NAVAL MEDICAL RESEARCH UNIT DAYTON

UAS Cross Platform JTA Final Report

Mangos, Vincenzi, Shrader, Williams, Arnold

NAMRU-D REPORT NUMBER 14-44

Reviewed and Approved
28 JULY 2014

Jeffrey M. Andrews, CAPT, MSC, USN
Commanding Officer

The views expressed in this article are those of the author and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, nor the U.S. Government.

This work was funded by work unit number 71002.

The study protocol was approved by the Naval Air Warfare Center (NAVAIR) in compliance with all applicable Federal regulations governing the protection of human subjects.

REPORT DOCUMENTATION PAGE

1. REPORT DATE (DD MM YY)
18 JULY 2014

2. REPORT TYPE
Technical Report

3. DATES COVERED (from – to)
Dec 2009 – Dec 2011

4. TITLE
UAS Cross Platform JTA Final Report

5a. Contract Number:
5b. Grant Number:
5c. Program Element Number:
5d. Project Number:
5e. Task Number:
5f. Work Unit Number: 71002

6. AUTHORS
Mangos, Vincenzi, Shrader, Williams, Arnold

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Medical Research Unit Dayton
2624 Q Street, Bldg. 851, Area B
WPAFB, OH 45433-7955

8. PERFORMING ORGANIZATION REPORT NUMBER
NAMRU-D-14-44

8. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)
Naval Air Warfare Center (NAVAIR)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(s)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

A comprehensive job analysis was conducted to describe task and knowledge, skill, ability, and other characteristics (KSAO) profiles for several Unmanned Aircraft Systems (UAS) in the U.S. Navy and U.S. Marine Corps. The primary data collection tool was a survey consisting of 256 task statements organized into 20 task categories, and 67 KSAOs organized into 17 categories. The survey was developed through an iterative process of deriving task statements from multiple operational and training-related UAS source references, integrating and eliminating redundant statements, and validating statements through subject matter expert (SME) reviews. Data regarding task frequency, importance, difficulty to learn, and mastery requirements, and KSAO importance were collected across 18 platform/position combinations. Mean task and KSAO rating profiles, interrater agreement statistics, and pairwise position similarity statistics (hierarchical cluster analysis results and Squared Euclidean Distance [SED] values) are provided for all platforms, positions, and platform/position combinations. Results highlight key task requirements and relevant competencies for UAS work. Tasks related to airspace and operating area management, crew task management, fuel and power management, intelligence, surveillance, and reconnaissance (ISR) were rated consistently high in terms of importance and frequency. KSAOs related to conscientiousness, communication skills, multitasking and attention skills, coping with stress and emergencies, and social and interpersonal skills were rated as universally important. Results will be used to support a variety of UAS performance prediction and improvement initiatives, including personnel selection, training, human-system engineering, equipment enhancements, and manpower and personnel applications.

15. SUBJECT TERMS
UAS human factors; UAS job analysis; UAS task analysis; UAS operator requirements.

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	18a. NAME OF RESPONSIBLE PERSON
UNCL	UNCL	UNCL	UNCL	142	CAPT Jeffrey M. Andrews, Commanding Officer

18b. TELEPHONE NUMBER (INCLUDING AREA CODE)
COMM/DSN: 937-938-3872 (DSN: 798)

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18

Acknowledgements:

The authors wish to acknowledge and thank the many individuals who assisted and supported this project, including our NAVAIR sponsors, all members of our tri-laboratory research team whose invaluable contributions ensured project success, and most importantly the UAS operators and other subject matter experts who generously offered their time and expertise to assist with development of our task survey, and ultimately as survey respondents.

Executive Summary

A comprehensive job analysis was conducted to describe task and knowledge, skill, ability, and other characteristics (KSAO) profiles for several Unmanned Aircraft Systems (UAS) in the U.S. Navy and U.S. Marine Corps. The primary data collection tool was a survey consisting of 256 task statements organized into 20 task categories, and 67 KSAOs organized into 17 categories. The survey was developed through an iterative process of deriving task statements from multiple operational and training-related UAS source references, integrating and eliminating redundant statements, and validating statements through subject matter expert (SME) reviews. Data regarding task frequency, importance, difficulty to learn, and mastery requirements, and KSAO importance were collected across 18 platform/position combinations. Mean task and KSAO rating profiles, interrater agreement statistics, and pairwise position similarity statistics (hierarchical cluster analysis results and Squared Euclidean Distance [SED] values) are provided for all platforms, positions, and platform/position combinations. Results highlight key task requirements and relevant competencies for UAS work. Tasks related to airspace and operating area management, crew task management, fuel and power management, intelligence, surveillance, and reconnaissance (ISR) were rated consistently high in terms of importance and frequency. KSAOs related to conscientiousness, communication skills, multitasking and attention skills, coping with stress and emergencies, and social and interpersonal skills were rated as universally important. Results will be used to support a variety of UAS performance prediction and improvement initiatives, including personnel selection, training, human-system engineering, equipment enhancements, and manpower and personnel applications.

Keywords: UAS human factors; UAS job analysis; UAS task analysis; UAS operator requirements.

Table of Contents

Problem Background

Use of unmanned aircraft systems (UAS) has proliferated throughout U.S. military communities. Increased use of UAS technologies has changed the role of the human operator in hazardous, high-stakes military operations. In many cases, unmanned systems can remove human assets from direct exposure to the most hazardous elements of flight. However, UAS operations place a different set of demands on operators than those experienced during manned flight. In contrast to manned flight, UAS operators must act as supervisory monitors and controllers of multiple, complex systems related to a vehicle in which they are not physically present. One might expect that a unique constellation of both cognitive skills and noncognitive attributes (e.g., personality traits) are essential for this unique role.

Multiple efforts have been pursued to attempt to define and quantify the range of personal attributes associated with effective UAS operation. These efforts have been conducted relatively independently as each has focused on a different mechanism of operator performance improvement, for example, personnel selection, training, human-system engineering, equipment enhancements, or manpower and personnel applications. To date, a unified effort to systematically describe and quantify competency requirements associated with effective UAS operation across Navy and Marine Corps positions and platforms has not been conducted. However, before one can even begin to describe cognitive or noncognitive attributes (collectively referred to as knowledge, skills, abilities, and other personal characteristics, or KSAOs) associated with UAS operation, one must accurately define what UAS operators actually do in the course of their work.

Objective

These issues described above drive the primary objective of the current study: **to systematically define, quantify, and describe both task and competency requirements of effective UAS operation via a systematic, comprehensive job analysis of all extant Navy and Marine Corps UAS platforms and positions.** This analysis is intended to serve as the basis for multiple, cross-platform HSI-related applications targeting operator performance improvement. A comprehensive and detailed task analytic foundation is necessary to support the development of relevant, synergistically connected performance improvement applications (e.g., skill assessments that inform both immediate personnel selection and long-term performance management and training). However, existing task analyses have been conducted in a relatively disconnected manner, as each has focused on specific applications or systems. The few studies that have addressed cross-platform UAS issues have often lacked the level of detail with respect to task and KSAO requirements to inform multiple HSI applications (e.g. Weeks, 2000; Tvaryanas, 2006). Other analyses have addressed only single UAS types or small groups of systems (e.g., Pioneer – Biggerstaff, Blower, Portman and Chapman, 1998; Reaper and Predator (AF) – Tvaryanas, 2006; Shadow 200 and Hunter (Army) – Bruskiewicz, Houston, Hezlett and Ferstl, 2007; Predator (AF) – Triplett, 2008). Among available system-specific analyses, only the Bruskiewicz et al. (2007) study approaches the level of detail required to inform multiple specific HSI applications. However, even in this case, the job analysis methods used were designed specifically for personnel selection applications, and thus lacked rating scales such as "task difficulty to learn", "minimum required level of task performance - novice", or "minimum required level of task performance - expert" that could adequately inform applications such as training system development. An effort to standardize UAS training requirements across platforms in a joint and coalition context is found in NATO STANAG 4670 (NATO, 2006). Although the NATO document provides a fairly comprehensive general UAS task taxonomy, its focus is on training requirements, and the task statements reflect this. Essential KSAOs required to effectively operate UAS platforms are only tangentially addressed. Considering all extant task analyses, what is missing – and what is required for effective, empirically grounded UAS standardization efforts – is a comprehensive cross-platform UAS task analysis, addressing operator task and KSAO requirements in detail, identifying those elements common to all UAS, those common to subsets of UAS, and those unique to each system or crew position.

In sum, no effort to date has encompassed a wide sampling of extant UAS platforms to identify both common and unique operator task and KSAO requirements, including requirements by crew position (e.g., mission commander, air vehicle operator, payload operator). A current trend toward standardization of UAS operations highlights the need for an overarching analysis of the operator task requirements across UAS platforms, to inform applications such as: standardized interfaces, general and unique system training requirements, and manpower and personnel requirements across platforms. Therefore, the current study represents the first effort to conduct a comprehensive job-task analysis of large diverse sampling of extant UAS platforms, including all crew positions in each system examined.

Job Analysis – Background and Applications

Job analysis is the process of systematically analyzing, quantifying, and describing task and competency requirements of a predefined work domain. Job analysis has many potential applications, ranging from personnel selection assessment and training development to human factors applications. The broad applicability of job analysis as a foundation for multiple human performance improvement initiatives can be attributed to its provision of task-based “blueprint” of work and worker requirements. By quantifying the range of tasks that comprise a given work domain, and the range of competencies required for effective performance in that domain, job analysis results can be used to inform, plan, and evaluate a range of initiatives.

Job analysis efforts can range in terms of their level of comprehensiveness and detail. In personnel selection applications, job analysis results must be able to support inferences about performance prediction in the target domain. This involves understanding relationships among task demands, personal attributes underlying effective performance (e.g., cognitive abilities, personality traits), and measures of task performance and effectiveness in the domain. Human-systems engineering applications may require a level of detail sufficient for a cognitive task analytic approach to decompose and quantify domain tasks. Such applications may require a deep and detailed understanding of the sequence of cognitive events underlying observable task performance. In order to meet the demands of multiple human performance initiatives, a comprehensive cross-platform UAS task analysis must achieve a balance between level of detail and comprehensiveness/scope.

To meet our objective of conducting a job analysis with true cross-platform applicability, we relied primarily on a hierarchically organized job analysis questionnaire (JAQ). Hierarchical organization of task and competency information would allow us to flexibly sample job information at multiple levels of analysis. Furthermore, it would allow a mechanism for capturing only essential information from subject matter experts (SMEs) while minimizing survey time requirements. Our approach to developing and administering the JAQ, discussed in greater detail below, was guided by existing legal and professional guidelines (e.g., the Uniform Guidelines on Employee Selection Procedures, 1978, set forth by the Equal Employment Opportunity Commission, Civil Service Commission, Department of Labor, and Department of Justice, Society for Industrial and Organizational Psychology's Principles for the Validation and Use of Personnel Selection Procedures, 2003).

Given the potential scope of a Navy-wide, cross-platform job analysis, an additional challenge was to efficiently collect a large amount of detailed task and competency data. Data collection efficiency and comprehensiveness are potentially conflicting objectives in job analysis. Furthermore, because survey-based job analysis methods rely heavily on subjective human judgments, the possibility of overwhelming SMEs with long lists of detailed tasks and KSAs and can have a direct, negative influence on data quality. Researchers have been concerned enough with this issue to study it specifically (e.g., Dierdorff & Rubin, 2007; Dierdorff & Wilson, 2003; Morgeson, Delaney-Klinger, Mayfield, Ferrara, & Campion, 2004). Results from these studies highlight the pervasiveness, sources, and consequences of inaccuracy in job analysis, and emphasize key sources of inaccuracy in job analysis ratings (e.g., social influences, self-presentation influences, and cognitive biases related to excess or deficient work domain information).

Findings such as these motivated us to pay special attention to the quality and accuracy of our job analysis data, in addition to its comprehensiveness and inherent detail. We employed a number of measures to ensure an accurate yet efficient data collection methodology (e.g., hierarchical JAQ organization, branching survey methodology, comprehensive data cleaning, interrater agreement and reliability analyses; discussed in greater detail below). To establish context for our technical job analytic approach, we begin with a brief description of the individual training pipelines.

Group 1: RQ-11 Raven

The RQ-11 Raven was developed in 2002 by AeroVironment Inc, (AV) as a Group 1, man-portable tactical UAS for battalion level and below operations. Early deployment was in 2004 in support of Operation Enduring Freedom and Operation Iraqi Freedom (OEF/OIF) where it proved invaluable to tactical ground units for over-the-hill, real-time direct situational awareness for combat support and target information. The "B" variant began production in 2006 and is currently fielded by all branches of the U.S. military and a number of NATO nations with over 13,000 delivered.

The Raven is hand-launched with typical operating range of 10 KM and altitude of 500 to 1,000 ft. above ground level (AGL), weighs 4.2 lbs., and contains a rechargeable, battery operated powerplant for flight endurance of 60-90 minutes. Modular, fixed camera payloads with digital pan-tilt-zoom include electro-optical (EO), Infrared (IR), and eye-safe IR illuminator. The air vehicle (AV) is controlled through a ground control station for manual or autonomous GPS point-to-point navigation and flight maneuvering.

Specifications

Length	3.0 ft (0.9 m)
Wing Span	4.5 ft (1.4 m)
Weight	4.2 lbs (1.9 kg)
Speed	17-44 knots (32-81 km/h)
Operating Altitude	(Typ.) 100-500 ft (30-152 m) AGL, 14,000 ft MSL max launch altitude
Endurance	60–90 minutes (Rechargeable Battery), 80–110 Minutes (Single Use Battery)
Range	10 km
Standard Payloads	Dual Forward and Side-Look EO Camera Nose, Electronic Pan-tilt-zoom with Stabilization, Forward and Side-Look IR Camera Nose (6.5 oz payloads).
GCS	Lightweight, Modual Components, Waterproof Softcase, Optional FalconView Moving Map and Mission Planning Laptop Interface, Digital Video Recorder and Frame Capture.
Launch & Recovery Method	Hand-Launched, Deep Stall Landing

Group 2: ScanEagle

ScanEagle is a long-endurance Group 2 UAS manufactured by Insitu Group, a subsidiary of Boeing.

It is fielded by the U.S. Navy, U.S.M.C., and U.S.A.F with the majority of those systems under service contracts. As of July 2011 ScanEagle had logged 500,000 combat flight hours and flown more than 56,000 sorties.

ScanEagle's unique runway-independent catapult launcher and Skyhook recovery system make it ideal for Navy/Marine Corps remote and ship-board operations. Differential GPS units on both the Skyhook and onboard the ScanEagle guide the UAV to a suspended cable on the Skyhook where a patented clip mechanism at the end of each wingtip captures the cable.

Payload packages are modular, with the basic configuration an inertial stabilized and gimbaled, high-resolution EO or IR camera. Sensor data links have integrated cursor-on-target capability for integrated operations and a communications range greater than 55 nautical miles (100 km). Conversion variants of the ScanEagle platform include the ScanEagle Dual Bay, an elongated fuselage supporting the world's smallest Synthetic Aperture Radar, or the NightEagle, equipped with a mid-wave infrared (MWIR) camera for enhanced day/nighttime imaging.

Specifications

Length	4.5 ft (1.37 m)
Wing Span	10.2 ft (3.11 m)
Empty Weight	28.8 lb (13.1 kg)
Maximum Takeoff Weight	44.0 lb (20.0 kg)
Max Speed	80 knots (148 kph)
Cruise Speed	48 kts (89 kph)
Ceiling	19,500 ft (5,944 m)
Endurance	24+ hours
Propulsion	1.9 hp (1.4 kw), 2-stroke engine
Fuel	Gasoline (100 octane unleaded non-oxygenated gas) or Heavy fuel (JP5, JP8, Jet-A)
Navigation	GPS/Inertial

Group 3: RQ-7 Shadow

Manufactured by AAI Corp, the group 3 RQ-7 Shadow is the current U.S. Army and Marine Corps mainstay for brigade level UAS ISR products. The first RQ-7 Shadows were acquired by the Army in 1999 with the Marine Corps adopting the Shadow in 2006 to replace their Pioneer UASs. As of 2010 the Shadow has logged more than 505,000 combat flight hours in direct support of Operations Enduring Freedom (OEF), Iraqi Freedom (OIF), and New Dawn (OND).

The Shadow is rail-launched via catapult or unassisted takeoff from improved surfaces. Recovery is automated through a Take-off and Landing System (TALS) and arresting gear. It is controlled through AAI Corp's STANAG 4586 compliant interoperative One System Ground Control System (OSGCS) and crewed by an Air Vehicle Operator (AVO) and a Mission Payload Operator (MPO). The OSGCS can upload imagery, telemetry, and targeting data directly to the Joint Surveillance and Target Attack Radar System, All Sources Analysis System, and the Advanced Field Artillery Tactical Data System in near real time. Payloads are gimbaled plug-in optical payloads (POP) EO/IR sensors with laser-pointing capabilities with the POP 300 and Laser Designation (LD) with the POP 400 sensor payload packages. The EO/IR, payload can detect targets at a 10-km slant range from an altitude of 15,000 ft. and transmit data approximately 125 kilometers (km) from the ground control station.

Specifications

Length	11.8 ft. (3.6 m)
Wingspan	20.4 ft. (6.2 m)
Maximum gross weight	460 lb. (208 kg)
Maximum speed	110 kts (203 kph)
Cruise speed	90 kts (166 kph)
Loiter speed	65 kts (120 kph)
Maximum altitude	15,000 ft. (4,572 m)
Endurance	nine hours
Payload capacity	45-80 lb. (36 kg)
Powerplant	Rotary engine (gasoline)

Group 4: MQ-8 Fire Scout

The MQ-8 Fire Scout was developed by Northrop-Grumman as a Group 4 multi-mission, vertical takeoff and landing (VTOL), unmanned platform for air-capable ship operations. The platform's primary design capabilities are in support of Littoral Combat Ship (LCS), anti-submarine, anti-surface, and anti-mine warfare operations. It has the ability to autonomously take-off and land on remote stationary landing sites or capable warships. The Navy's first deployment of the MA-8B variant was in September 2009 aboard the Frigate USS McInerney (FFG-8). Projected Navy production is for 168 platforms.

Fire Scout provides day and night real-time intelligence, surveillance, and reconnaissance (ISR), targeting, and communications relay with battlefield management capabilities all interfacing through Tactical Common Data Link. Fire Scout has a 600 pound lift capacity and utilizes Modular Mission Payloads, including EO/IR base optics and laser range finder/designator capabilities. Growth payloads include: Communications Intelligence/Signals Intelligence (COMINT/SIGINT), Tactical Synthetic Aperture Radar/Moving Target Indicator (SAR/MTI), Joint Tactical Radio System (JTRS), Traffic Collision Avoidance System (TCAS), SATCOM, Sonobuoy delivery, expendables employment, threat countermeasures, and mine detection.

Specifications

Length	31.7 ft
Height	9.8 ft
Weight	zero fuel weight - 2,073 lbs; maximum takeoff, 3,150 lbs
Speed	125+ kts (231+ kph)
Ceiling	20,000 ft
Range	110 nm radius, five-plus hours on station
Endurance	>8 hours continuous system on station coverage >5 hours on station time (single vehicle) at 110 nm
Powerplant	one Rolls-Royce 250C20W heavy fuel turboshaft engine
Payload	600 pounds, including electro-optical/infrared sensor and laser designator

Group 5: RQ-4A BAMS-D

The Broad Area Maritime Surveillance – Demonstrator (BAMS-D) is administered through PMA-262 and based at Patuxent River NAS. The BAMS-D program consists of two Northrop-Grumman Block 10 RQ-4A Global Hawk UAVs and support equipment that are specifically adapted to maritime and littoral ISR missions. The purpose of the program is to demonstrate Naval multi-intelligence, high-altitude, long endurance, persistent ISR capabilities, develop Concept of Operations (CONOPS), and refine Tactics, Techniques, and Procedures (TTP) for use in the maritime environment.

The RQ-4A operates at altitudes up to 65,000 feet with a maximum endurance of 35 hours. Platform control, imagery, and other data products are transferred through satellite communications to a Tactical Auxiliary Ground Station (TAGS). BAMS-D first successfully deployed in 2008 supporting the Trident Warrior and RIMPAC exercises and was used to develop methods for integrating the Automatic Identification System (AIS) into Fleet operations. Among other missions, BAMS-D supports U.S. Northern Command collecting Fleet-relevant meteorological data and providing civilian wildfire and severe weather reconnaissance.

