JSTARS Mission Functions: GLO and DMCC

SKILL/ABILITY CLUSTER	JSTARS MISSION FUNCTION											
	MISSION PLANNING		BRIEF		PREFLIGHT		OUTBOUND		ON-STATION		POST MISSION/ DEBRIEF/ OFF-STATION	
	GLO	DMCC	GLO	DMCC	GLO	DMCC	GLO	DMCC	GLO	DMCC	GLO	DMCC
Communication	4.04	5.87	5.37	5.87	3.66	4.12	3.58	4.12	4.95	5.00	5.37	5.87
Conceptual	3.60	3.94	2.51	3.56	2.37	2.88	2.99	3.31	4.37	4.62	3.72	3.69
Reasoning	3.60	4.67	2.44	3.58	1.44	2.25	1.60	2.50	4.03	4.50	3.89	4.41
Speed-Loaded	2.86	3.60	1.99	2.80	2.46	3.70	2.86	3.90	4.43	4.50	1.99	2.90
Visual	2.04	2.79	1.94	2.86	2.09	3.07	2.09	3.07	2.28	3.14	2.04	3.14
Auditory	2.66	3.33	2.66	3.00	3.88	4.50	3.99	4.83	4.44	5.17	2.66	3.00
Psychomotor	1.33	1.93	1.28	1.86	2.19	3.14	2.19	3.14	2.19	3.14	1.52	2.29
Gross Motor	1.09	1.60	1.09	1.60	1.66	2.45	1.76	2.60	1.86	2.75	1.50	2.00

Performance Demand Levels: 0-4 Low 4-6 Medium 6-7 High

order of those cluster ratings is as follows (from most to least critical): auditory, communication, conceptual, reasoning, speed-loaded. In each of these clusters, certain skills or abilities are the "high drivers," based on average ratings for each skill across raters. Table 8 shows the skills or abilities lists for each cluster, ranked from most to least critical, for the DMCC position. Of the 25 skills or abilities listed, 14 are in the mid-range, indicated by an asterisk in the chart. These 14 form a sort of "profile" of expertise required for the DMCC to achieve high quality performance. Note that in the communication cluster, all four skills are in mid-range (non-entry level), with oral comprehension first. Auditory attention is the high driver ability for the profile. The remaining skills in the profile are inductive reasoning, deductive reasoning, information ordering, originality, problem sensitivity, memorization, speed of closure, and time sharing; also required is general hearing ability.

AST and TSS Positions. A matrix of skills-abilities clusters and JSTARS mission functions for the AST-ODS, AST-Objective System, and TSS portions is shown in Table 9. Certain findings are immediately apparent from the matrix. First, the skill-ability demands for all functions increase for nearly all cells from AST-ODS to AST-OBJ and TSS. Second, as in the senior level DMCC and GLO positions, the greatest demand is for communication skills across all functions, and the majority of workload occurs "On-Station." Third, higher level ability demands exist On-Station for the AST-OBJ than for either the AST-ODS or the TSS. This is also a departure from the DMCC and GLO profile.

The profile of the TSS is more closely aligned with the DMCC than with the AST; the AST position has the added ability clusters of vision and psychomotor demand at the mid-level. The rank order of all of the clusters at mid-level for the AST-OBJ On-Station function is as follows: audition, communication, speed-loaded, conceptual, reasoning, vision, and psychomotor; note that the two added clusters, (vision and psychomotor) are also lowest in criticality or rank. Decomposition of these clusters into specific, high-driver skills or abilities (shown in Table 10) reveals that only seven elements within the clusters are primarily responsible for the performance demands: oral comprehension, auditory attention, written comprehension, general hearing, memorization, oral expression, and written expression. Even though the reasoning, speed-loaded, visual, and psychomotor clusters are of overall importance for the On-Station function, some skill-ability elements are very minimally required. With the exception of oral comprehension, all skill or ability elements are at a lower level of proficiency than for the DMCC.

The rank order of the five required skill-ability clusters for the TSS On-Station function is: conceptual, reasoning, auditory, speed-loaded, and communication. Although these are the same clusters as for the DMCC, the rank order of the profile is

Table 8

Decomposition of Critical JCAT Clusters into Skill and Ability Elements for DMCC Position

<u>CLUSTER</u>	<u>SKILL/ABILITY ELEMENT</u>	<u>(AVERAGE DEMAND LEVEL, 0-7 SCALE)</u>
Auditory	*Auditory Attention	(4.75)
	*General Hearing	(4.58)
	Sound Localization	
Communication	*Oral Comprehension	(5.58)
	*Oral Expression	(5.16)
	*Written Expression	(5.00)
	*Written Comprehension	(4.83)
Conceptual	*Originality	(4.50)
	*Problem Sensitivity	(4.41)
	*Memorization	(4.50)
	Selective Attention/Visualization	
	Flexibility of Closure	
	Fluency of Ideas	
Reasoning	Spatial Orientation	
	*Inductive	(4.75)
	*Deductive	(4.25)
	*Information Ordering	(4.08)
	Category Flexibility	
	Mathematical Reasoning	
	Number Facility	
Speed-Loaded	*Speed of Closure	(4.33)
	*Time Sharing	(4.08)
	Perceptual Speed & Accuracy	
	Reaction Time	
	Choice Reaction Time	

*Skill/ability elements are in mid-level range (4-6) on 0-7 scale of performance demand.

Table 9

Skill and Ability Demands for JSTARS Mission Functions: AST and TSS Positions

SKILL/ABILITY CLUSTER	MISSION PLANNING			BRIEF			PREFLIGHT			OUTBOUND			ON-STATION			POST-MISSION DEBRIEF		
	AST-ODS	AST-OBJ	TSS	AST-ODS	AST-OBJ	TSS	AST-ODS	AST-OBJ	TSS	AST-ODS	AST-OBJ	TSS	AST-ODS	AST-OBJ	TSS	AST-ODS	AST-OBJ	TSS
Communication	4.35	4.00	4.60	2.90	4.25	3.75	2.90	4.38	3.15	3.08	4.38	3.32	4.18	5.13	4.35	4.25	5.25	4.70
Conceptual	3.25	3.13	3.45	2.68	3.06	2.46	2.50	2.69	2.46	2.59	3.13	3.51	4.59	4.88	4.95	2.76	3.13	3.37
Reasoning	2.95	3.58	4.00	2.31	3.42	2.33	1.63	2.25	1.93	1.78	2.67	2.35	3.45	4.75	4.62	2.33	3.50	3.10
Speed-Loaded	2.08	2.80	2.68	1.74	2.60	1.82	1.98	3.10	2.14	2.26	3.50	2.86	4.28	5.10	4.38	2.20	3.00	2.06
Visual	2.11	2.57	2.18	1.91	2.71	2.01	2.33	3.36	2.56	2.39	3.43	2.71	2.94	4.21	2.94	2.24	3.28	2.81
Auditory	2.67	3.00	3.10	2.43	2.83	2.57	3.80	4.83	3.90	4.10	5.17	4.10	4.23	5.17	4.43	2.77	3.17	2.67
Psychomotor	1.57	2.28	1.57	1.30	2.00	1.30	2.61	3.93	2.51	2.66	4.00	2.57	2.66	4.00	2.57	1.64	2.57	1.58
Gross Motor	1.06	1.65	1.01	1.06	1.65	1.01	1.63	2.50	1.72	1.73	2.70	1.89	1.83	2.85	1.89	1.45	2.35	1.49

Performance Demand Levels: 0-4 Low 4.6 Medium 6-7 High

Table 10

Decomposition of Critical JCAT Clusters into Skill and Ability Elements for AST Position