Specifications

Length	44.0 feet (13.4 meters)
Height	15.2 feet (4.6 meters)
Wingspan	116 feet (35.4 meters)
Weight	Max design gross take-off 25,750 pounds
Airspeed	340 knots (630 kph)
Ceiling	65,000 feet (19.8 km)
Endurance	35 hours (with reserves)
Range	12,000 nautical miles (22,236 kilometers)
Propulsion	1 Rolls-Royce AE3007H turbofan
Crew	2 pilots, 2 sensor operators, 1 Tactical Coordinator (TACCO), 1 Tactical Auxiliary Ground Station Operations Officer (TOPS)
Sensors	Automatic Identification System (AIS) receiver, Electronic Support Measures (ESM) and the following side-looking sensors Electro-Optical/Infrared(EO/IR) camera, maritime-enabled Synthetic Aperture Radar (SAR) and Inverse Synthetic Aperture Radar (ISAR)
Communications	Ku SATCOM Datalink, Dual Band CDL LOS (X, Ku), UHF SATCOM/LOS via C2 INMARSAT, and C2 ATC Voice

Group 5: MQ-4C BAMS

The MQ-4C is the next generation naval derivative of the U.S.A.F.'s RQ-4 Global Hawk high altitude, long endurance advanced UAS. The Navy awarded the MQ-4C BAMS program to Northrop-Grumman in April 2008 and it is managed through PMA-262. The program successfully completed its System Functional Review (SFR) in 2009 with System Development and Demonstration (SDD) aircraft delivery planned for 2012 and Initial Operational Capability (IOC) for 2015. BAMS will be integrated into the Navy's Maritime Patrol and Reconnaissance Force (MPRF) Family of Systems (FoS) airborne assets to compliment the P-8A, EP-X and P-3 manned aircraft missions.

As a multi-mission platform, BAMS will provide persistent ISR, strike, signals intelligence, and communications relay in support of theater-level, operational, and tactical users over large maritime distances (2000 nm) for long durations with 80% Effective Time on Station (ETOS). The MQ-4C platform can carry a wide variety of sensors including maritime radar, EO/IR, Electronic Support Measures (ESM), Automatic Identification System (AIS), 360 degree Multi-Function Active Sensor (MFAS) for 360 degree Field of Regard, MTS-B multi-spectral targeting, AN\ZLQ-1 Electronic Support Measures (ESM), and a full complement of basic and advanced communications.

Specifications

Length	47.6 feet (14.5 meters)
Height	15.3 feet (4.7 meters)
Wingspan	130.9 feet (39.9 meters)
Weight	Max design gross take-off 32,250 pounds (14,628.4 kilograms)
Airspeed	310 knots (574 kph)
Ceiling	60,000 feet (18,288 meters)
Endurance	30 hours
Range	>9,950 nautical miles (>18,427 kilometers), max unrefueled range
Propulsion	Rolls-Royce AE3007H
Crew	4 per ground station (Air Vehicle Operator, Mission Commander/Comms., 2 Sensor Operators)
Payloads	Communications relay capability, beyond line of sight and line of sight communications and the following 360-degree Field Of Regard (FOR) sensors Multi-Function Active Sensor (MFAS) Maritime Radar, Electro-Optical / Infrared (EO/IR) sensor, Automatic Identification System (AIS) receiver and Electronic Support Measures (ESM)

Group 5: X-47 UCAS

The initial UCAS demonstrator prototype programs for the U.S.A.F. (Boeing X-45) and U.S.N. (Northrop-Grumman X-47) were consolidated into the Joint Unmanned Combat Aircraft System (J-UCAS) in 2004.

Following a Quadrennial Defense Review (QDR) the J-UCAS program was restructured as the UCAS-Carrier Demonstration (UCAS-D). In 2007, Northrop-Grumman's X-47 was chosen over Boeing's X-45, although Boeing has continued development of the X-45, now "C" variant, with in-house funding.

PMA-268 oversees the UCAS-D program and is charged with the mission to "mature technologies for a carrier suitable, low observable relevant, unmanned air system in support of a potential follow-on acquisition milestone for an unmanned air system capable of providing persistent, penetrating surveillance, and penetrating strike capability in high threat areas" (NAVAIR Aircraft and Weapons). The first successful flights of the X-47B occurred in early 2011 followed by a successful carrier landing on July 5, 2011 of an F/A-18D manned surrogate aircraft emulating the X-47 autonomous flight system. Sea trials and an attempt of the X-47 at a carrier landing are scheduled for 2012. Two platforms will be built for testing and the final capabilities demonstration in 2013.

Specifications

Length	38.2 ft
Height	10.4 ft
Wingspan	62.1 ft
MGTOW-Carrier	44,500 lbs
Top Speed	High subsonic
Altitude	> 40,000 feet
Range	> 2,100 nm
Powerplant	Pratt & Whitney F100-PW-220U
Weapons Bay	4,500 pounds
Sensors	EO/IR/SAR/ISAR/GMTI/MMTI/ESM
Airborne Refueling	Autonomous Aerial Refueling Probe and Drogue (USN) Boom Receptacle (USAF)

Technical Approach – Job Analysis Questionnaire (JAQ) Development

Our data collection strategy revolved around the use of a single, comprehensive, hierarchically organized JAQ consisting of both task and KSAO statements. Our method for generating task statements for the task list was to 1) acquire, organize, and aggregate existing task information from each UAS platform and position to develop initial platform-specific task lists, 2) reduce and revise the initial lists with input from SMEs, 3) combine the platform- and position-specific lists into a single master task list, eliminating redundant task statements 3) organize the individual tasks into a hierarchy of task clusters, (to form the basis of a branching survey strategy); and 4) vet the revised, categorized list with the Navy UAS project team and select SMEs.

The first step involved acquiring all existing job/task analytic information, training curricula, and existing task lists. Many of these initial lists were drawn from materials supplied by training commands (e.g., Training and Education Command). We also derived tasks from platform-specific training curricula and syllabi and documents describing standard flight and emergency procedures for various platforms. These materials, identified in the Reference section (*) were used to construct an initial list of tasks specific to each platform and crew position.

We then combined the platform- and position-specific task statements into a single, comprehensive list. Individual tasks were assigned to initial task categories. We then sorted the initial list (consisting of ~2,000 task statements) by task category and removed or combined functionally similar/redundant statements. Our primary objective was to develop a logical sequence of tasks that corresponded generally to the sequence of tasks performed in a typical UAS mission. This would support effective task survey branching and allow respondents to mentally review the tasks in the same sequence in which they would perform them during a mission. Additionally, we attempted to write task statements with the highest level of specificity possible that would still allow SMEs from every platform to which a task applied to understand and respond accurately to the statement.

After multiple iterations of categorizing and reducing statements, we produced a revised list of 300 task statements organized into 21 mission phase categories. The project team then held an internal workshop for the purpose of further refining and reducing the list. In addition to the core project team, one SME was present to offer feedback on individual task statements and revisions. The list was reduced to 256 individual statements organized into 20 categories. The list was then vetted through multiple SMEs representing each platform to confirm structure, accuracy, comprehensiveness, and level of detail, and to verify technical language usage. Minor changes to individual statements were made as a result of this final SME screen. The final task list, provided in Appendix A, provides names and definitions of individual tasks organized by task group.

Rating Scales

Our choice of rating scales was guided by our goal to produce job analytic results that would support multiple performance improvement initiatives (e.g., personnel selection, training, human-systems engineering). We developed four rating scales targeting task importance, difficulty to learn, frequency, and level of mastery required for a qualified operator. Task importance was defined as the degree to which incorrect performance of the task would result in negative consequences to mission effectiveness or safety. The task importance dimension was measured as an absolute task scale, with respondents instructed to consider the importance of each task individually and not relative to each other. Difficulty to learn was defined as the degree of difficulty in learning to perform a task successfully and independently. The difficulty scale was defined as a relative (vice absolute) task scale in that respondents were instructed to consider the total amount of time and effort required to perform a task relative to all other tasks. Frequency was defined as the number of times a task is performed over the course of a predefined time period, such as a mission, and was defined as an absolute scale. Level of mastery for a qualified operator was defined as the percentage of time a qualified UAS operator must perform a task at a high level of mastery, without errors, delays, or assistance from others, and was defined as an absolute rating scale. Appendix B shows the actual instructions, wording, and response options of the rating scales.

KSAO List Development

Candidate KSAOs were drawn from a previous comprehensive task analysis of the manned flight domain (Mangos et al., 2005), as well as the research literature on cognitive and noncognitive attributes. The initial list of KSAOs was refined and supplemented with additional competencies suggested by the internal project team and SMEs. The KSAO list targeted cognitive abilities, noncognitive constructs (e.g., personality constructs) and physical, perceptual, and psychomotor abilities. The final list consisted of 67 KSAOs organized into 17 categories, and is included in Appendix C.

Data Collection

The final task and KSAO lists, in addition to a brief list of demographic items and informed consent documentation, were assembled into an online survey using the Key Survey program (http://www.keysurvey.com/). The study was reviewed and approved as exempt research under authority of the Naval Aerospace Medical Research Laboratory Institutional Review Board (IRB), which served as the single site IRB authority under an Institutional Agreement for IRB Review (IAIR) between the three participating laboratories. The study was also reviewed and approved by both Navy and Marine Corps survey review authorities. Surveys were administered to participants via unique survey link URLs.

Results

Participant Demographics

We distributed the JAQ to 106 participants and received 79 complete responses, reflecting a response rate of 74.5%. Participants reported an average of 3.09 years in their current reported position (SD = 2.77), and an average of 1218.43 manned (SD = 1887.99) and 710.11 unmanned (SD = 791.27) flight hours. Table 1 below shows the number of participants per each platform and position combination.

Table 1: Participant summary.

		Platform							Total
		MQ-8 Fire Scout	**RQ-11 Raven**	Scan Eagle	**RQ-7 Shadow**	MQ-4 BAMS	RQ-4A BAMS-D	Other	
Air Vehicle Operator/ Pilot	Count	5	4	0	29	1	6	1	46
	% within Position	10.9%	8.7%	.0%	63.0%	2.2%	13.0%	2.2%	100.0%
	% within Platform	100.0%	80.0%	.0%	87.9%	10.0%	27.3%	50.0%	58.2%
	% of Total	6.3%	5.1%	.0%	36.7%	1.3%	7.6%	1.3%	58.2%
Sensor/ Payload Operator	Count	0	1	0	4	6	5	1	17
	% within Position	.0%	5.9%	.0%	23.5%	35.3%	29.4%	5.9%	100.0%
	% within Platform	.0%	20.0%	.0%	12.1%	60.0%	22.7%	50.0%	21.5%
	% of Total	.0%	1.3%	.0%	5.1%	7.6%	6.3%	1.3%	21.5%
Mission Commander	Count	0	0	2	0	2	6	0	10
	% within Position	.0%	.0%	20.0%	.0%	20.0%	60.0%	.0%	100.0%
	% within Platform	.0%	.0%	100.0%	.0%	20.0%	27.3%	.0%	12.7%
	% of Total	.0%	.0%	2.5%	.0%	2.5%	7.6%	.0%	12.7%
TOPS	Count	0	0	0	0	0	2	0	2
	% within Position	.0%	.0%	.0%	.0%	.0%	100.0%	.0%	100.0%
	% within Platform	.0%	.0%	.0%	.0%	.0%	9.1%	.0%	2.5%
	% of Total	.0%	.0%	.0%	.0%	.0%	2.5%	.0%	2.5%
TACCO	Count	0	0	0	0	1	2	0	3
	% within Position	.0%	.0%	.0%	.0%	33.3%	66.7%	.0%	100.0%
	% within Platform	.0%	.0%	.0%	.0%	10.0%	9.1%	.0%	3.8%
	% of Total	.0%	.0%	.0%	.0%	1.3%	2.5%	.0%	3.8%
Other	Count	0	0	0	0	0	1	0	1
	% within Position	.0%	.0%	.0%	.0%	.0%	100.0%	.0%	100.0%
	% within Platform	.0%	.0%	.0%	.0%	.0%	4.5%	.0%	1.3%
	% of Total	.0%	.0%	.0%	.0%	.0%	1.3%	.0%	1.3%
Total	Count	5	5	2	33	10	22	2	79
	% within Position	6.3%	6.3%	2.5%	41.8%	12.7%	27.8%	2.5%	100.0%
	% within Platform	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	% of Total	6.3%	6.3%	2.5%	41.8%	12.7%	27.8%	2.5%	100.0%

Interrater Agreement

We calculated two interrater agreement metrics: the r_{wg} and a_{wg} statistics. These indices are designed to provide a metric of the absolute level of consensus among groups of raters providing ratings with respect to a common target. The a_{wg} statistic (Brown & Hauenstein, 2005) is an extension of r_{wg} (Lindell & Brandt, 1999) and is designed to provide more robust, accurate results across a range of distributional assumptions. These two indices provide equivalent results only when the mean rating is at the mid-point (i.e., 3 for the importance, difficulty, and mastery scales; 3.5 for frequency). The a_{wg} ranges from -1 (indicating maximum disagreement) to +1 (indicating perfect agreement), with values of 0 indicating that the observed variance in the ratings is 50% the maximum agreement at the observed mean.

In some cases, extreme values of a_{wg} (i.e., beyond the -1 to 1 range) may be observed and are considered non-interpretable. Such values occur when the mean rating for an item coincides with the extremes of the rating scale (i.e., 1 and 5). According to Brown and Hauenstein (2005), the allowable range of means resulting in an interpretable a_{wg} value is between 2-4 for a 5 point scale. However, this range can vary depending on the number of raters. Higher numbers of raters can increase the allowable mean range, though Brown and Hauenstein recommend a minimum of *A*-1 raters for an *A* point scale. For many platform-position combinations, this criterion was not satisfied. A summary of the ranges of r_{wg} and a_{wg} values are provided in the table below. (Note, a complete table of ranges of r_{wg} and a_{wg} values for all position-platform combinations was provided in another document as a separate deliverable for this effort).

Table 2: Interrater agreement by task and KSAO rating scale.

Task/KSAO Scale	r_{wg}				a_{wg}			
	Minimum	Maximum	Average Value	Average # of Raters	Minimum	Maximum	Average Value	Average # of Raters
Task Importance	-3.00	1.00	0.61	3	-1.00	1.00	0.02	3
Task Difficulty	-3.00	1.00	0.50	3	-1.00	1.00	0.12	3
Task Frequency	-3.29	1.00	0.30	3	-1.00	1.00	-0.14	3
Task Mastery	-3.00	1.00	0.45	3	-1.00	1.00	-0.07	3
KSAO Importance	-7.00	1.00	0.10	4	-3.00	1.00	0.57	4

We observed relatively high levels of interrater agreement for most tasks for most platform-position combinations that included at least three raters (Note: some position-platform combinations included only one rater; no interrater agreement statistics are provided for these combinations). Statistics for each of the task rating scales showed that respondents had relatively higher levels of agreement for specific task clusters (e.g., Airspace and operating area management, Flight maneuvers, Intelligence, Surveillance, and Reconnaissance, and Shipboard tasks) and lower levels of agreement for others (e.g., Mission planning). Patterns of interrater agreement were generally consistent across the four task rating scales, although slightly lower agreement levels were observed for the Mastery scale. Agreement statistics for the KSAO Importance ratings were generally favorable, and slightly higher overall than the task ratings. Among KSAOs, relatively higher levels of agreement were observed for Adaptability and Self-Discipline, and lower levels for Reaction Time and Planning Skills.

There was considerable variability observed for individual tasks within the task clusters. Relatively lower levels of interrater agreement observed for some individual tasks could reflect true differences in the nature of taskwork as perceived by individual respondents, even those with the same job title. For such tasks, it is important to note that measures of central tendency (e.g., means, as provided below) may not tell a complete story regarding the nature of taskwork for a certain platform-position combination. Therefore, both means and 95% confidence intervals are included for the platform-position task profiles provided below.

Results

Task Profiles by Platform and Position

One key objective of the current cross-platform job analysis effort is to accurately describe commonalities and differences among UAS platforms, positions, and platform-position combinations with respect to critical tasks. We present this information in two different ways. First, we include a set of interactive tables that provide rankings for each individual task statement by each platform-position combination. These tables include filters to allow a quick review of task rankings for each platform-position combination. There is one table for each of the four task rating scales (importance, difficulty, frequency, and mastery), and they are attached as a separate sortable document.

Second, we produced a set of figures depicting task cluster profiles for each platform-position combination. Individual task statement ratings were averaged across all of the tasks within a task cluster for each respondent. These mean values were then averaged across respondents within each platform-position combination, and for each position (i.e., combining data across platforms). We provided 95% confidence intervals for all point estimates based on a sample size greater than one. However, because each individual respondent was given the option of skipping either entire task clusters (via survey branching) or individual tasks, confidence intervals for different task clusters may be based on different sample sizes, even for the same platform-position combination.

Profiles Based on Task Importance

The task importance profiles are shown in Figures 1 - 18. The position profiles based on the task importance ratings revealed a number of clusters that met or exceeded the importance threshold of the rating scale (i.e., 3 on a 1-5 scale, reflecting a rating of "Moderately Important"). The combined, cross platform AVO/Pilot data revealed that all task clusters had mean ratings at or above the 4.00 range, with lower bound confidence intervals for all clusters exceeding the importance threshold. The cross-platform Mission Commander profile revealed similarly high means for all task clusters, with values for airspace area management, crew task management, navigation, and fuel/power management all exceeding 4.50. A similar pattern was observed for the cross-platform Sensor/Payload Operator data, though confidence intervals were larger due to the relatively smaller sample size (the lower bound interval for air vehicle approach/landing dipped below the importance threshold).

Profiles for the BAMS positions revealed that both the Sensor/Payload Operator and the AVO positions share a strong emphasis on airspace and crew task management; the Mission Commander profile also emphasized ISR. Similar patterns were observed for the BAMS-D profiles. Although some profiles were incomplete or highly variable (owing to small sample sizes), nearly all clusters were rated as highly important. Airspace management, emergency tasks, system configuration and start-up (Sensor/Payload Operator), and Navigation all emerged as especially important. The Fire Scout and Raven AVO profiles revealed that nearly all task clusters were rated as highly important. For the Fire Scout profile, only the relatively wide confidence intervals for flight maneuvers and air vehicle approach and landing dipped below the midpoint threshold; system configuration and air vehicle launch were especially important for Raven AVOs. The ScanEagle Mission Commander profile, although based on a very low sample size, revealed that all tasks for which importance ratings were provided had mean rating scores at or above

4.50. Some core flight clusters (in-flight operations, flight maneuvers, air vehicle approach/landing) included no ratings, indicating that none of the tasks within these clusters were relevant to the raters' work. Profiles for the two Shadow positions were remarkably similar, with the AVO importance ratings all in the 4.00 range or above, and the Sensor/Payload Operator ratings elevated above these.

Profiles Based on Difficulty to Learn

The task difficulty profiles are shown in Figures 19 – 36. The task difficulty to learn profiles were markedly lower and more variable than the importance profiles. The difficulty profile for AVOs collapsing across platforms revealed only two task clusters that exceeded the midpoint of the scale (flight maneuvers and target management). Slightly more task clusters exceeding the difficulty midpoint were observed for Mission Commander and Sensor/Payload Operator profiles, notably the flight maneuvers cluster for Sensor/Payload Operators. The flight maneuvers cluster was observed to be especially important for Sensor/Payload Operators operating the Raven and Shadow platforms. Although most of the mean difficulty ratings means for overall task clusters were at or below the difficulty midpoint, means for several individual tasks were above it. Approximately 1/3rd of the individual tasks had difficulty means above the midpoint as rated by AVOs (e.g., "Identify, track, manage, and engage targets using the appropriate procedures and resources…", "Perform planning tasks [for example, collateral damage estimation] in preparation for weapons engagement", "Select weapon type, features, or parameters depending on target or environmental factors"). Sensor/Payload Operators reported the highest rates of at least moderately difficult to learn individual tasks (~80%; e.g., tasks focusing on shipboard takeoff or landing, manual landing, and advanced flight techniques). Mission Commanders also reported relatively difficulty to learn tasks related to tracking targets, calls for fire, interpreting topographical maps, troubleshooting air vehicle hand-offs, maintaining flight profile, managing potential for fratricide, and making flight adjustments for turbulent conditions.

Profiles Based on Task Frequency

The task frequency profiles are shown in Figures 37 – 54. The task frequency profiles showed substantial variability among task clusters, with fewer task clusters exceeding the scale midpoint as there were clusters exceeding the importance midpoint. The collapsed AVO, Sensor/Payload Operator, and Mission Commander profiles all shared an emphasis on ISR frequency; the Mission Commander profile included four additional clusters with a mean greater than 4.50, and the Sensor/Payload Operator included an additional five.

However, this pattern does not necessarily indicate that a similar proportion of individual tasks were rated as less than moderately frequent. For example, 45% of the individual tasks had means at or above the scale midpoint for the platform-collapsed AVO data. Some individual tasks (e.g., "Use onboard navigation equipment to maintain aircraft position", "Perform intelligence, surveillance, and reconnaissance tasks, including collecting, reporting, and disseminating intelligence information", "Perform area reconnaissance tasks", "Coordinate with crew members regarding aircraft or mission payload control") had mean ratings that exceeded 5.0 for some positions, reflecting nearly continuous task performance. Over 75% of the tasks exceeded the frequency midpoint for the collapsed Sensor/Payload Operator data. Tasks performed nearly continuously included communications and terminology usage, basic aircraft operation under instrument flight rules, monitoring power status, complying with air traffic control procedures, and airspace coordination, among others. Over 46 tasks had mean ratings of 5.00 or above, indicating nearly continuous task performance.