<u>CLUSTER</u>	<u>SKILL/ABILITY ELEMENT</u>	<u>(AVERAGE DEMAND LEVEL, 0-7 SCALE)</u>
Auditory	*Auditory Attention	(4.68)
	*General Hearing	(4.58)
	Sound Localization	
Communication	*Oral Comprehension	(5.08)
	*Written Comprehension	(4.66)
	*Oral Expression	(4.41)
	*Written Expression	(4.08)
Speed-Loaded	Time Sharing	
	Perceptual Speed/Choice Reaction Time	
	Speed of Closure	
	Reaction Time	
Conceptual	*Memorization	(4.58)
	Flexibility of Closure	
	Visualization	
	Problem Sensitivity	
	Spatial Orientation	
	Fluency of Ideas/Selective Attention	
	Originality	
Reasoning	Information Ordering	
	Inductive	
	Deductive	
	Number Facility	
	Mathematical Reasoning	
	Category Flexibility	
Visual	Near Vision	
	Visual Color Discrimination	
	Glare Sensitivity	
	Depth Perception	
	Peripheral Vision	
	Far Vision	
	Night Vision	
Psychomotor	Wrist-Finger Speed	
	Control Precision	
	Finger Dexterity	
	Manual Dexterity	
	Multi-Limb Coordination	
	Arm-Hand Steadiness	
	Rate Control	

*Skill/ability elements are in mid-level range (4-6) on 0-7 scale of performance demand.

markedly different. A decomposition of these clusters according to specific, "high driver" skills or abilities is shown in Table 11. Here it can be seen that only five elements from the five clusters are in the mid-level: oral comprehension, auditory attention, general hearing, oral expression, and selective attention. With the exception of selective attention, these are the same skill or ability elements of most critical importance for the DMCC (top five). The DMCC is distinguished by the fact that mid-level elements are also required from reasoning, conceptual, and speed-loaded clusters.

Content Analysis of Lessons Learned

In addition to the data collected with the structured, systematic procedures such as JCAT and the task sorting, a less formal analysis of expert comments and "lessons learned" was conducted using a content analysis approach. The major sources of these data were lessons learned database from ODS (compiled by Planning Research Corporation, 1991), and interviews with key personnel listed above. From ten pages of documentation regarding personnel tasks for the aircrew, as well as notes from interviews, certain key phrases occurred with unmistakable regularity; the most compelling example was that the Army aircrew positions, "particularly the DMCC, must be experienced!." A list of these recurring phrases (those that occur on every or every other page of documentation, or occur more than three times in a one hour interview) is found in Table 12.

Content analyses are limited when input sources are minimal and anecdotal, as in this case. However, these data do suggest trends which can be related to other, more substantive findings, such as the JCAT and task sort procedures detailed above. For example, findings suggest that the DMCC position, the deputy crew commander, is a powerful and important role, which must be a "hybrid," able to represent needs for all the salient JSTARS mission objectives: Surveillance, Target, Attack. In order to embrace and synchronize these, the individual must be versed in all three; thereby implying an experienced officer, capable of rapid and sound judgment and decision-making in areas encompassing Order of Battle, analysis, collection management, and target exploitation. These involve largely cognitive, and especially communications, reasoning, and conceptual types of skills. The key action verbs seen repeatedly in the transcripts and used in interview are: "monitor," "arbitrate," "represent GSM Ground Commanders interests," "develop," "exploit." These are not only primarily cognitive in nature but require the complimentary auditory attention ability requirement drawn out above.

Discussion and Implications of Findings

From the results presented above, obtained from the JCAT job assessment tool, task demand sortings, and lessons learned transcripts and interviews, certain trends are apparent.

Table 11

Decomposition of Critical JCAT Clusters into Skill and Ability Elements for TSS Position (Ranked in Order From Most to Least Performance Demand)

<u>CLUSTER</u>	<u>SKILL/ABILITY ELEMENT</u>	<u>(AVERAGE DEMAND LEVEL, 0-7 SCALE)</u>
Conceptual	*Selective Attention Memorization Problem Sensitivity Spatial Orientation Visualization Flexibility of Closure Fluency of Ideas Originality	(4.10)
Reasoning	Inductive Information Ordering Deductive Category Flexibility Mathematical Reasoning Number Facility	
Auditory	*Auditory Attention *General Hearing Sound Localization	(4.26) (4.16)
Speed-Loaded	Time Sharing Perceptual Speed & Accuracy Choice Reaction Time Speed of Closure Reaction Time	
Communication	*Oral Comprehension *Oral Expression Written Expression Written Comprehension	(4.56) (4.11)

*Skill/ability elements are in mid-level range (4-6) on 0-7 scale of performance demand.

Table 12

Frequently Occurring Phrases Related to Personnel Position
Requirements for Army Aircrew on JSTARS

- A hybrid person: surveillance-target-attack functions
 - Experienced
 - Order of Battle/analysis/collection management/exploitation
 - Officer, junior officer, senior NCO
 - Monitor, develop, document, interpret, present
 - Judgment and decision making ability and communication-arbitration
 - Point of contact for ground operations & tactics on-board interface with deployed GSMs
 - DMCC not more than one rank lower than ACE (Air Control Element-Mission Commander)
-

All positions, senior and junior, Desert Storm operations or JSTARS objective system, have a demand for cognitive skills at the mid-level range. Values are low or entry-level for abilities, with the exception of auditory, especially auditory attention. This strongly suggests that entry-level personnel should not be considered for the system and that only experienced (senior CPT, MAJ, LTC, minimum three tours; NCO, minimum two tours; Warrants) be considered for the aircrew. Ideally, prior experience would include work on the JSTARS Ground Station Module (GSM). This would provide a strong base of understanding regarding the ground battle requirements. (Should ideally come up through "ranks" with GSM. With the school GSM training this would include some basic understanding of events occurring aboard the E-8 aircraft.)

All Deputy Mission Crew Commander requirements exceed those of the GLO (Ground Liaison Officer in Desert Storm). Although technology to be available in the objective system is purported to greatly enhance and overcome procedural and technological limits of the prototype model available for Desert Storm, the senior Army position will still face greater demands, primarily cognitive and particularly communicative in nature. This is less so for the junior level positions. Here, technology should make operational tasks somewhat easier to perform and distribute between a

technician and a manager so that overloads are avoided. This still presumes a baseline of mid-level expertise for these positions. The selection of these personnel is important due to the increased perceptual abilities demands of the AST - auditory, visual, psychomotor. These types of abilities are a cluster of fine hand-eye-ear coordination typically associated with the operations of a workstation, but with the added loading of important communicating and listening tasks via radios and face-to-face interactions.

The most intense workload for all positions occurs "On-Station" as opposed to mission preparations, flight out, flight back, or mission debrief. This stands to reason, since this is when radar is active and radar service requests are being processed. This finding holds for all positions since more skills and abilities clusters are required at a higher level than for the other functions, with the notable exception of communication, which is strongly required across all functions, especially for the DMCC. The DMCC, in fact, has a greater communications demand during mission planning, brief, and debrief, than time On-Station.

The profile for the demanding Deputy Crew Commander position is for emphasis on auditory attention, oral and written communication, oral and written expression. As stated, these elements are as important in mission planning, briefing, and debriefing, as they are for the On-Station time in orbit. While in orbit, conceptual, reasoning, and speed-loaded skills are also highly important for the DMCC. These include such skills as time sharing, inductive and deductive reasoning, problem sensitivity, and are an added challenge to the communications demands already present. In all 14 of 25 skills and abilities which comprise the critical DMCC clusters require mid-level proficiency.

The Aerial Surveillance Technician and Army Radar Systems Manager will absorb and divide duties that were managed by the GLO and AST of Desert Storm. This off-loading and division of labor allows the AST to become more of a technician, to smoothly carry out protocols and procedures, and the TSS to manage radar service requests with dedication and focus. The profiles of these positions reflect this philosophy. The first level demands for TSS are conceptual and reasoning, followed by auditory, speed-loaded and communications; this is in contrast to the DMCC, whose most critical skill is communication. The first level demands for the AST are auditory attention, oral and written comprehension, followed by more but much lower level clusters of skills and abilities in conceptualization, reasoning, vision, and fine psychomotor. The number of skills and abilities required at mid-level proficiency, for both the AST and the TSS, are only half those of the DMCC.

DMCC data indicate the need for an individual with a strong communications capability, able to transition rapidly from technical to tactical concern with great facility. This means being capable of mastering the technical workings of the system, flight and crew protocols, supervisory duties, the on-going concerns of senior level commanders on the ground, and the ground station technicians at myriad stages of endeavor. The implication is for a "big-picture" thinker, knowledgeable about systems, tactics, intelligence needs and functions, as well as able to successfully co-exist with, and commandeer cooperation from personnel spanning the range from junior to senior level, technical to tactical, and across service. A senior rank is imperative to ensure broad intelligence and operational knowledge base, planning and briefing experience, and interpersonal competence and credibility.