Profiles Based on Task Mastery Requirements

The task mastery profiles are shown in Figures 55 – 72. Ratings of high mastery requirements were observed for nearly all task clusters across the platform-collapsed position profiles, with mastery rating means generally in the 2.50 range or above. Similar patterns were observed for the AVO, Mission Commander, and Sensor/Payload Operator profiles. Especially high values (mean of 5.00) for specific individual tasks were observed for AVOs ("Perform shipboard takeoff or landing", "Communicate with ship Command and Control or other relevant agencies during takeoff/landing"), Sensor/Payload Operators (13 tasks, many focused on flight parameters under adverse conditions, advanced flight techniques, and operation of specific UAS systems), and Mission Commanders (39 tasks).

Generally low correlations were observed among the importance, frequency, difficulty, and mastery scales for a given task, although some moderate relations were observed between the importance and difficulty to learn and between the importance and mastery scales for specific tasks. The correlation between the cross-platform, cross-position means for task importance and task frequency was -.01, between importance and difficulty was .31, and between frequency and difficulty was -.03. Mastery ratings correlated significantly with importance (.66) and difficulty (.50), but not frequency (.00). This indicates the possibility of some tasks that were rated as important but performed infrequently ("Perform shipboard takeoff or landing"), frequent but low difficulty ("Use proper terminology and formats when communicating with crewmembers or other personnel"), and moderately important, frequent, and difficult but with a relatively high mastery requirement ("Communicate with ship Command and Control or other relevant agencies during takeoff/landing").

Figures 1: Task cluster profiles for Raven – Air vehicle operator/Pilot – Mean task importance

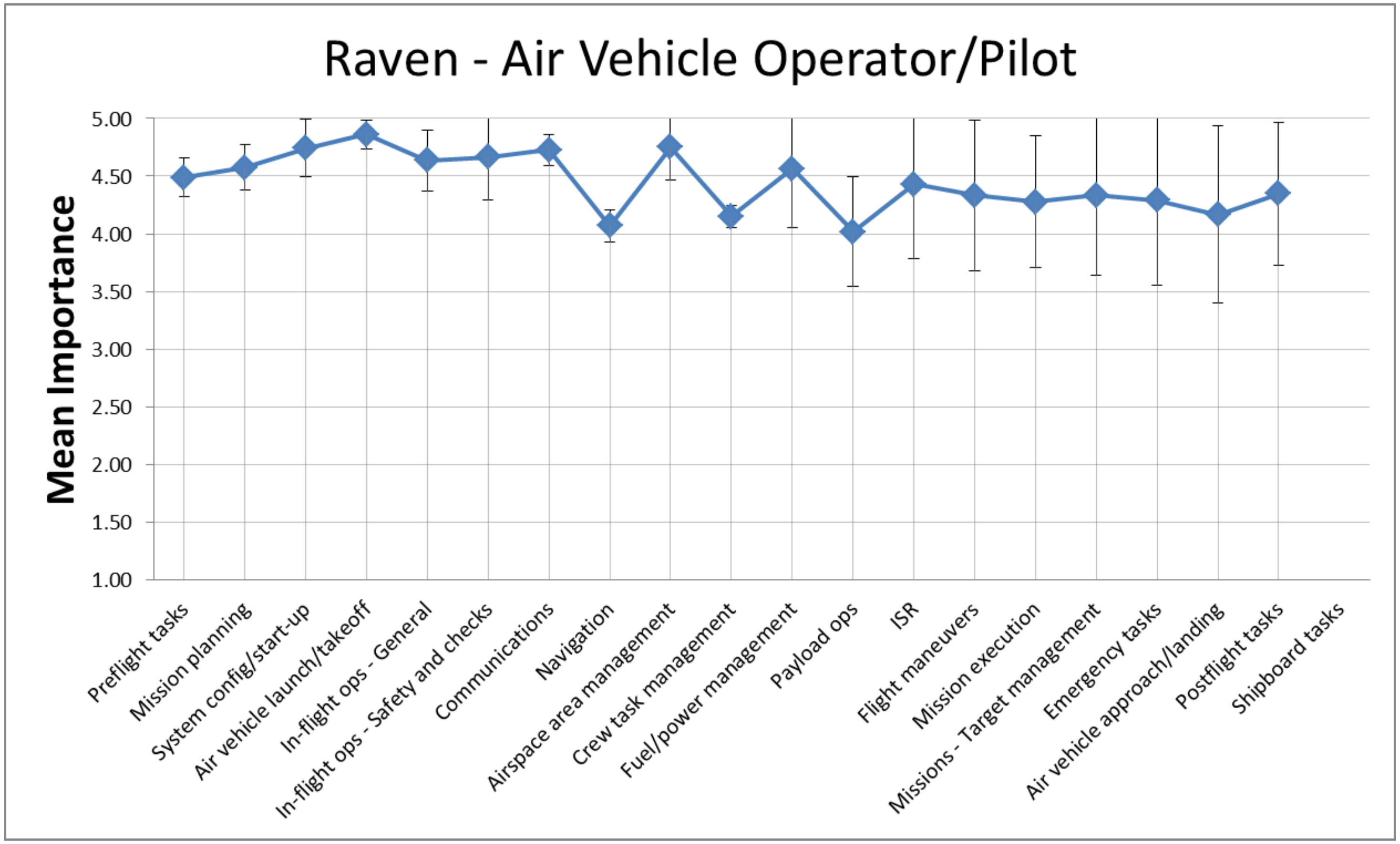


Figure 2: Task cluster profiles for Shadow – Air vehicle operator/Pilot – Mean task importance

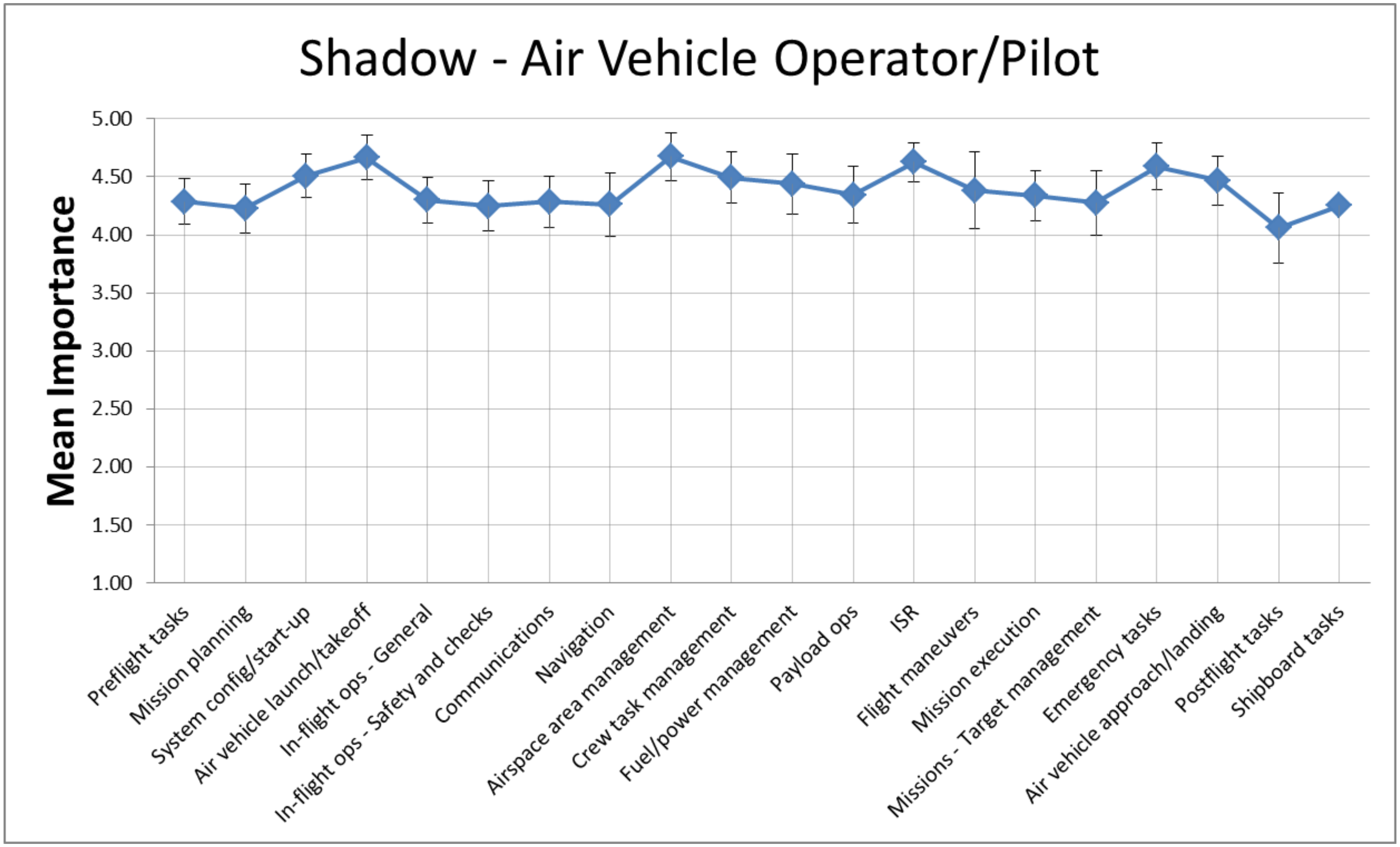


Figure 3: Task cluster profiles for Fire Scout – Air vehicle operator/Pilot – Mean task importance

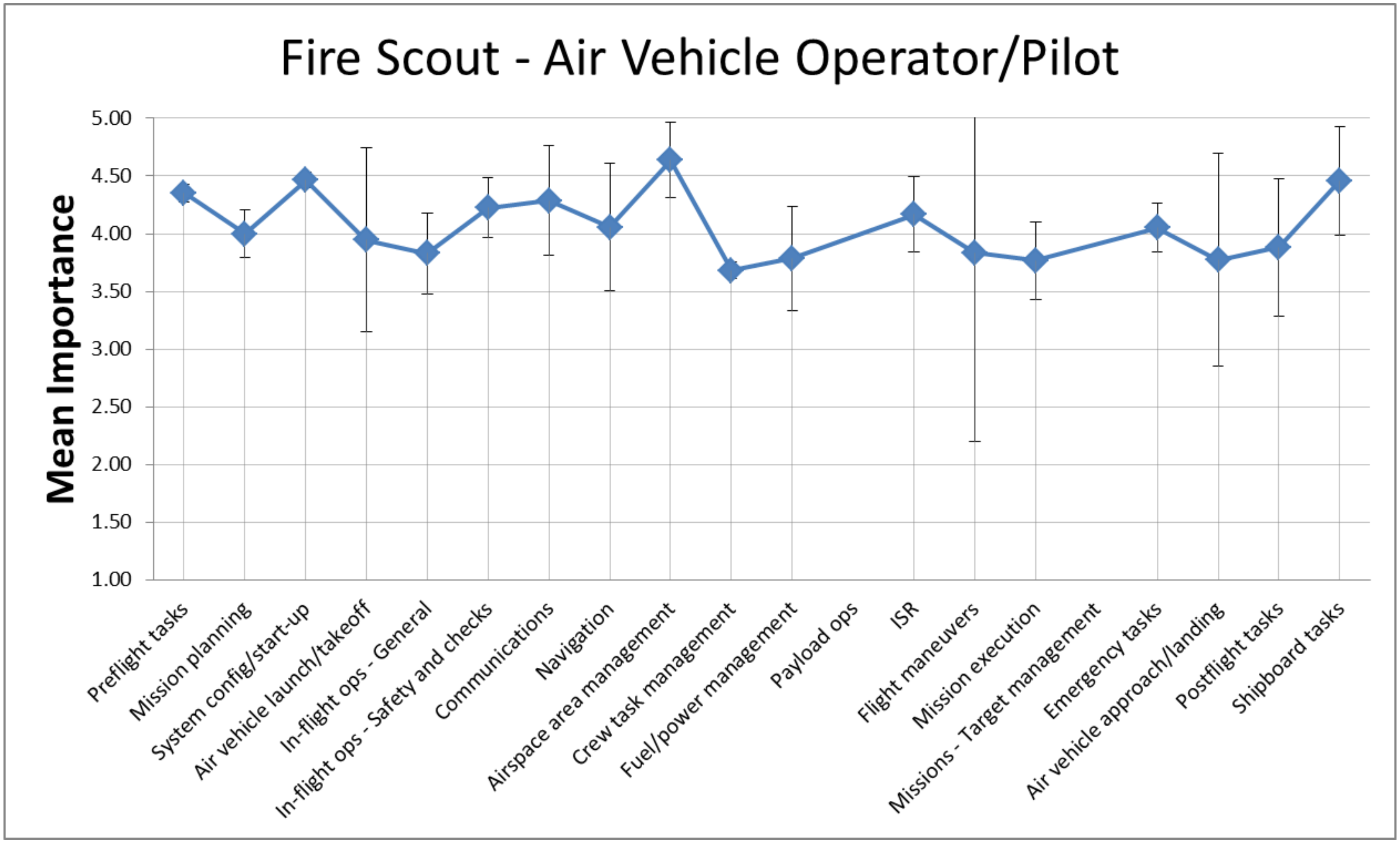


Figure 4: Task cluster profiles for BAMS-D – Air operator/Pilot – Mean task importance

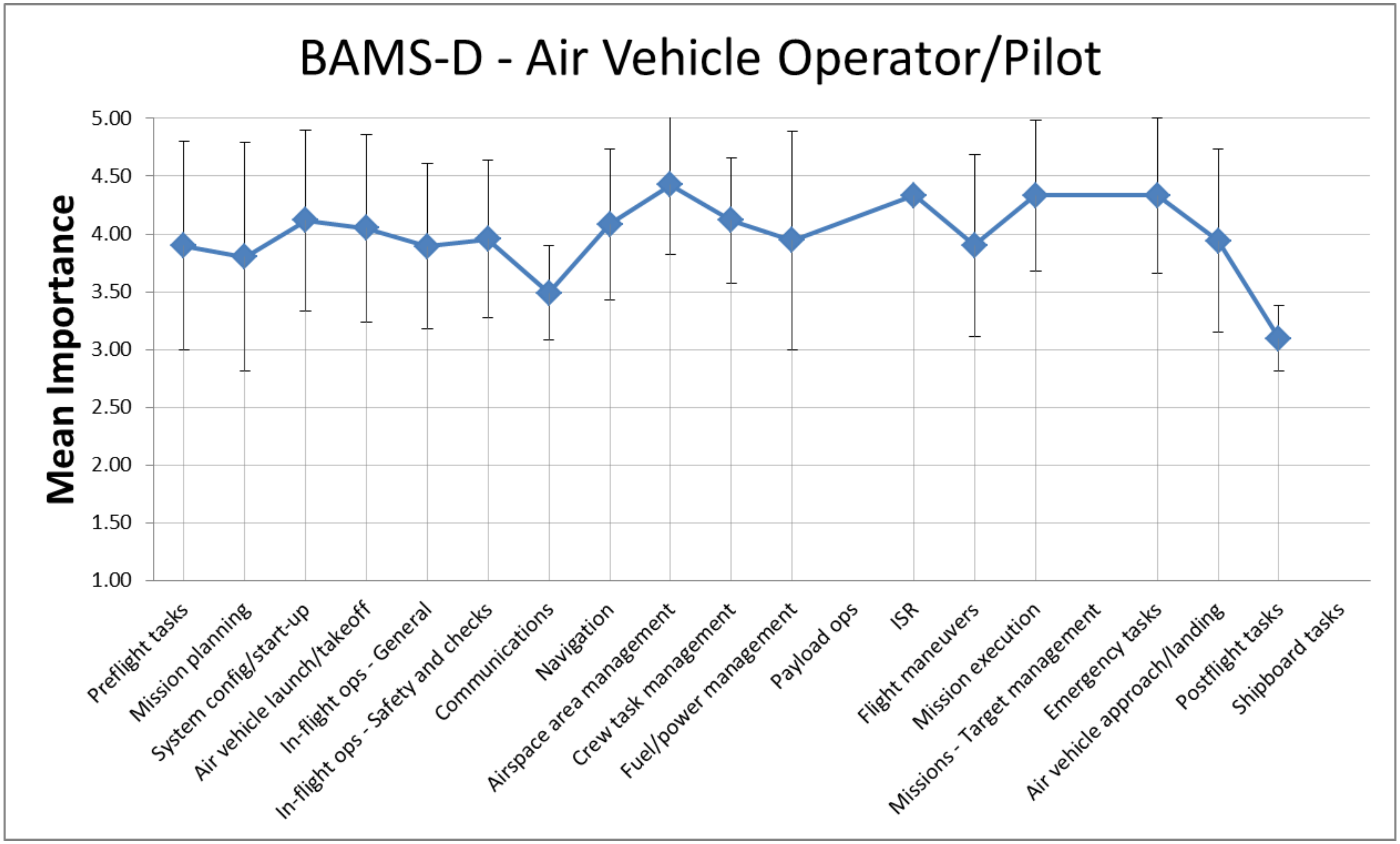


Figure 5: Task cluster profiles for BAMS – Air vehicle operator/Pilot – Mean task importance

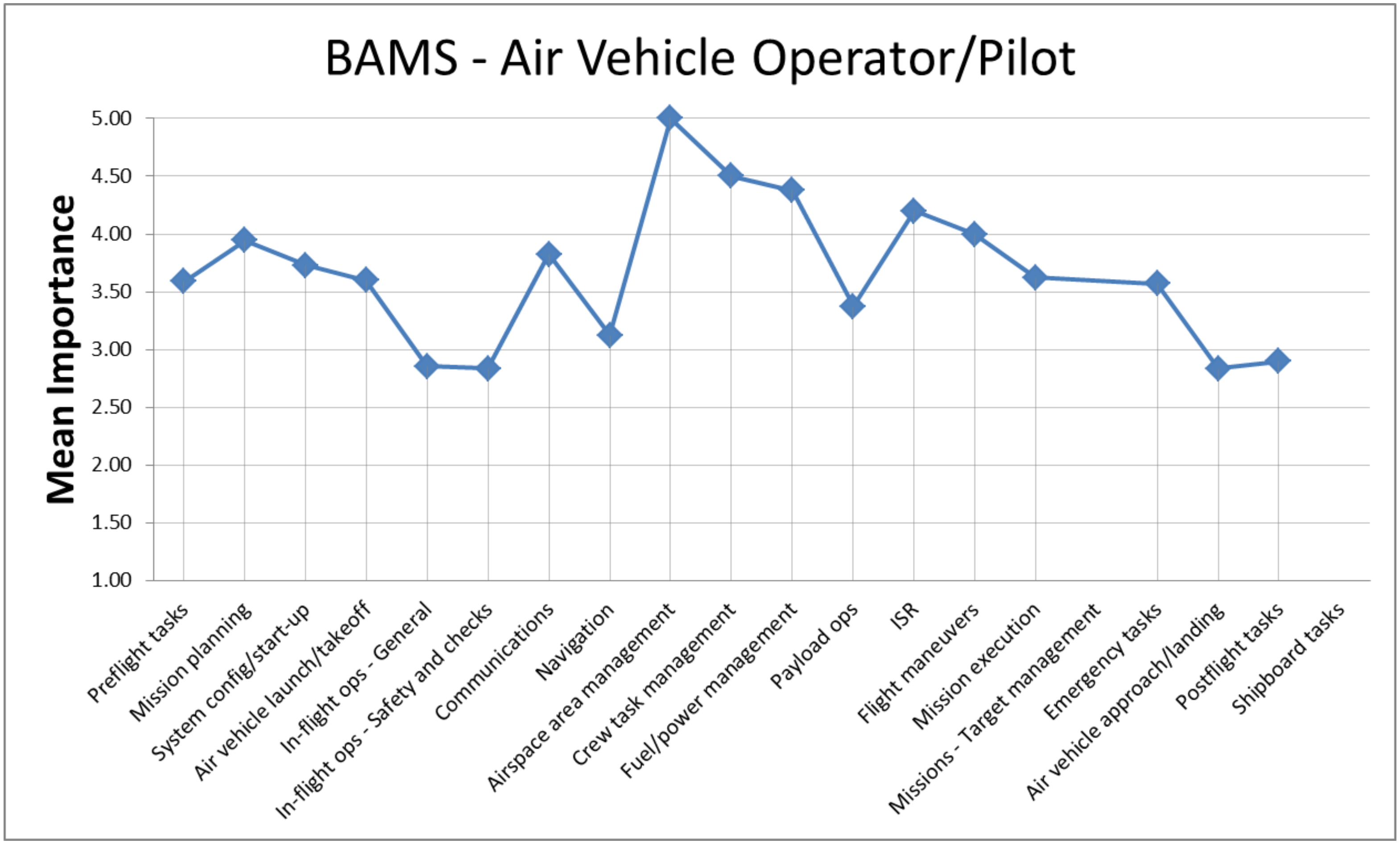


Figure 6: Task cluster profiles for all platforms – Air vehicle operator/Pilot – mean task importance

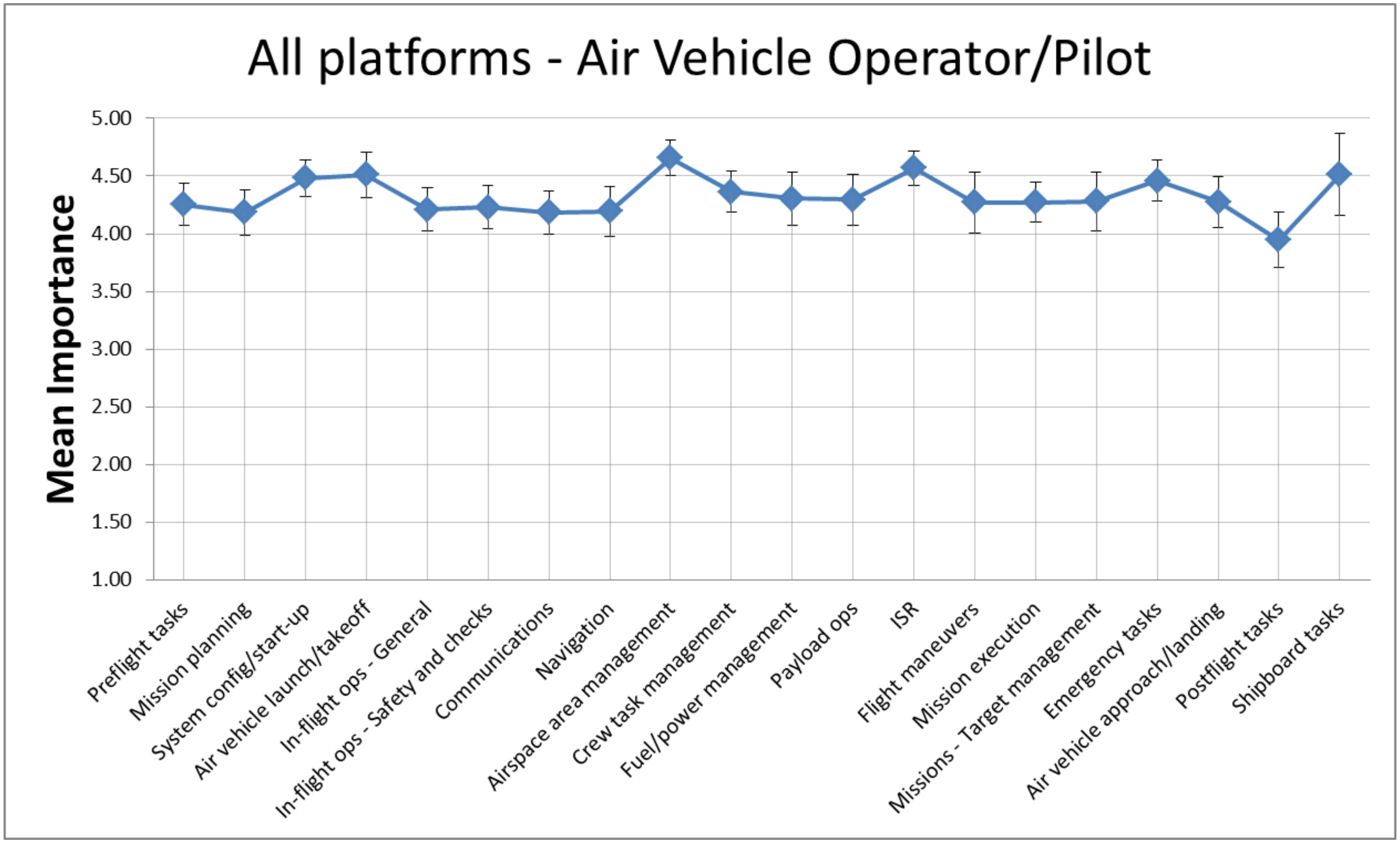


Figure 7: Task cluster profiles for Raven – Sensor/Payload operator – Mean task importance

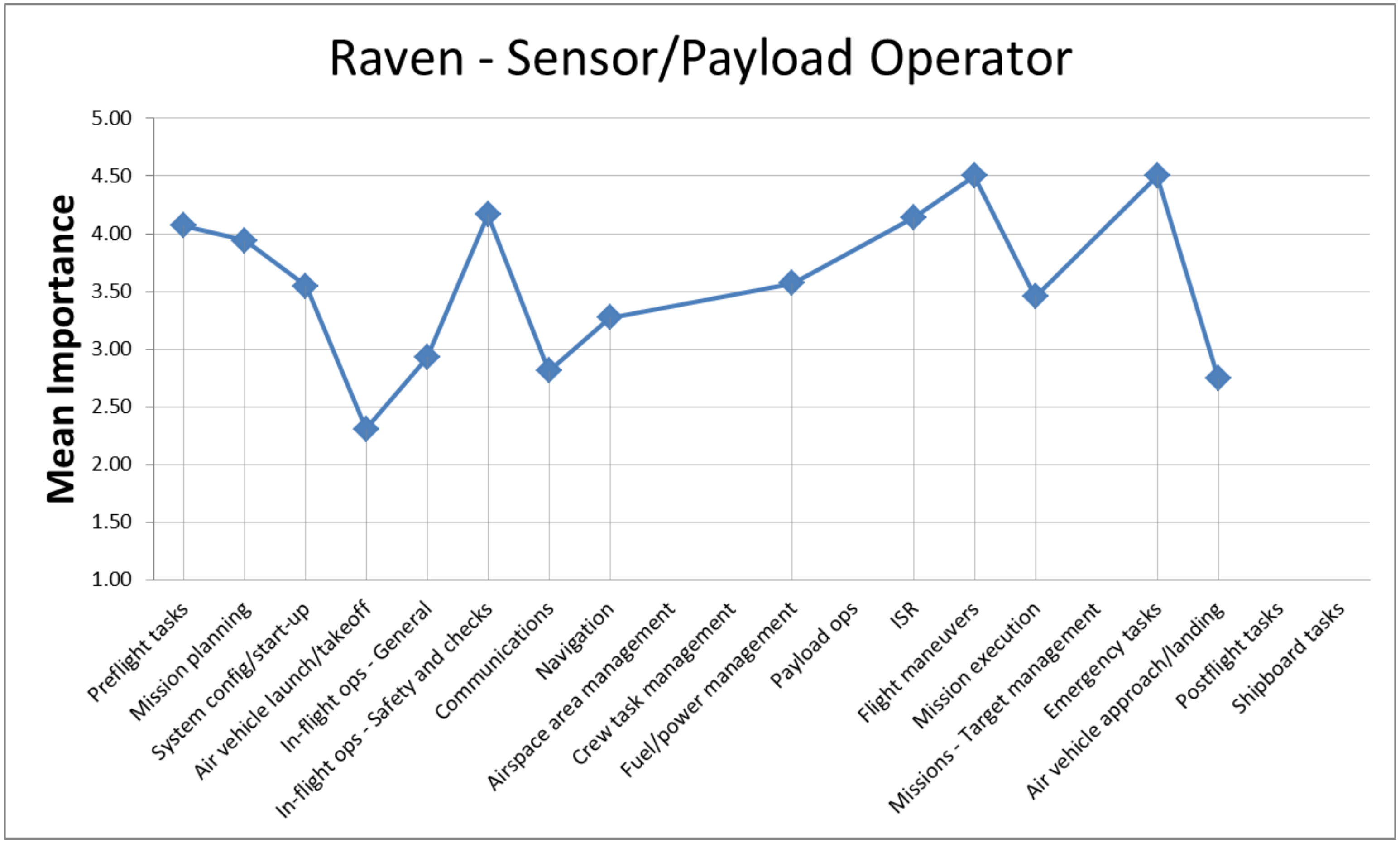


Figure 8: Task cluster profiles for Shadow – Sensor/Payload operator – Mean task importance

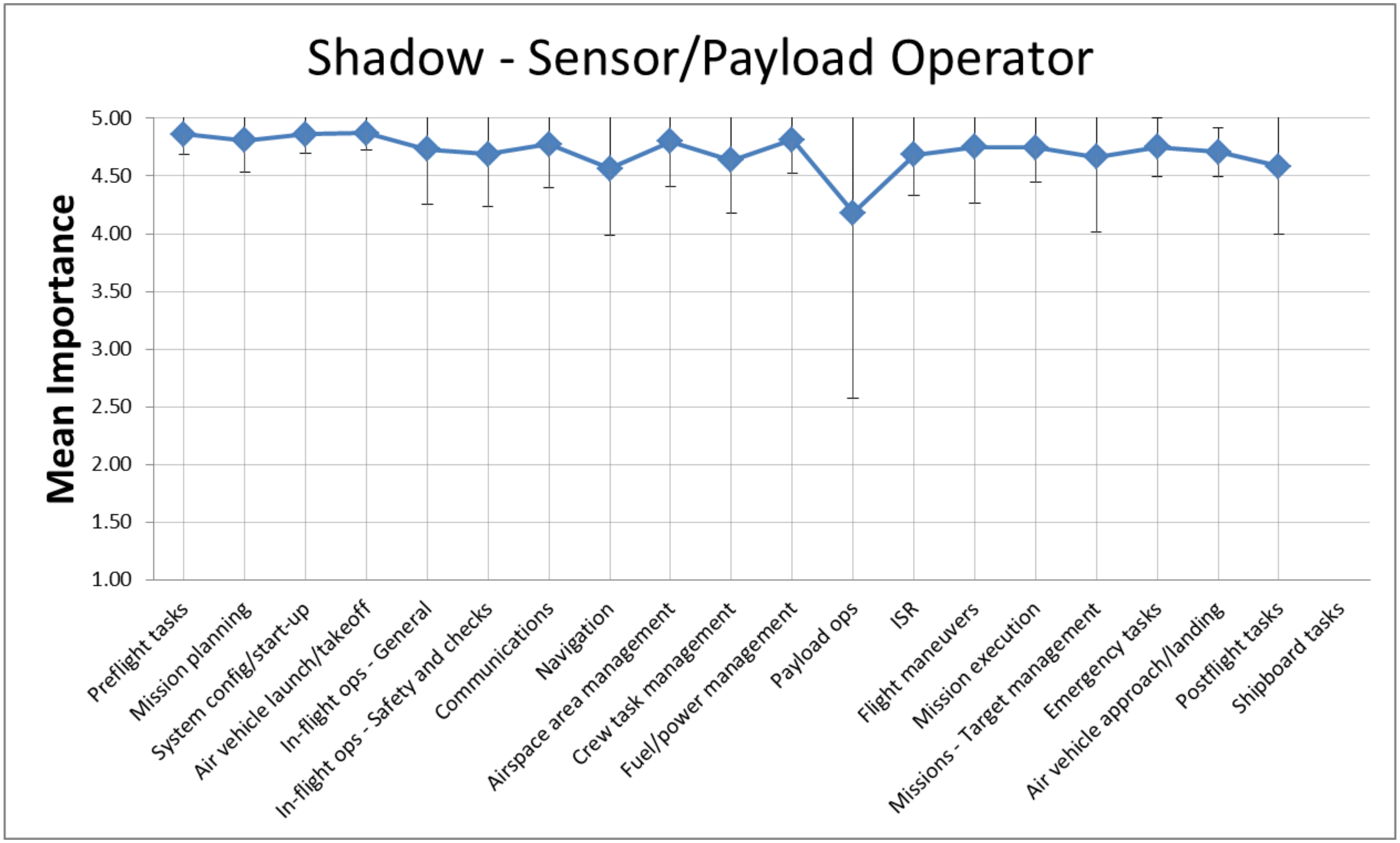


Figure 9: Task cluster profiles for BAMS-d – Sensor/Payload operator – Mean task importance

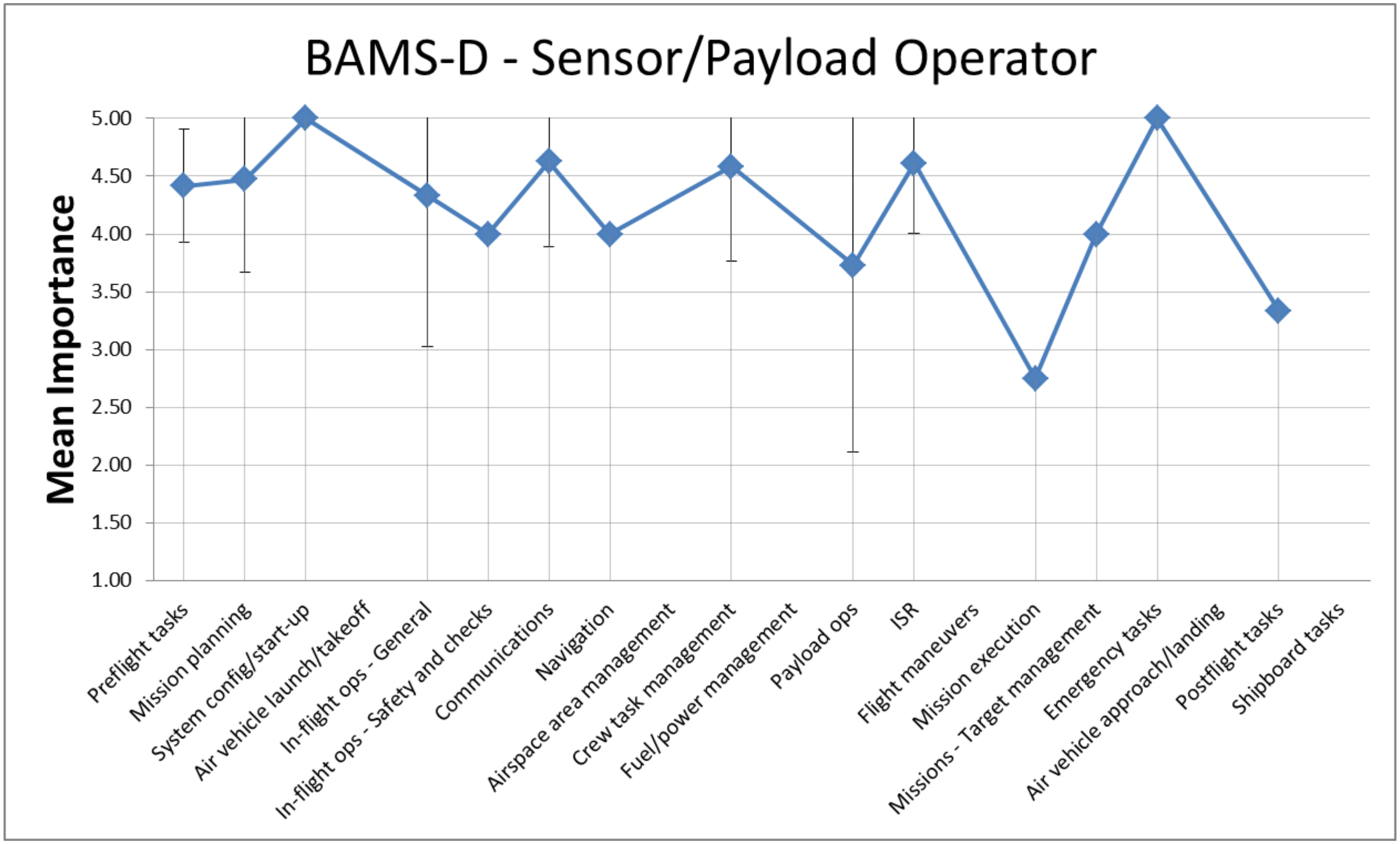


Figure 10: Task cluster profiles for BAMS – Sensor/Payload operator – Mean task importance

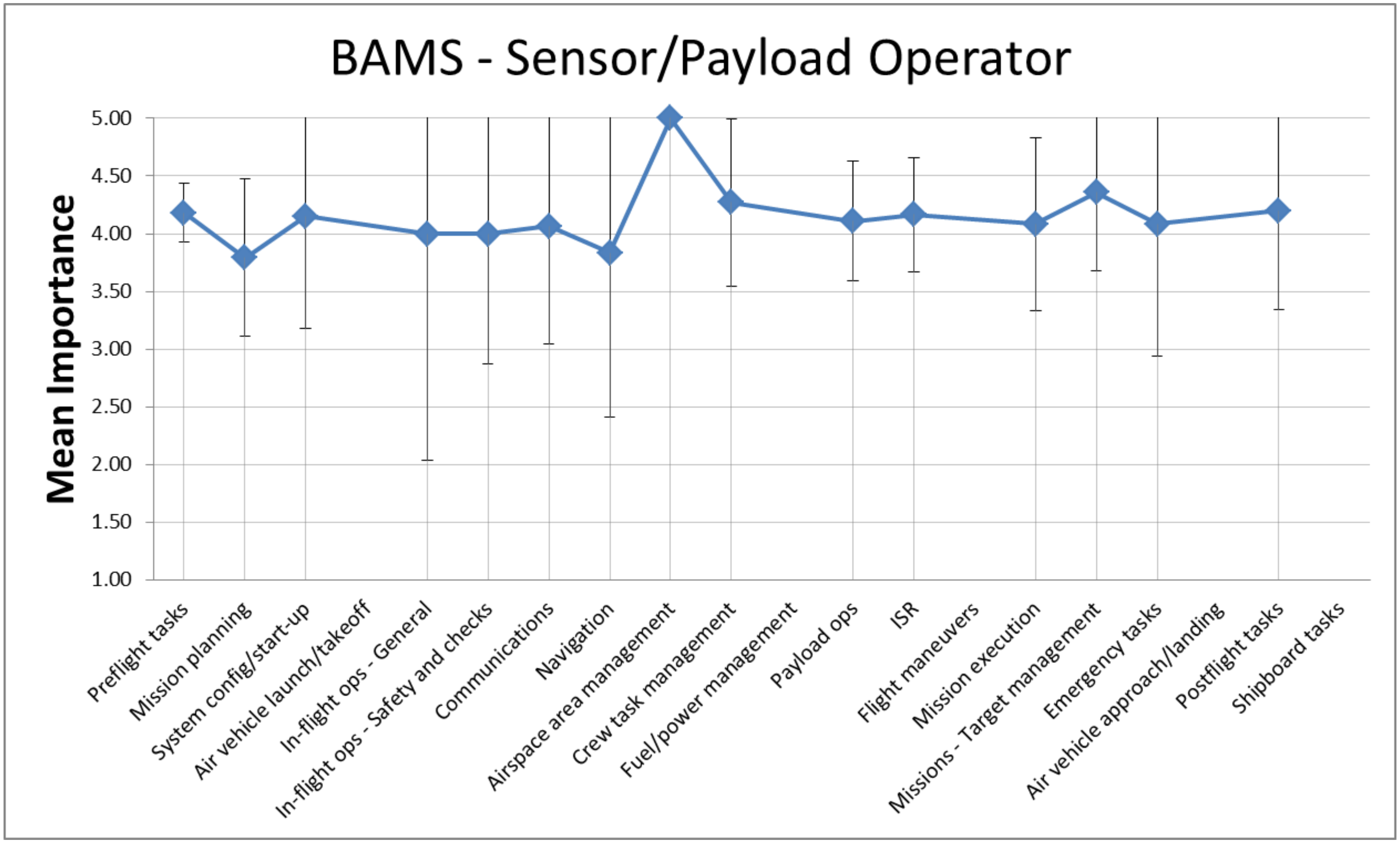


Figure 11: Task cluster profiles for all platforms – Sensor/Payload operator – Mean task importance