AST and TSS data suggest the need for individuals at the higher NCO or warrant range, to effectively distribute technical duties on the aircraft which will serve the needs of the ground battle, under direction of the DMCC and other supervisors. The AST emerges as a technician, highly involved with a workstation console in order to perform processing tasks On-Station, and keeping in the communications net in both an oral and a message text (digital) mode. The TSS has less emphasis on the written (digital) communications, but greater focus on oral skills and auditory (listening) capability; being able to see a bigger picture than the AST technician is shown in the demand for refined conceptual and reasoning processes. This is the nature of the TSS function: managing radar service requests, timelines, and making sure priority needs are met in a timely fashion. AST and TSS perform planning and briefing functions only in a back-up or supportive role to the DMCC.

The consistent mid-level demands on communications, conceptual and reasoning processes, and auditory attention for all positions suggest a training plan that includes cognitive skill development and refinement in addition to technical procedures acquisition. The greatest demand for this will be for the DMCC. A parallel requirement is for interpersonal communications skills and the ability to relay as well as interpret data effectively. This can be trained but must be accompanied by on-the-job experience in a variety of situations.

Summary

A preliminary analysis of JSTARS Army aircrew positions was conducted using experts from the Operation Desert Storm JSTARS experience. The analysis approach consisted of a psychologically-based, systematic job assessment technique (JCAT), cognitive demand task-sort procedures, and content analysis of lessons learned data from Desert Storm. Trends drawn from these data indicate a significant cognitive (mental) demand for all

positions, a need for auditory attention ability, and interpersonal and written communication skills spanning the entire JSTARS mission flow from pre-flight to de-brief. These requirements are particularly compelling and critical for the Deputy Mission Crew Commander, the senior Army person on-board.

The Army aircrew mix as configured (Senior CPT, MAJ or LTC for DMCC; Warrant or Senior NCO, minimum E-7, for TSS; Junior NCO, minimum E-6, for AST) appears to be correct to meet the technical demands of the system. No less than these levels would be acceptable, as this would seriously compromise the required knowledge and integration of ground battle doctrine, tactics, and commander's needs which are an integral part of each of the jobs. Additionally, the heavy cognitive and attentional demands are also partially a function of Army and systems experience and cannot be adequately performed by initial entry level personnel or through short term OJT. This is most critical for the DMCC, but also, E-6 and E-7 must be the junior position baselines.

The analysis is preliminary in nature due to the limited number of experts available; however, the trends discovered strongly indicate the need to ensure that persons selected for these roles are not entry-level, so that they are capable of complex data handling and facility in interpersonal relations and communication. These types of skills are those typically produced most in depth in the Military Intelligence Branch, as professionalism is developed through rank.

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APPENDIX A

Definition and Commentary for Skills, Abilities, and Skill-Abilities Clusters in Current JCAT Configuration

In the current research, "abilities and skills" has been selected as a point of departure because of (1) its importance in describing both soldier capabilities and equipment demands, (2) the absence currently in the MI community of any systematic method for producing such descriptions, and (3) the body of past research providing a strong theoretical basis for methodological development.

For the JCAT application, the abilities and skills have been clustered to allow more efficient data analysis.

Grouping the abilities into clusters is an attempt to provide a procedural simplification. Clusters are not intended to be a substitute for the individual abilities but an adjunct to them. The clusters are meant to provide a shortcut, where appropriate, a way of speeding up description and comparison, more rapidly identifying where the emphasis should be, and easing the burden of dealing with 50 abilities.

The 50 individual abilities deal with cognitive, perceptual, psychomotor, and gross motor functions. For use with JCAT, they were organized into eight clusters. The clusters included from three to ten individual abilities. Each cluster has a particular focus, differing in scope and concreteness.

Briefly, the first three clusters all have a cognitive focus. The first, communication, includes four skills concerning the use of language. The second cluster, conceptual, is somewhat heterogeneous. Skills dealing with structuring, retaining, creating, recognizing, and focusing on information are included. The third cluster, reasoning, groups skill dealing with drawing conclusions, orderly thought, calculation, and the application of rules.