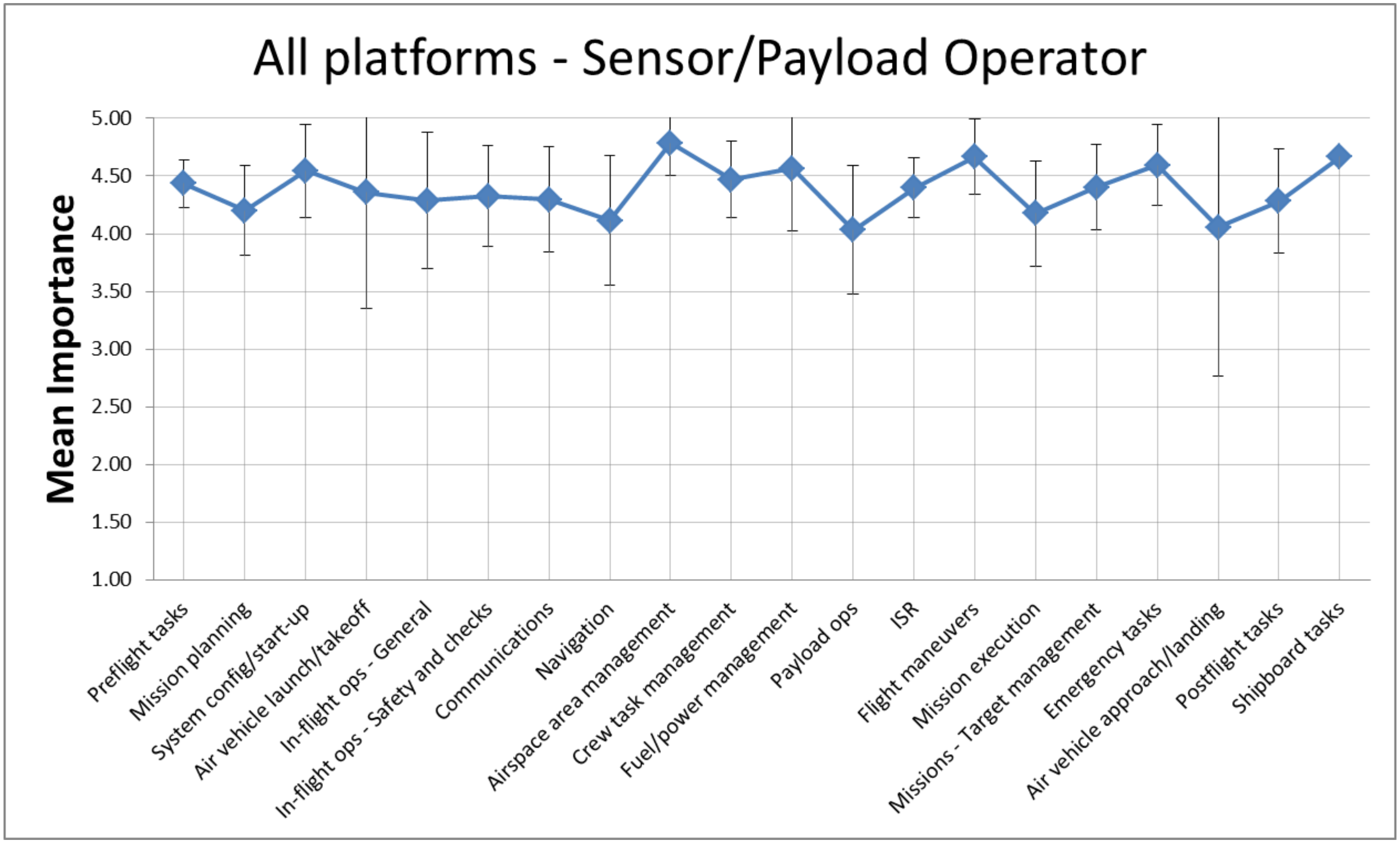


Figure 12: Task cluster profiles for ScanEagle – Mission commander – Mean task importance

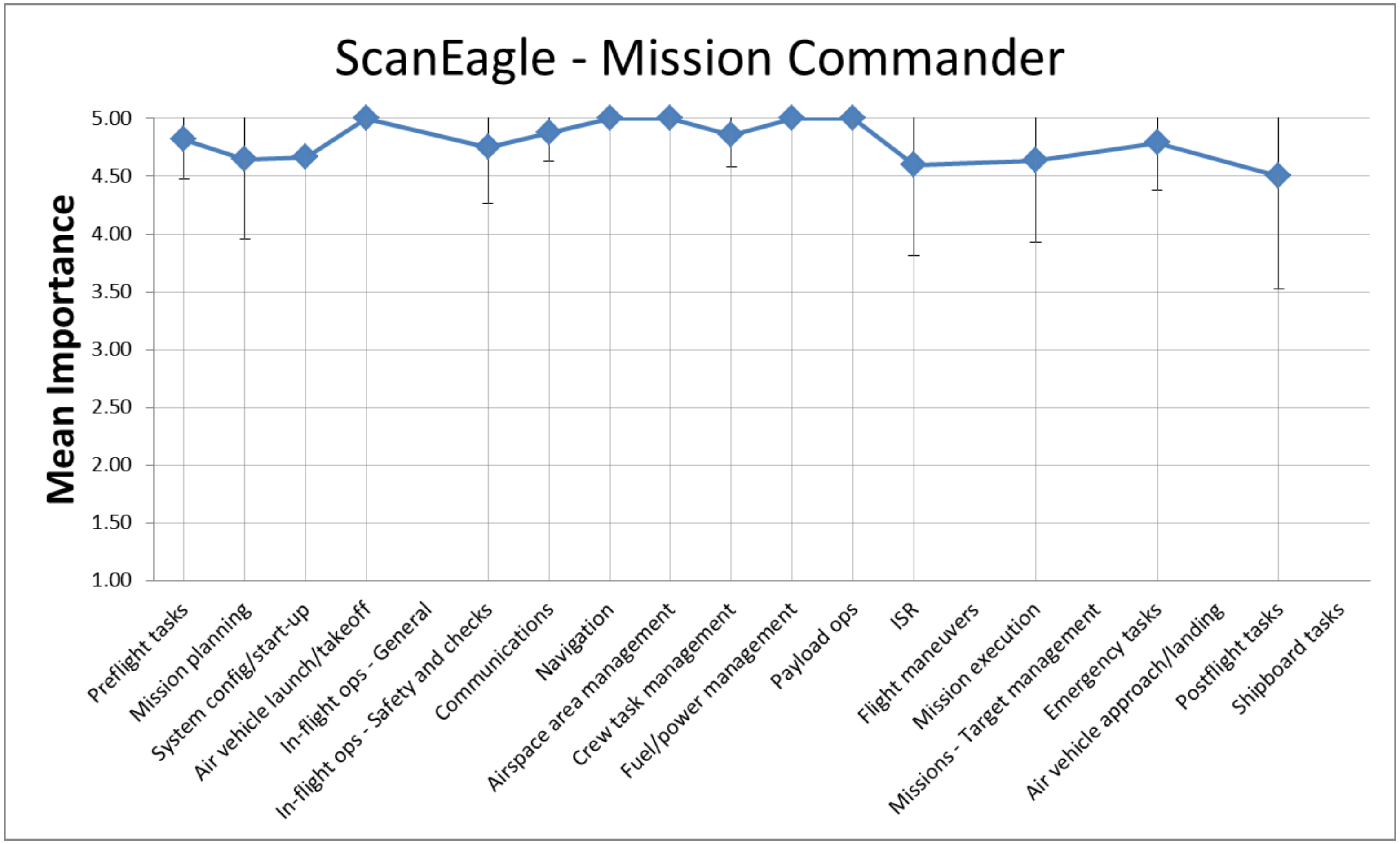


Figure 13: Task cluster profiles for BAMS-D – Mission commander – Mean task importance

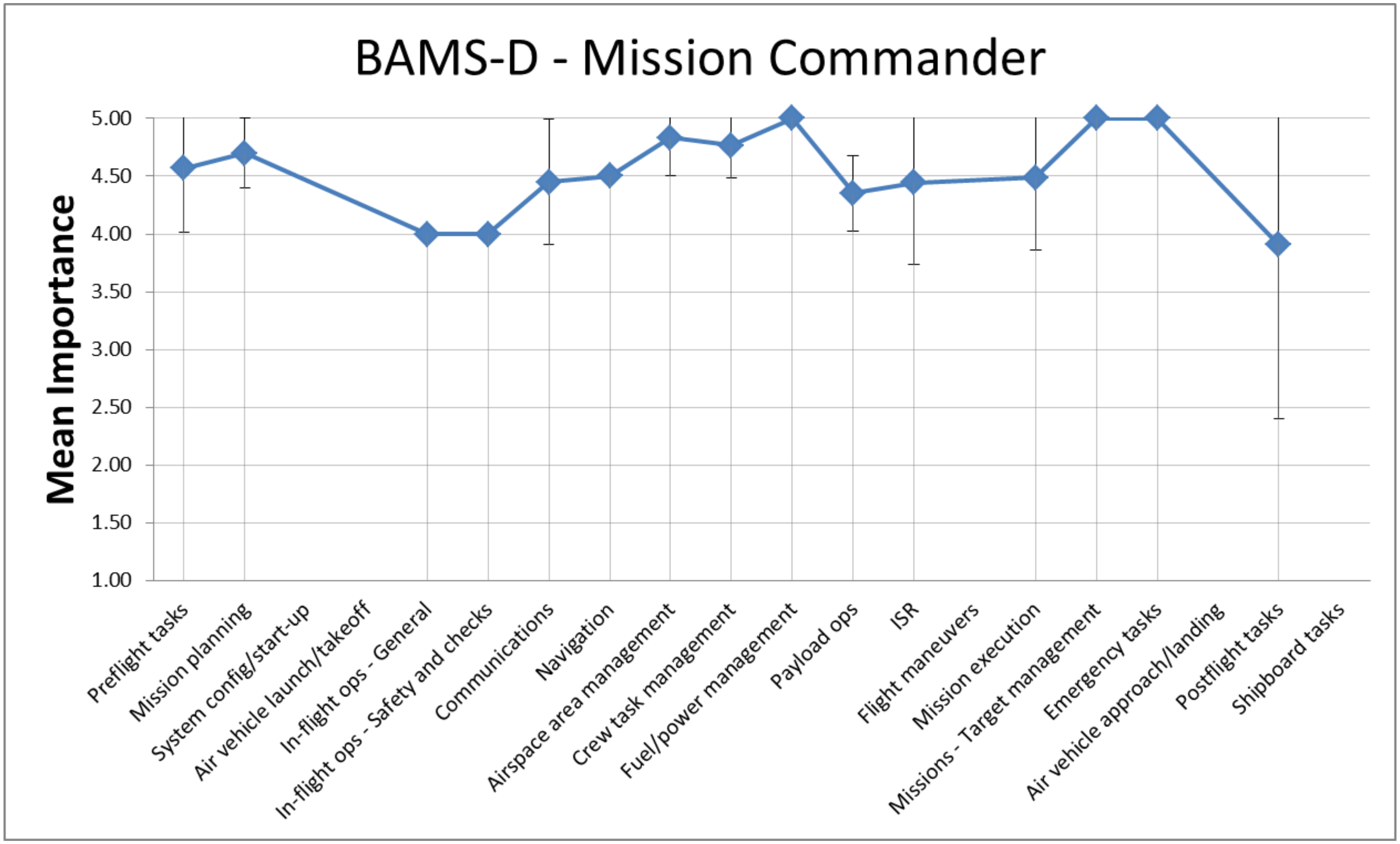


Figure 14: Task cluster profiles for BAMS – Mission commander – Mean task importance

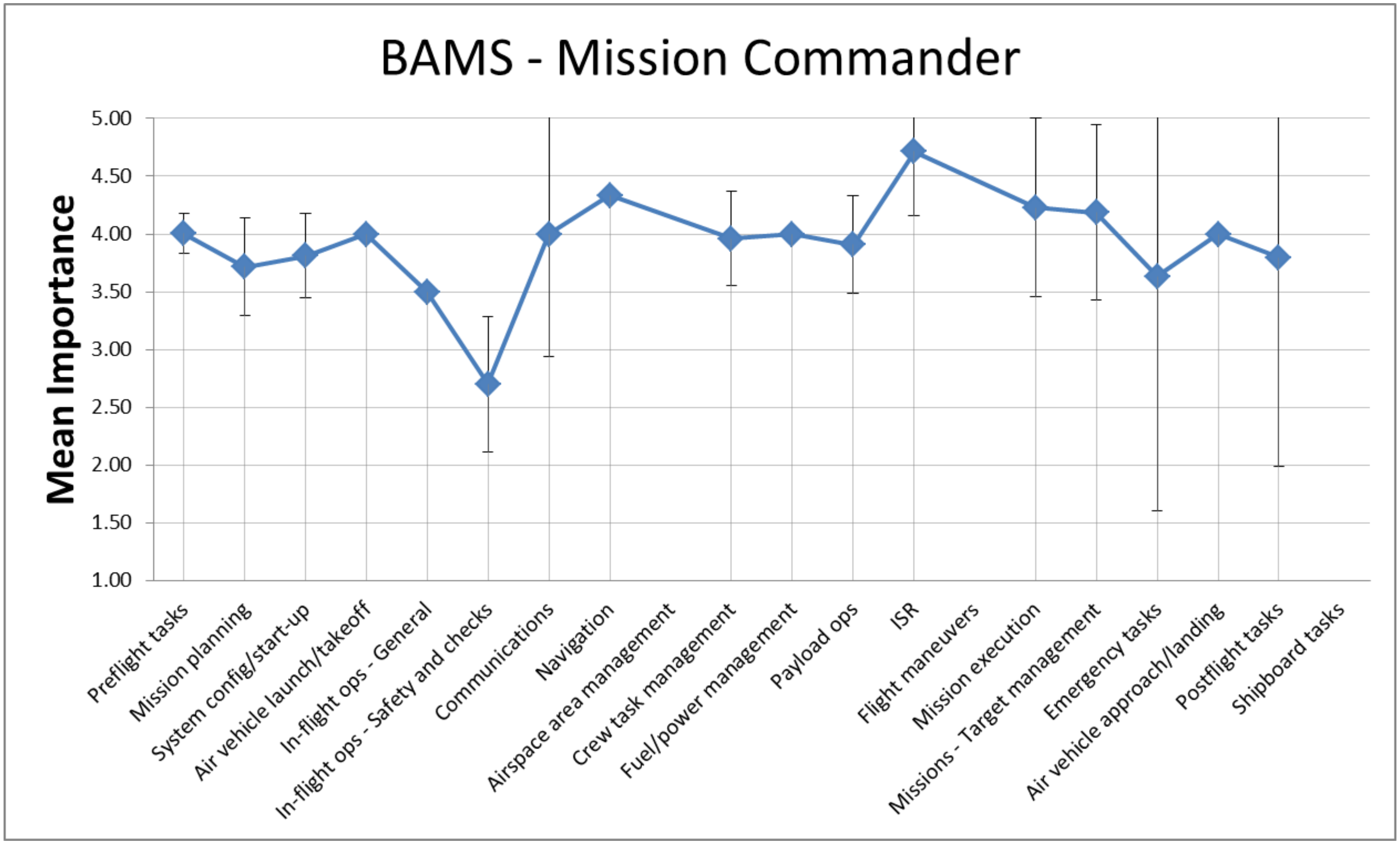


Figure 15: Task cluster profiles for all platforms – Mission commander – Mean task importance

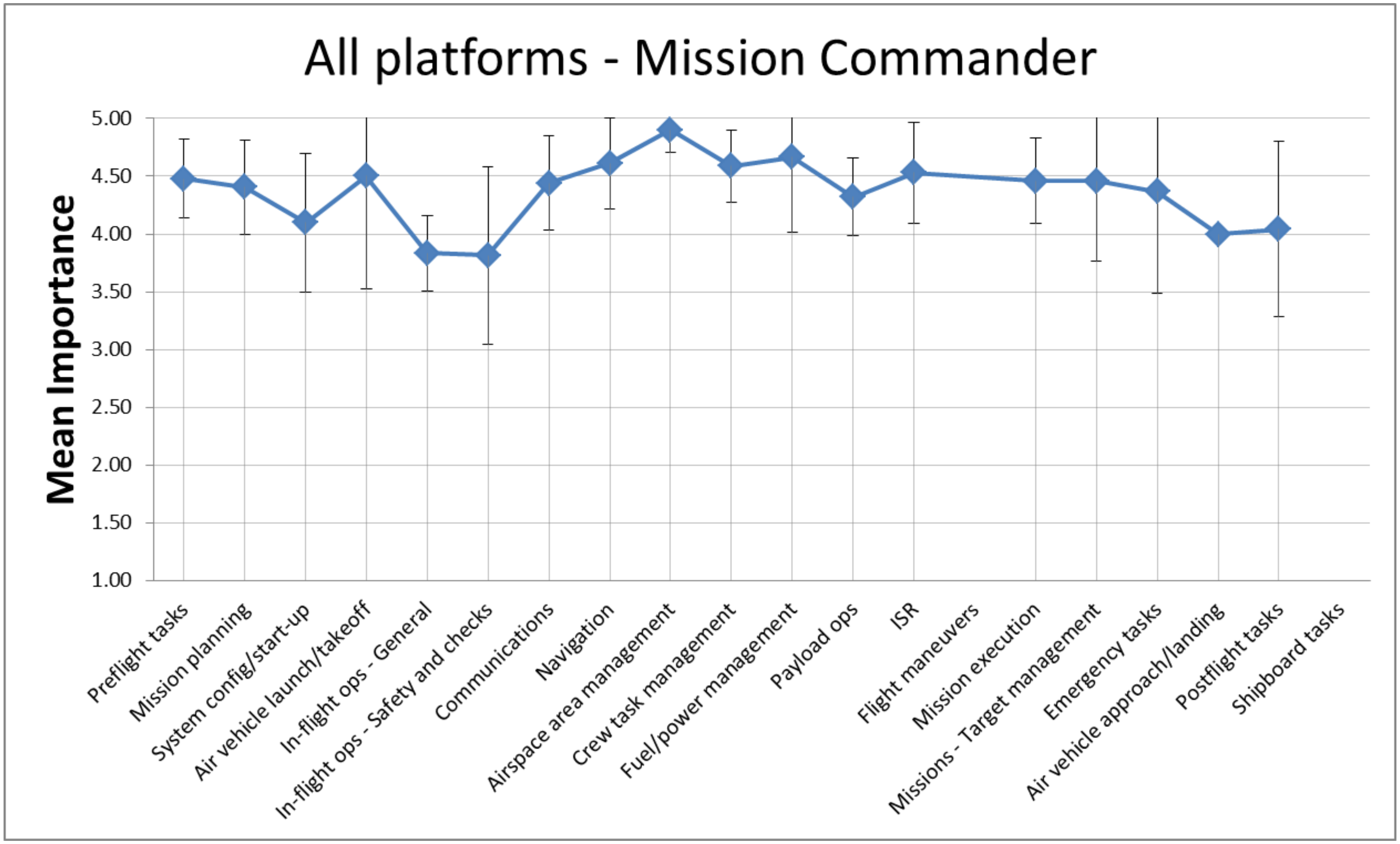


Figure 16: Task cluster profiles for BAMS-D – TACCO – Mean task importance

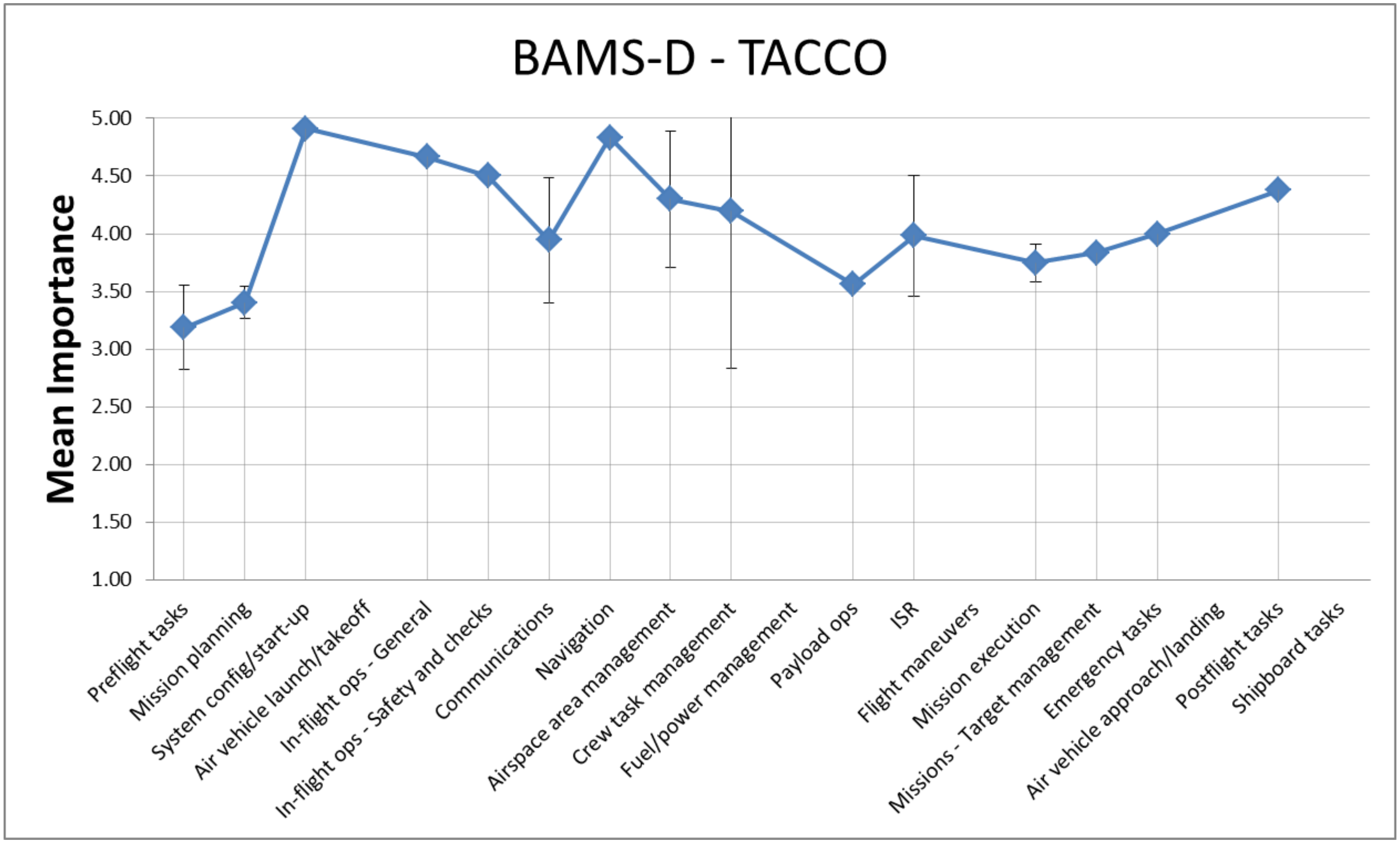


Figure 17: Task cluster profiles for BAMS – TACCO – Mean task importance

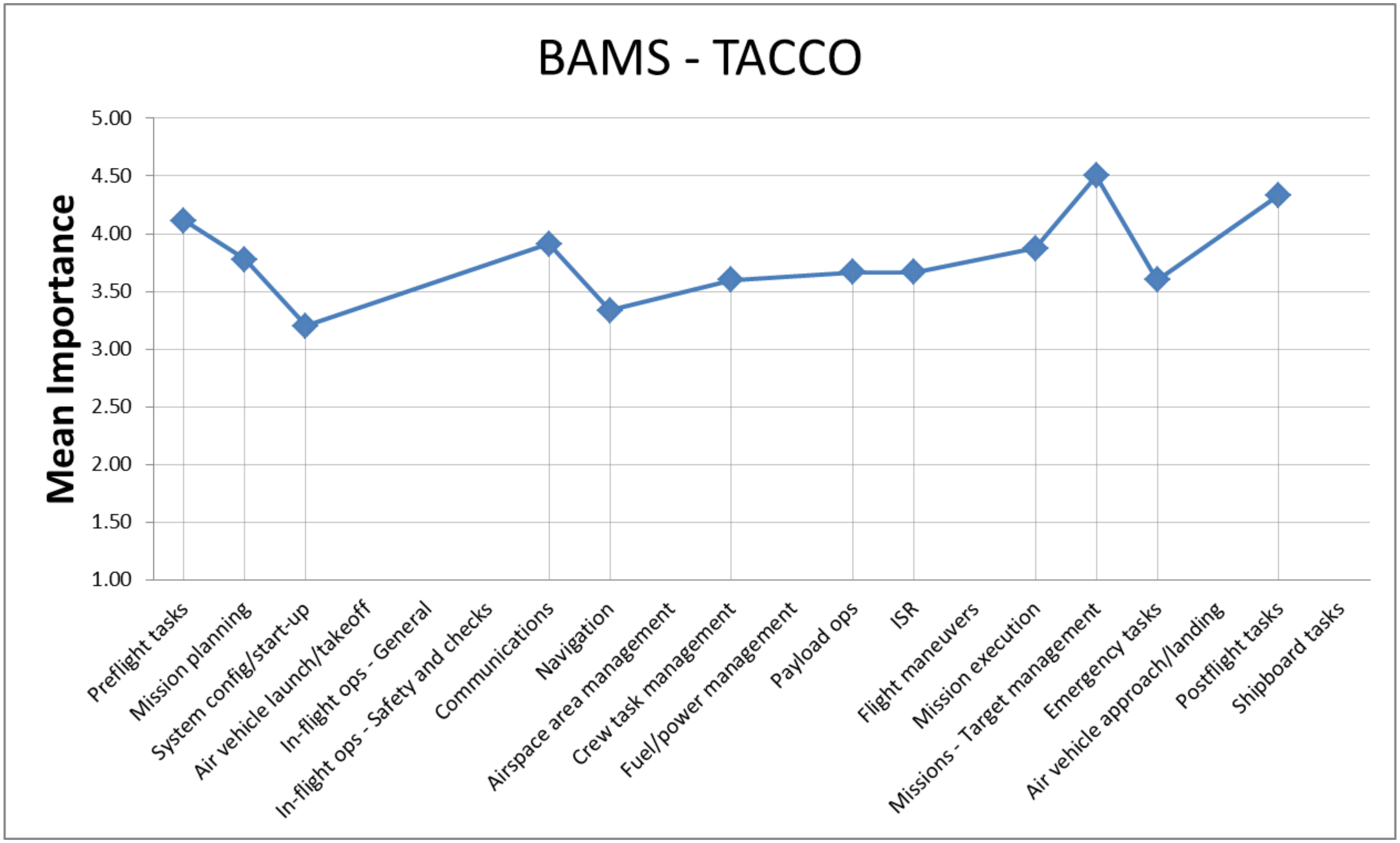
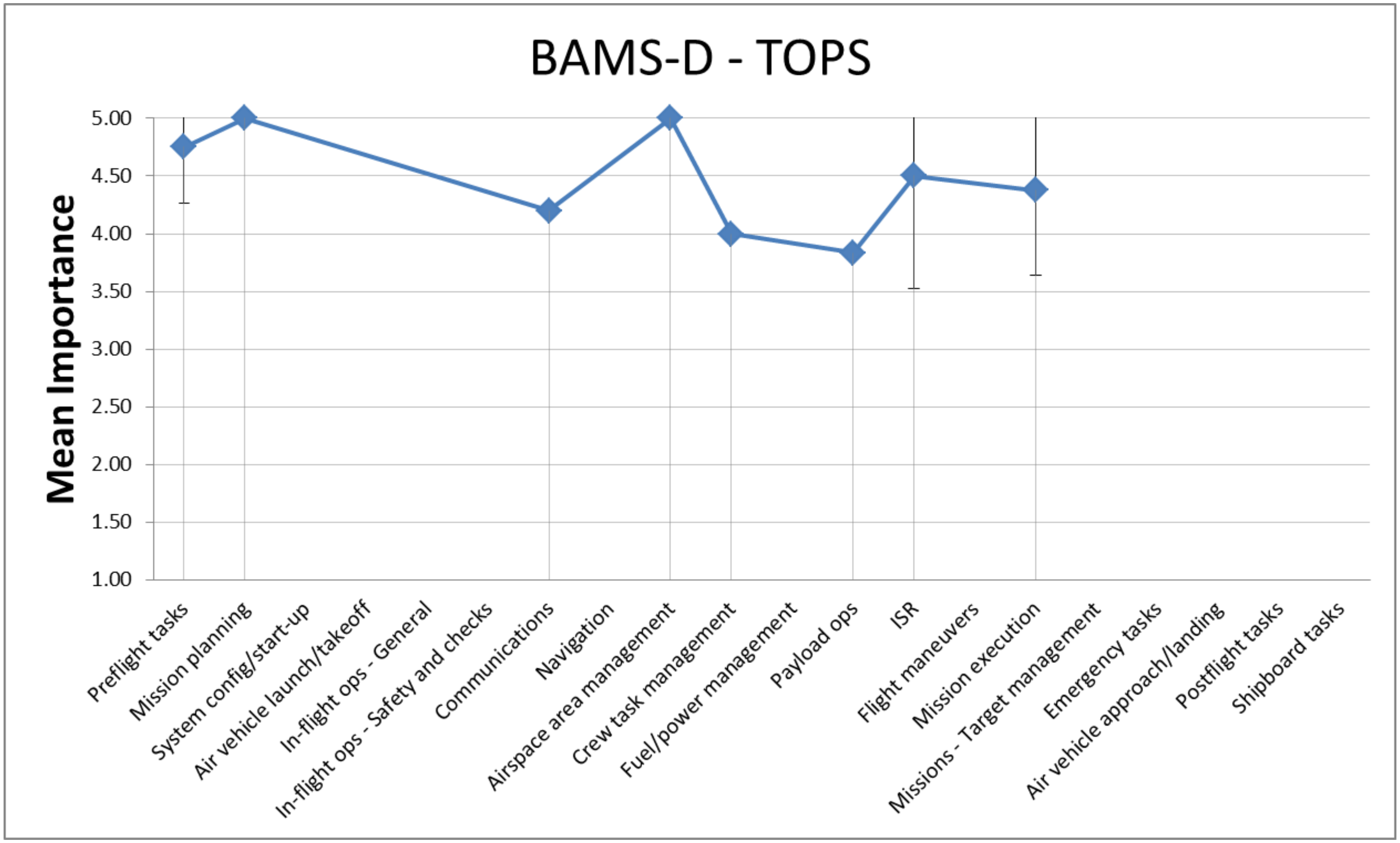


Figure 18: Task cluster profiles for BAMS-D – TOPS – Mean task importance



Figures 19: Task cluster profiles for Raven – Air vehicle operator/Pilot – Mean task difficulty

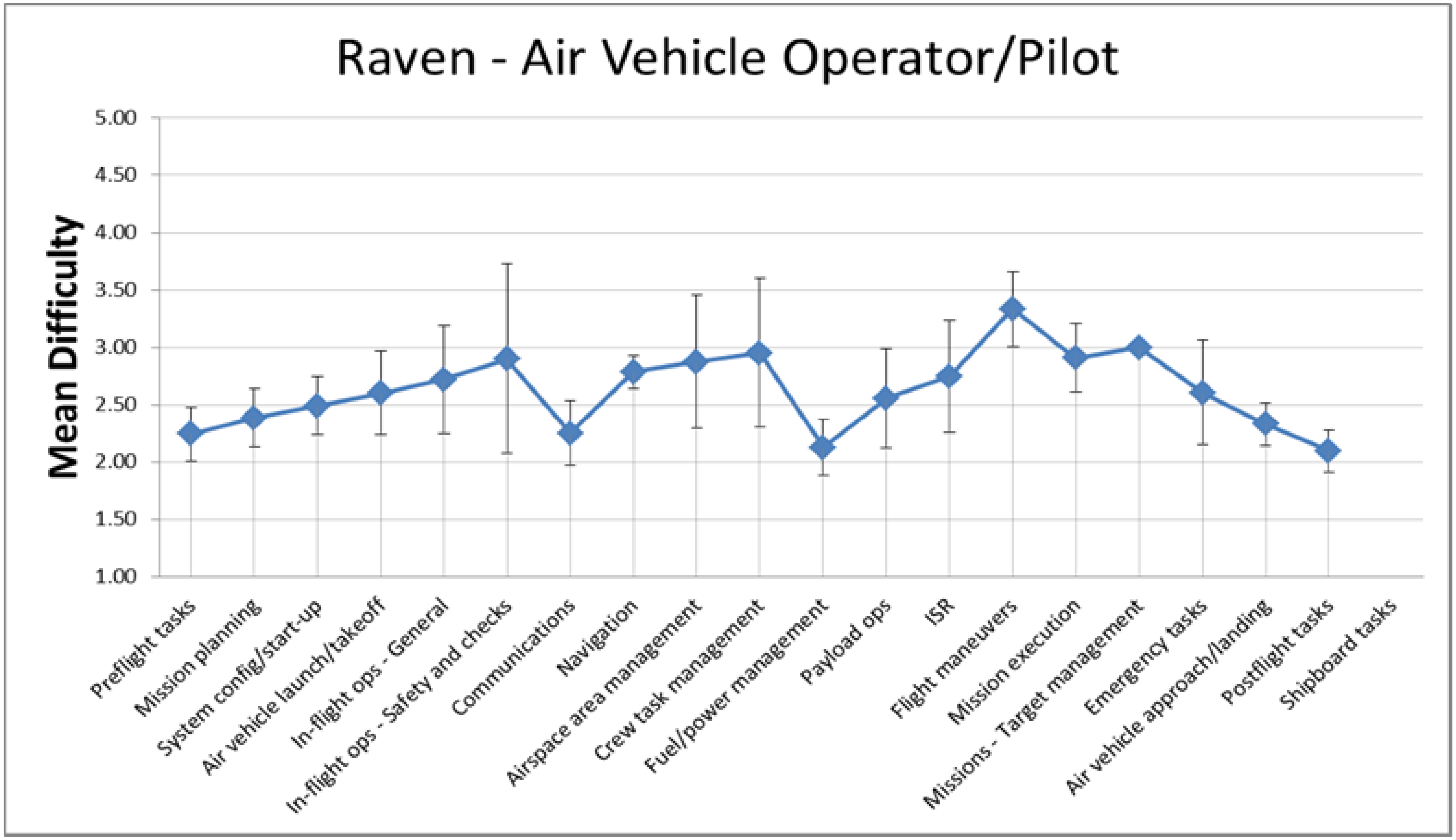


Figure 20: Task cluster profiles for Shadow – Air vehicle operator/Pilot – Mean task difficulty

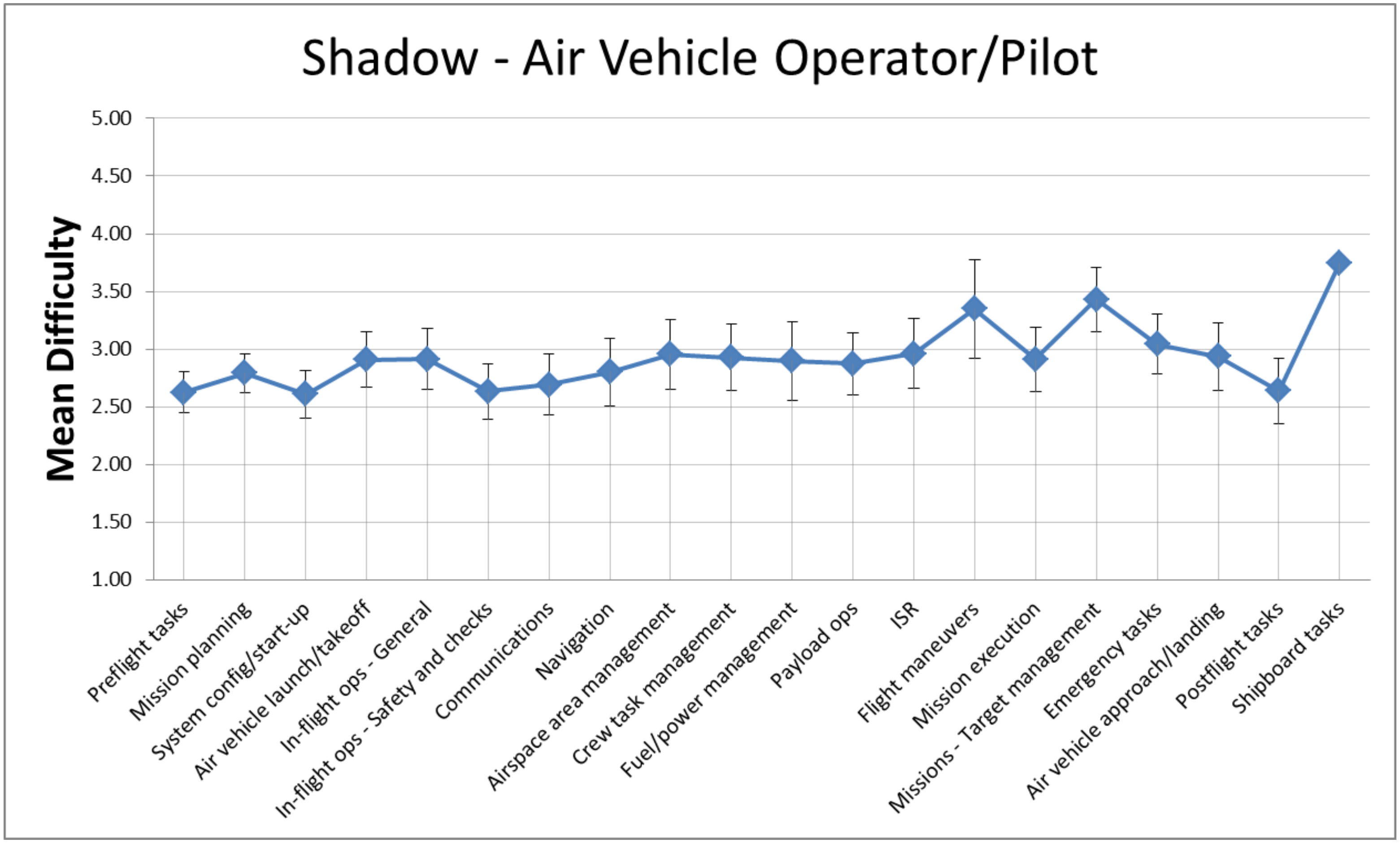


Figure 21: Task cluster profiles for Fire Scout – Air vehicle operator/Pilot – Mean task difficulty

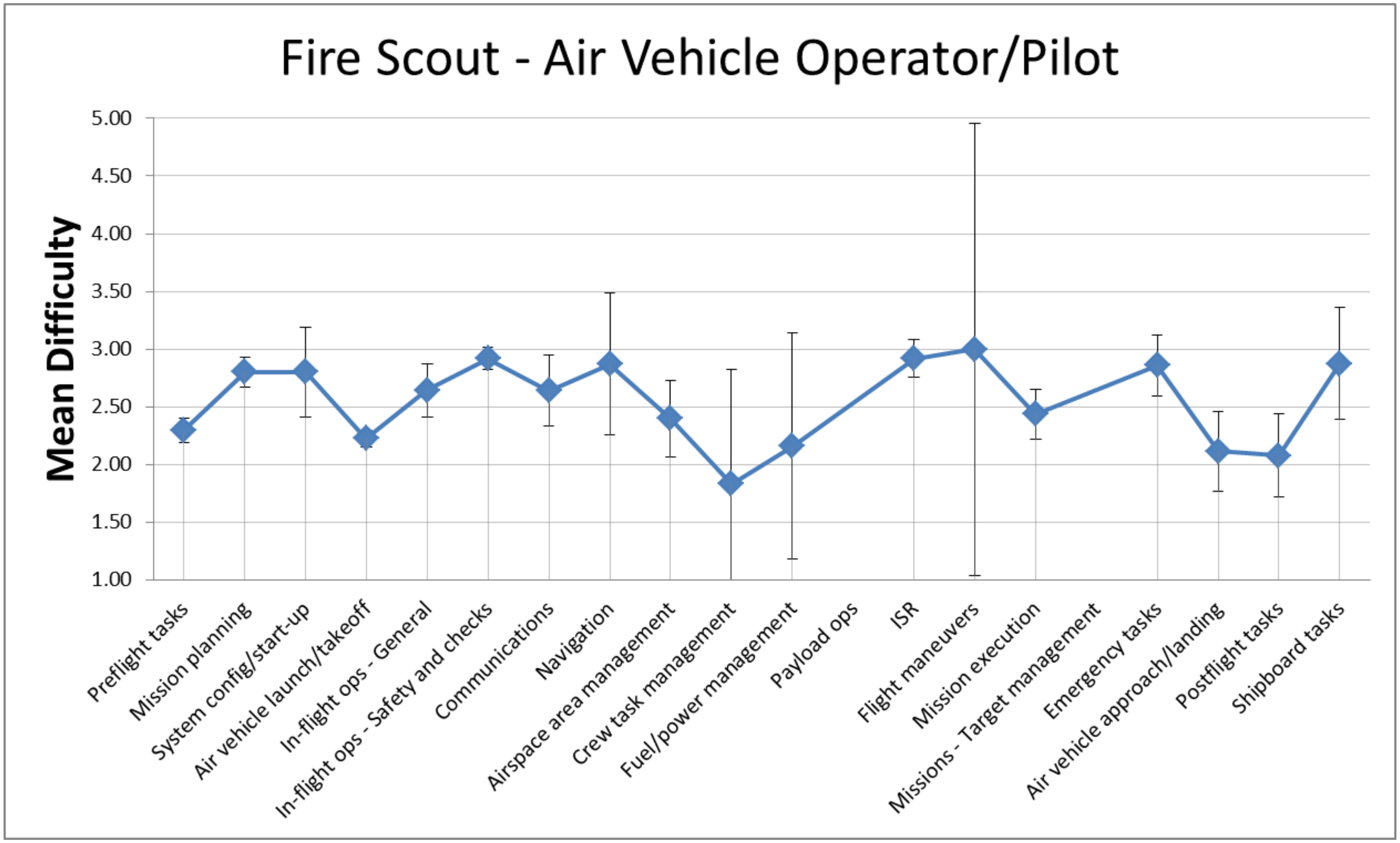


Figure 22: Task Cluster profiles for BAMS-D – Air vehicle operator/Pilot – Mean task difficulty