The fourth cluster, speed-loaded, includes decision making and perceptual functions, as well as reaction time, so it overlaps the concerns of the other clusters. The focus on timing is what sets it apart.

The fifth and sixth clusters group visual and auditory perceptual abilities, respectively. These two clusters are particularly good illustrations of how separate and discriminable abilities can have a common focus. No one visual ability is a substitute for any other, but all depend on the ability to see.

The seventh cluster includes a variety of psychomotor abilities and the eighth encompasses gross motor abilities associated with flexibility, equilibrium, coordination, strength, and stamina.

Definitions of 50 Skills and Abilities

1. **Oral Comprehension:** The ability to listen to and understand words and sentences.
2. **Written Comprehension:** The ability to understand written words, sentences, and paragraphs.
3. **Oral Expression:** The ability to use words or sentences in speaking so that others will understand.
4. **Written Expression:** The ability to use words or sentences in writing so that others will understand.
5. **Memorization:** The ability to memorize and remember information, such as words, numbers, pictures, and procedures. Pieces of information can be remembered by themselves or with other pieces of information.
6. **Problem Sensitivity:** The ability to tell when something is wrong or is likely to go wrong. It includes being able to identify the whole problem as well as the elements of the problem.
7. **Originality:** The ability to produce unusual or clever ideas about a given topic or situation. It is the ability to invent creative solutions to problems or develop new procedures for situations in which standard procedures do not apply or are not working.
8. **Fluency of Ideas:** The ability to produce a number of ideas about a given topic.
9. **Flexibility of Closure:** The ability to identify or detect a known pattern (like a figure, word, or object) that is hidden in other material. The task is to pick out the disguised pattern from the background material. (Pattern Recognition)
10. **Selective Attention:** The ability to concentrate on a task one is doing. This ability includes concentrating while performing a boring task and not being distracted.
11. **Spatial Orientation:** The ability to tell where you are in relation to the location of some object or to tell where the object is in relation to you.
12. **Visualization:** The ability to imagine how something will look when it is moved around or when its parts are moved or rearranged. It requires the forming of mental images of how patterns or objects would look after certain changes, such as unfolding or rotation. One has to predict how an object, set of objects, or pattern will appear after the changes are carried out.

13. **Inductive Reasoning:** The ability to combine separate pieces of information, or specific answers to problems, to form general rules or conclusions. It involves the ability to think of possible reasons for why things go together.

14. **Category Flexibility:** The ability to produce many rules so that each rule tells how to group a set of things in a different way. Each different group must contain at least two things from the original set of things.

15. **Deductive Reasoning:** The ability to apply general rules to specific problems to come up with logical answers. It involves deciding if an answer makes sense.

16. **Information Ordering:** The ability to follow correctly a rule or set of rules to arrange things or actions in a certain order. The rule or set of rules used must be given. The things or actions to be put in order can include numbers, letters, words, pictures, procedures, sentences, and mathematical or logical operations.

17. **Mathematical Reasoning:** The ability to understand and organize a problem and then select a mathematical method or formula to solve the problem. It encompasses reasoning through mathematical problems to determine appropriate operations that can be performed to solve problems. It also includes the understanding or structuring of mathematical problems. The actual manipulation of numbers is not included in this ability.

18. **Number Facility:** Involves the degree to which adding, subtracting, multiplying, and dividing can be done quickly and correctly. These can be steps in other operations like finding percentages and taking square roots.

19. **Time Sharing:** The ability to shift back and forth between two or more sources of information.

20. **Speed of Closure:** Involves the degree to which different pieces of information can be combined and organized into one meaningful pattern quickly. It is not known beforehand what the pattern will be. The material may be visual or auditory.

21. **Perceptual Speed and Accuracy:** Involves the degree to which one can compare letters, numbers, objects, pictures, or patterns, quickly and accurately. The things to be compared may be presented at the same time or one after the other. This ability also includes comparing a presented object with a remembered object.

22. **Reaction Time:** The ability to give one fast response to one signal (sound, light, picture) when it appears. This ability is concerned with the speed with which the movement can be started with the hand, foot, or other parts of the body.