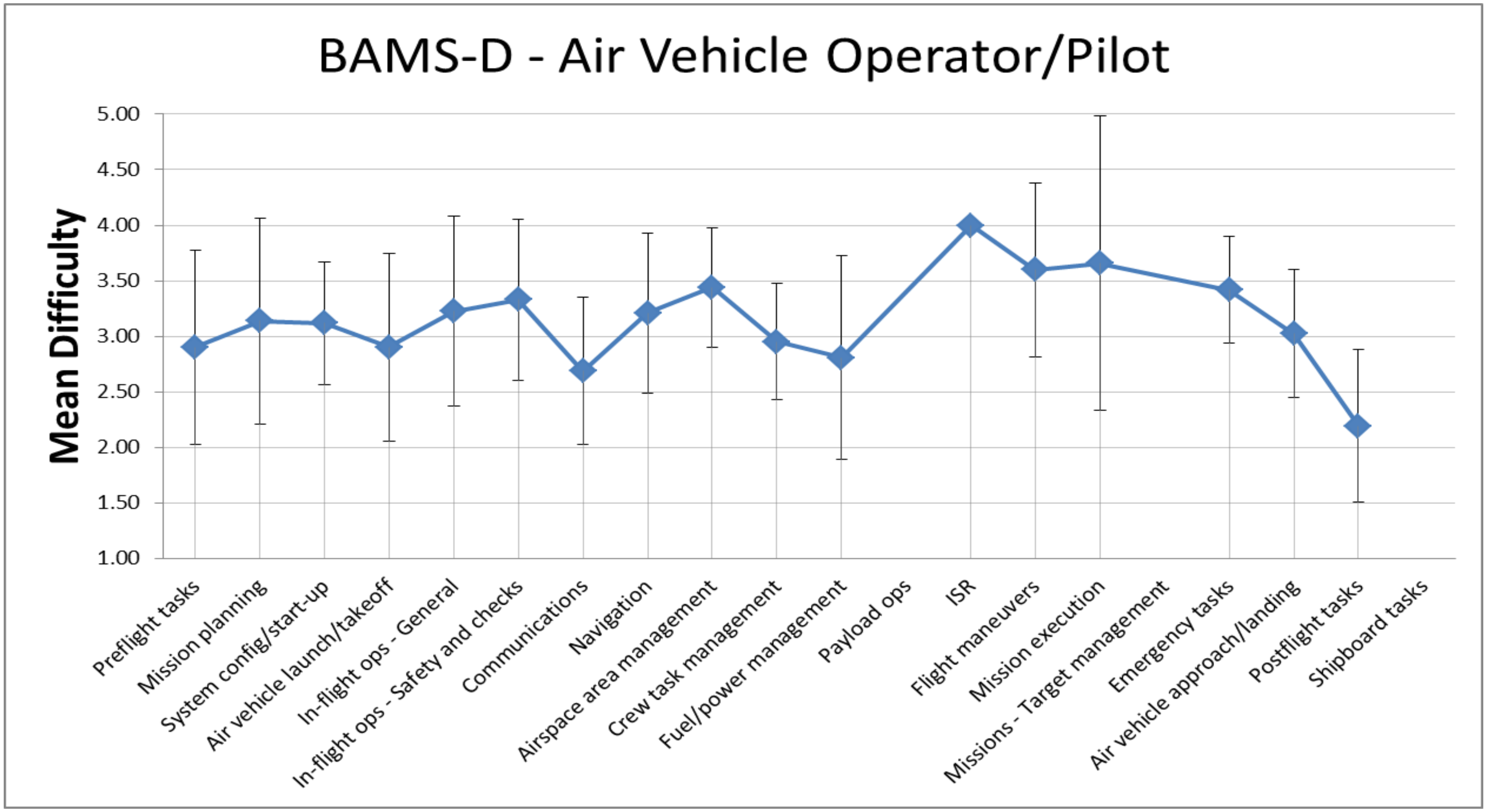


Figure 23: Task cluster profiles for BAMS – Air vehicle operator/Pilot – Mean task difficulty

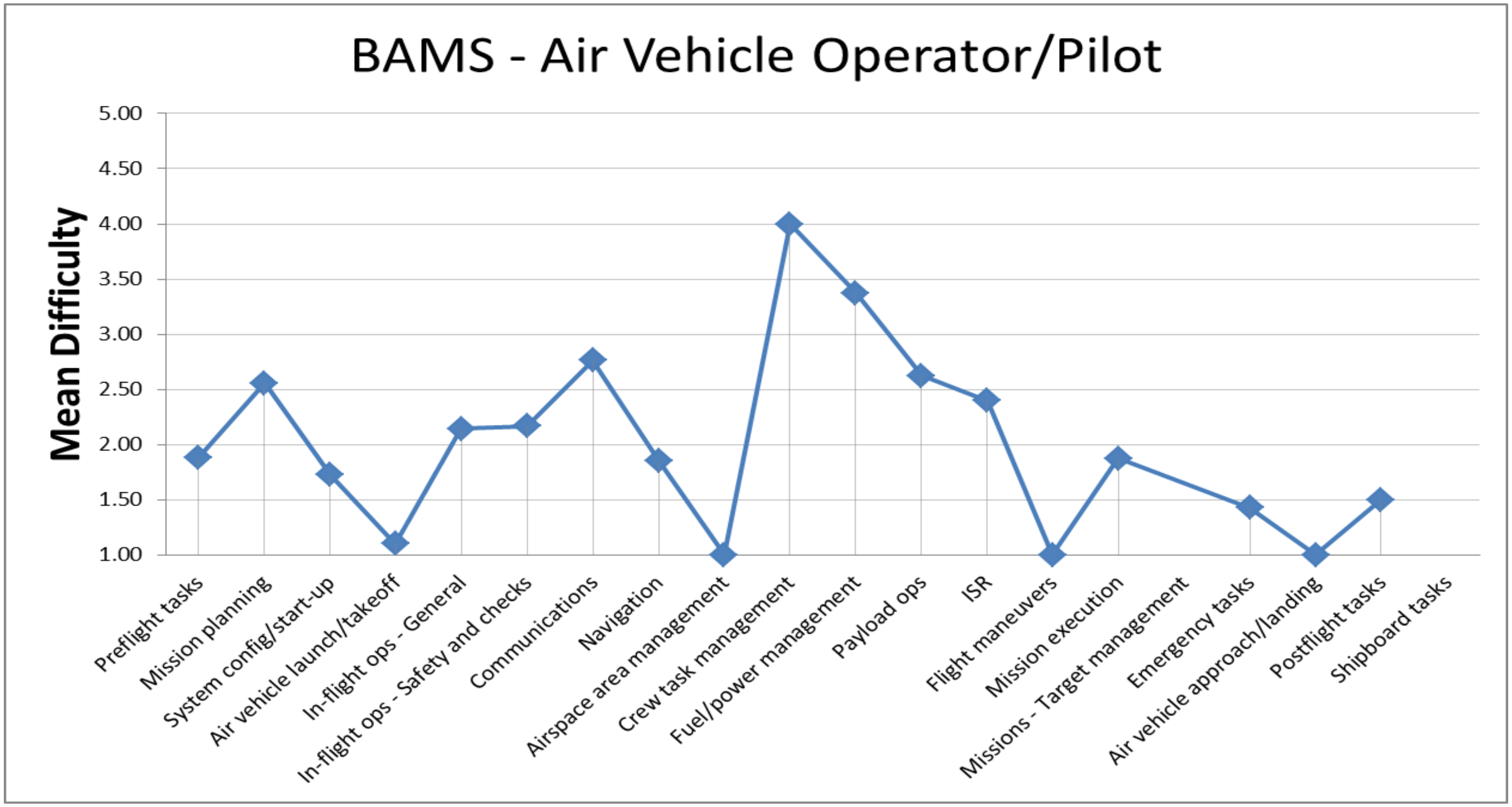


Figure 24: Task cluster profiles for all platforms – Air vehicle operator/Pilot – Mean task difficulty

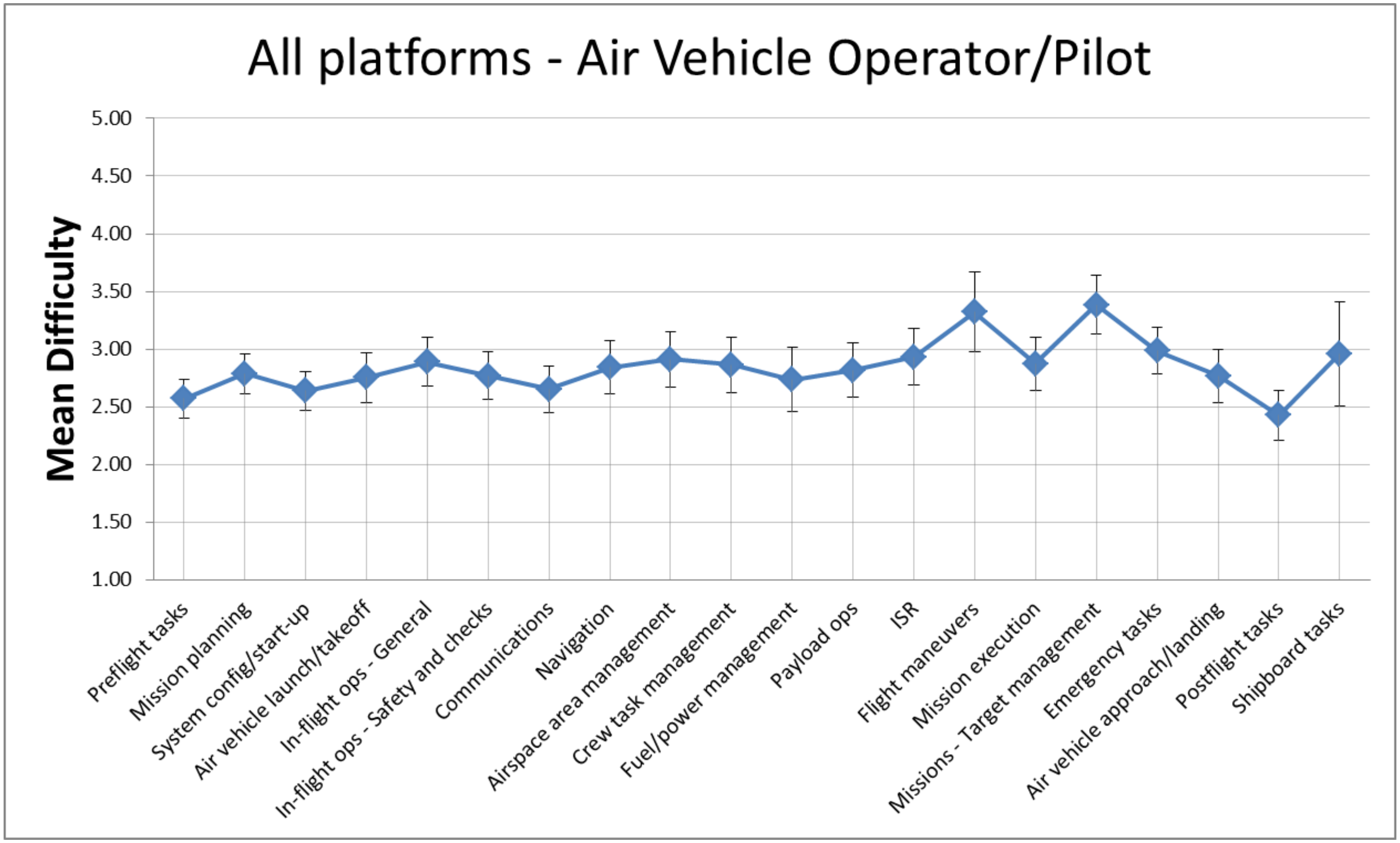


Figure 25: Task cluster profiles for Raven – Sensor/Payload operator – Mean task difficulty

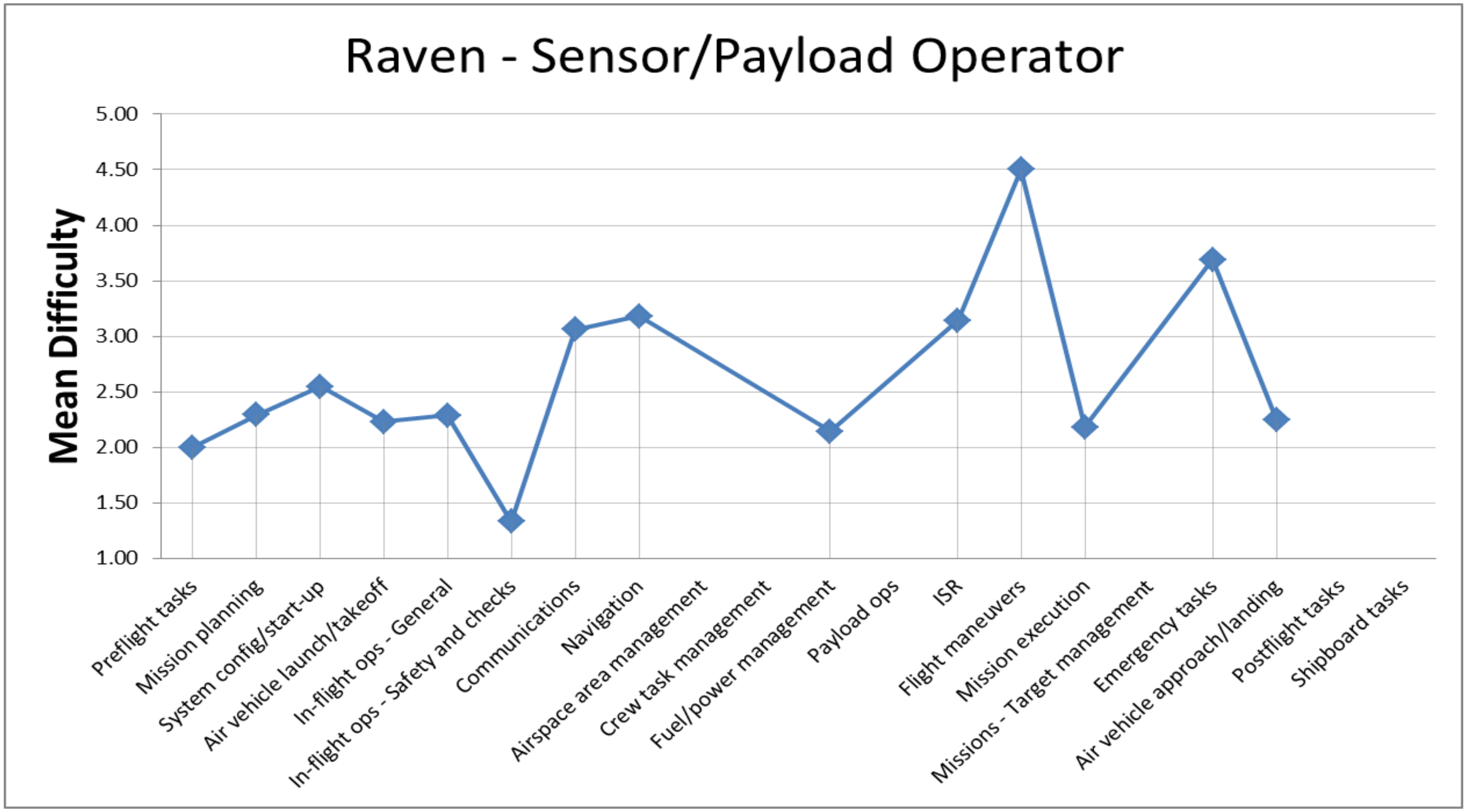


Figure 26: Task cluster profiles for Shadow – Sensor/Payload operator – Mean task difficulty

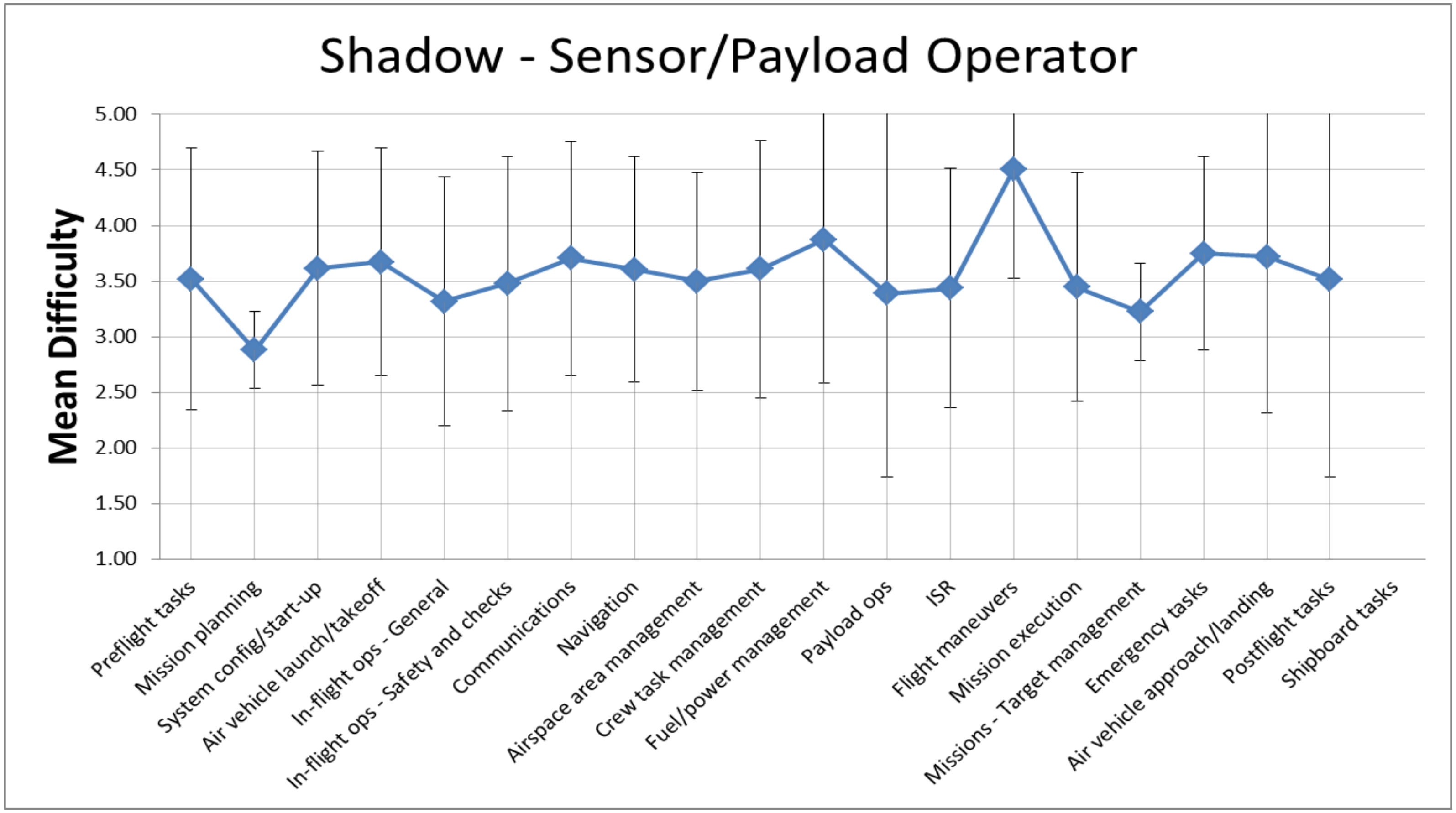


Figure 27: Task cluster profiles for BA<S-D – Sensor/Payload operator – Mean task difficulty

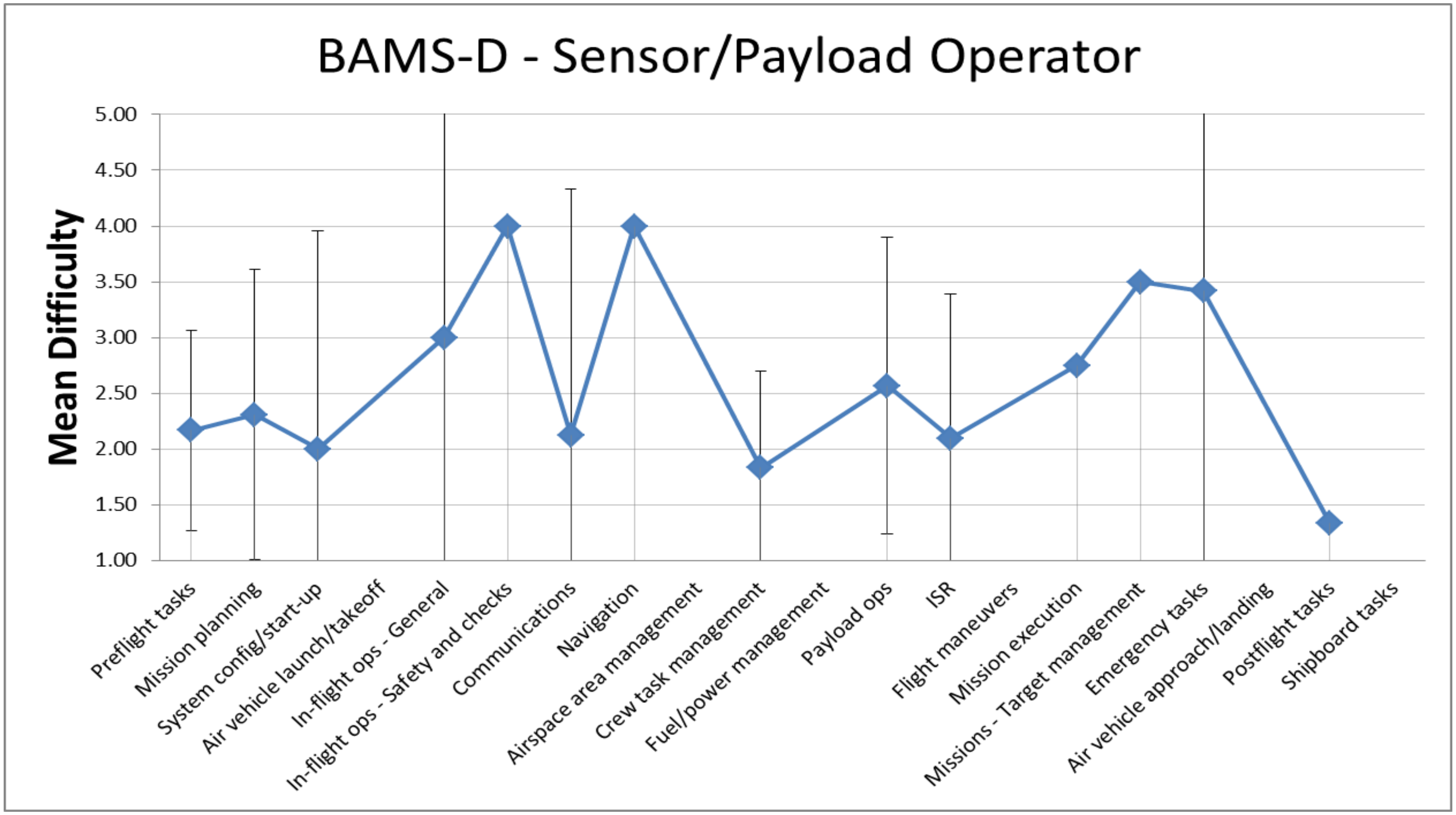


Figure 28: Task cluster profiles for BAMS – Sensor/Payload operator – Mean task difficulty