23. **Choice Reaction Time:** The ability to choose between two or more movements quickly and accurately when two or more different signals (lights, sounds, pictures) are given. The ability is concerned with the speed with which the right response can be started with the hand, foot, or other parts of the body.
24. **Near Vision:** The capacity to see close environmental surroundings.
25. **Far Vision:** The capacity to see distant environmental surroundings.
26. **Night Vision:** The ability to see under low light conditions.
27. **Visual Color Discrimination:** The capacity to match or discriminate between colors. This capacity also includes detecting differences in color purity (saturation) and brightness (brilliance).
28. **Peripheral Vision:** The ability to perceive objects or movements towards the edges of the visual field.
29. **Depth Perception:** The ability to distinguish which of several objects is more distant from or nearer to the observer, or to judge the distance of an object from the observer.
30. **Glare Sensitivity:** The ability to see objects in the presence of glare or bright ambient lighting.
31. **General Hearing:** The ability to detect and to discriminate among sound that vary over broad ranges of pitch and/or loudness.
32. **Auditory Attention:** The ability to focus on a single source of auditory information in the presence of other distracting and irrelevant auditory stimuli.
33. **Sound Localization:** The ability to identify the direction from which an auditory stimulus originated relative to the observer.
34. **Control Precision:** The ability to move controls of a machine or vehicle. This involves the degree to which these controls can be moved quickly and repeatedly to exact positions.
35. **Rate Control:** The ability to adjust an equipment control in response to changes in the speed and/or direction of a continuously moving object or scene. The ability does not extend to situations in which the speed and direction of the object are perfectly predictable.

36. Wrist-Finger Speed: The ability to make fast, simple, repeated movements of the fingers, hands, and wrists. It involves little, if any, accuracy or eye-hand coordination.

37. Finger Dexterity: The ability to make skillful, coordinated movements of the fingers of one or both hands and to grasp, place, or move small objects. This ability involves the degree to which these finger movements can be carried out quickly.

38. Manual Dexterity: The ability to make skillful coordinated movements of one hand, a hand together with its arm, or two hands to grasp, place, move, or assemble objects like hand tools or blocks. This ability involves the degree to which these arm-hand movements can be carried out quickly. It does not involve moving machine or equipment controls like levers.

39. Arm-Hand Steadiness: The ability to keep the hand and arm steady. It includes steadiness while making an arm movement as well as while holding the arm and hand in one position. This ability does not involve strength or speed.

40. Multi-Limb Coordination: The ability to coordinate movements of two or more limbs (for example, two legs, or one leg and one arm), such as in moving equipment controls. Two or more limbs are in motion while the individual is sitting, standing, or lying down.

41. Extent Flexibility: The ability to bend, stretch, twist, or reach out with the body, arms or legs.

42. Dynamic Flexibility: The ability to bend, stretch, twist, or reach out with the body, arms, and/or legs, both quickly and repeatedly.

43. Speed of Limb Movement: Involves the speed with which a single movement of the arms or legs can be made and/or repeated. This ability does not include accuracy, careful control, or coordination of movement.

44. Gross Body Equilibrium: The ability to keep or regain one's body balance or to stay upright when in an unstable position. This ability includes maintaining one's balance when changing direction while moving or standing motionless.

45. Gross Body Coordination: The ability to coordinate the movement of the arms, legs, and torso together in activities in which the whole body is in motion.

46. Static Strength: The ability to use muscle force in order to lift, push, pull, or carry objects. It is the maximum force that one can exert for a brief period of time.

47. **Explosive Strength:** The ability to use short bursts of muscle force to propel oneself or an object. It requires gathering energy for bursts of muscle effort over a very short time period.

48. **Dynamic Strength:** The ability of the muscles to exert force repeatedly or continuously over a long time period. This is the ability to support, hold up, or move the body's own weight and/or objects repeatedly over time. It represents muscular endurance and emphasizes the resistance of the muscles to fatigue.

49. **Trunk Strength:** Involves the degree to which one's stomach and lower back muscles can support part of the body repeatedly or continuously over time. The ability involves the degree to which these trunk muscles do not fatigue when they are put under repeated or continuous strain.

50. **Stamina:** The ability of the lungs and circulatory systems of the body to perform efficiently over long time periods. This is the ability to exert oneself physically without getting out of breath.