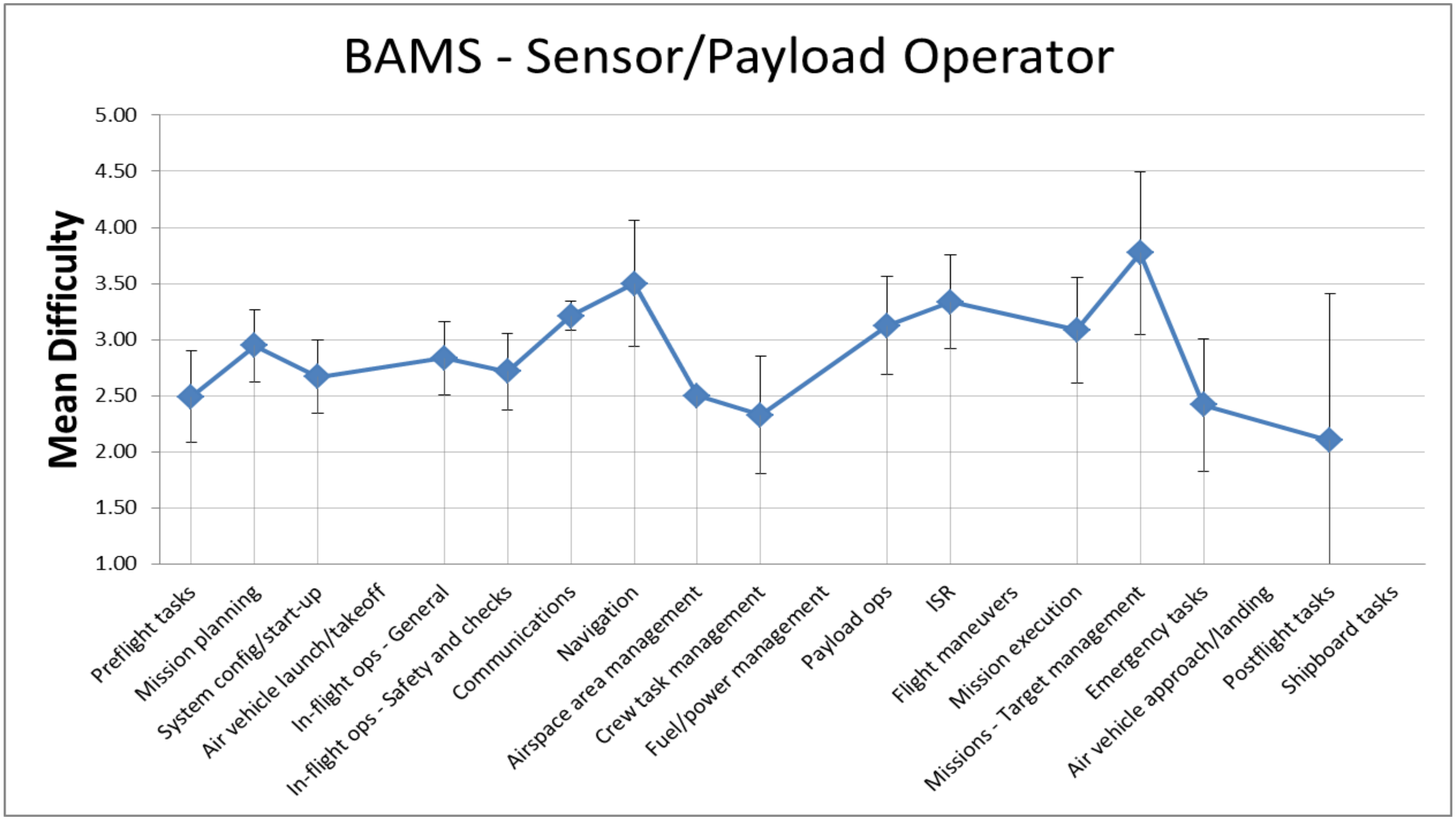


Figure 29: Task cluster profiles for all platforms – Sensor/Payload operator – Mean task difficulty

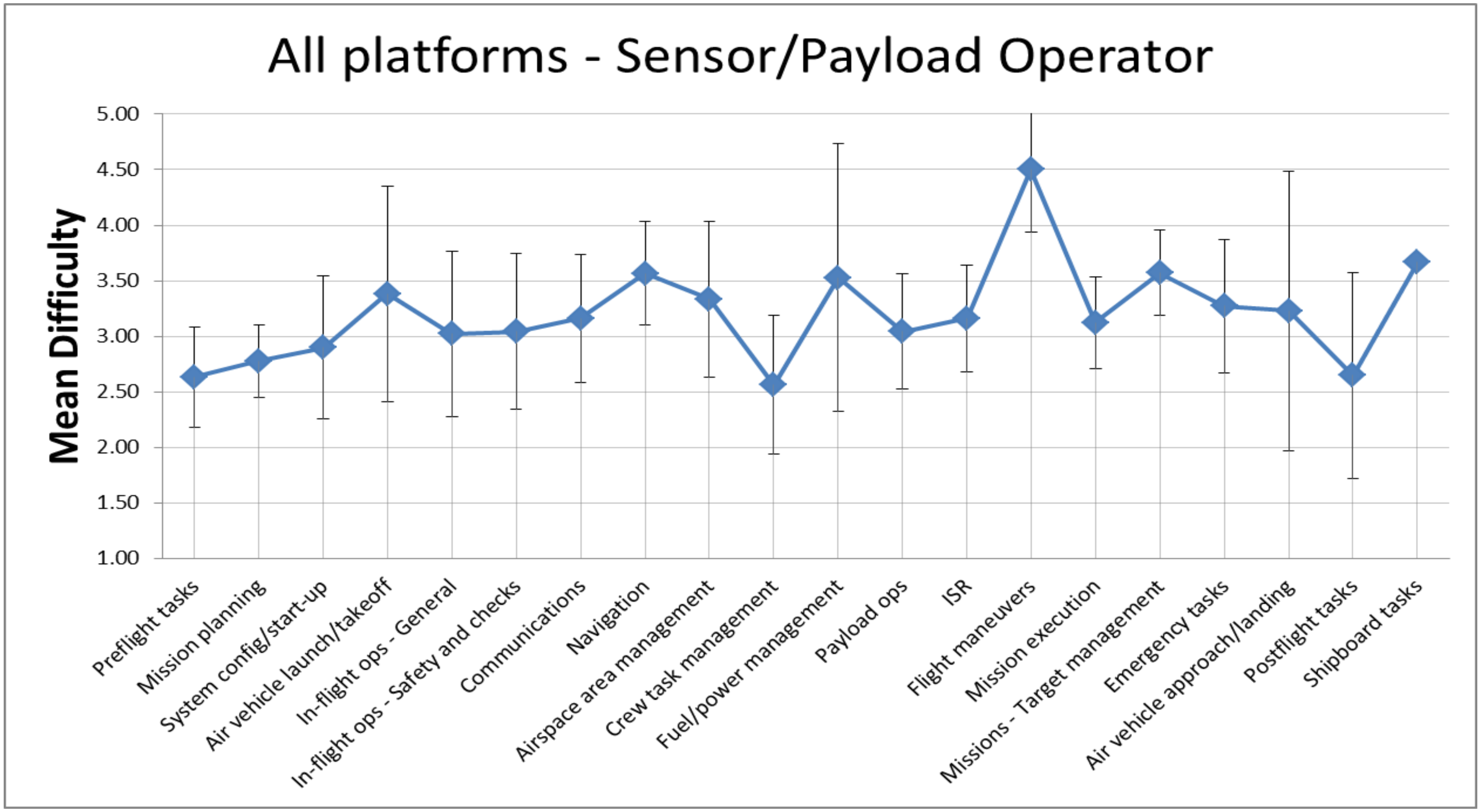


Figure 30: Task cluster profiles for ScanEagle – Mission commander – Mean task difficulty

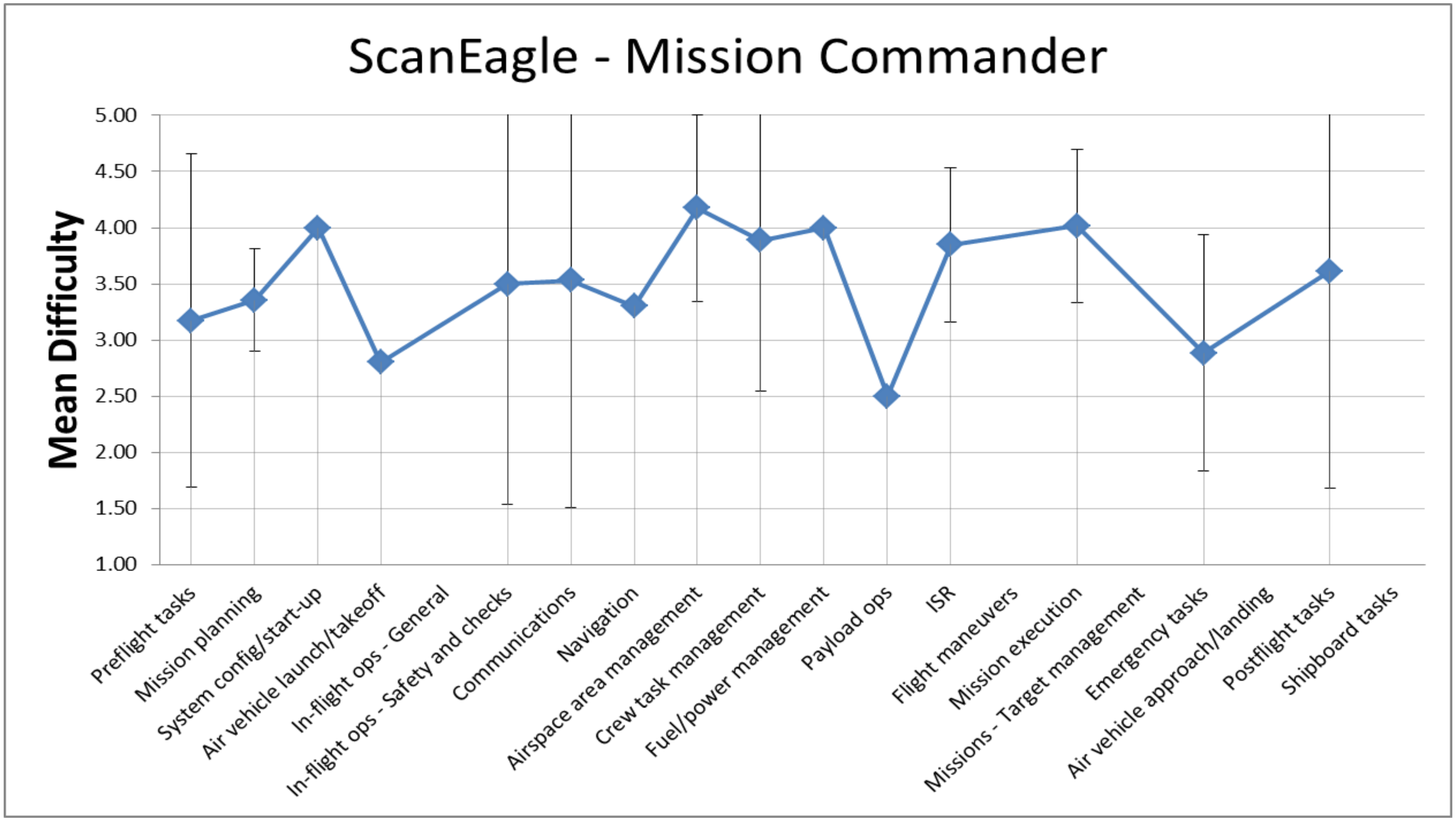


Figure 31: Task cluster profiles for BAMS-D – Mission commander – Mean task difficulty

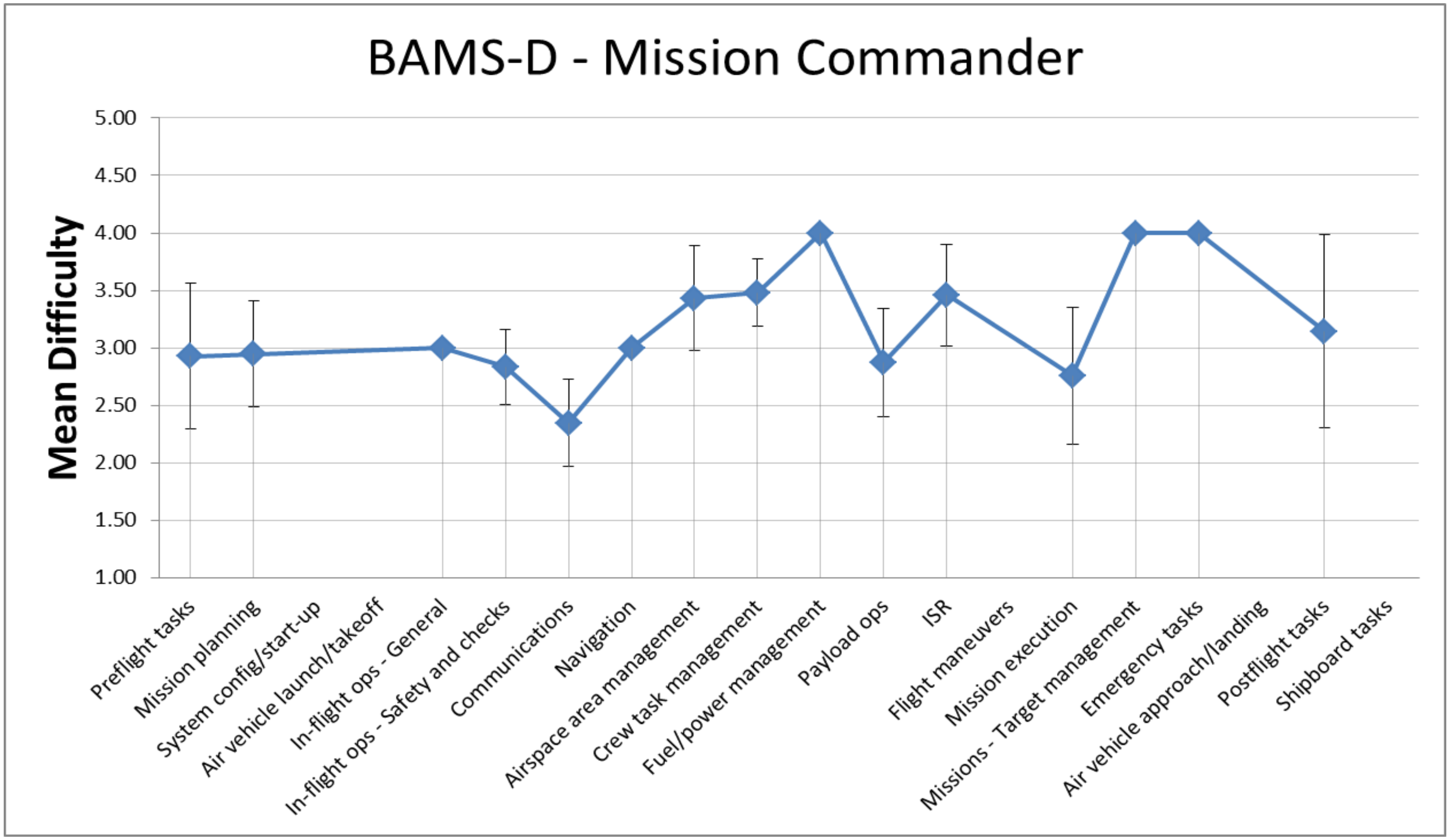


Figure 32: Task cluster profiles for BAMS – Mission commander – Mean task difficulty

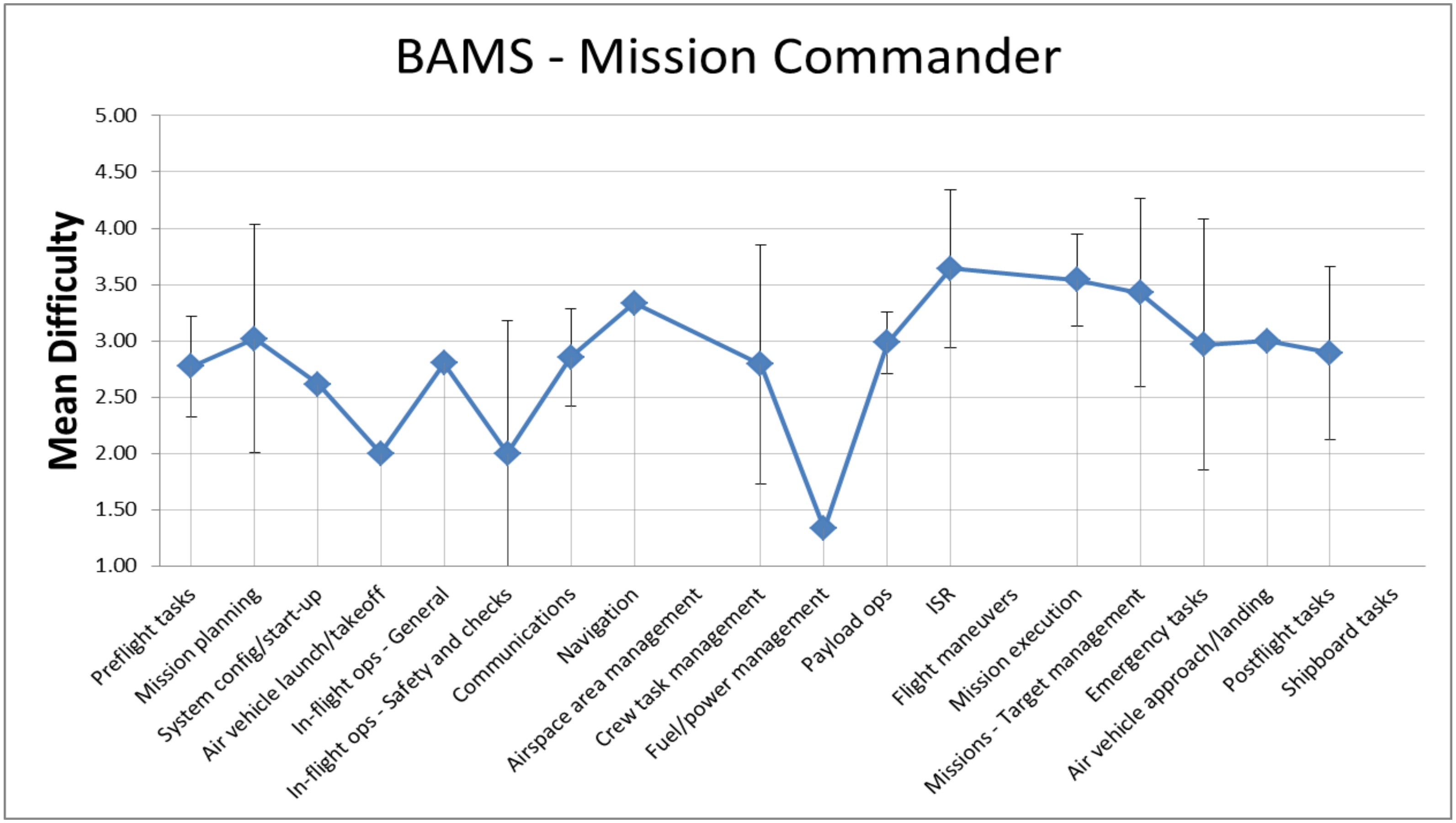


Figure 33: Task cluster profiles for all platforms – Mission commander – Mean task difficulty

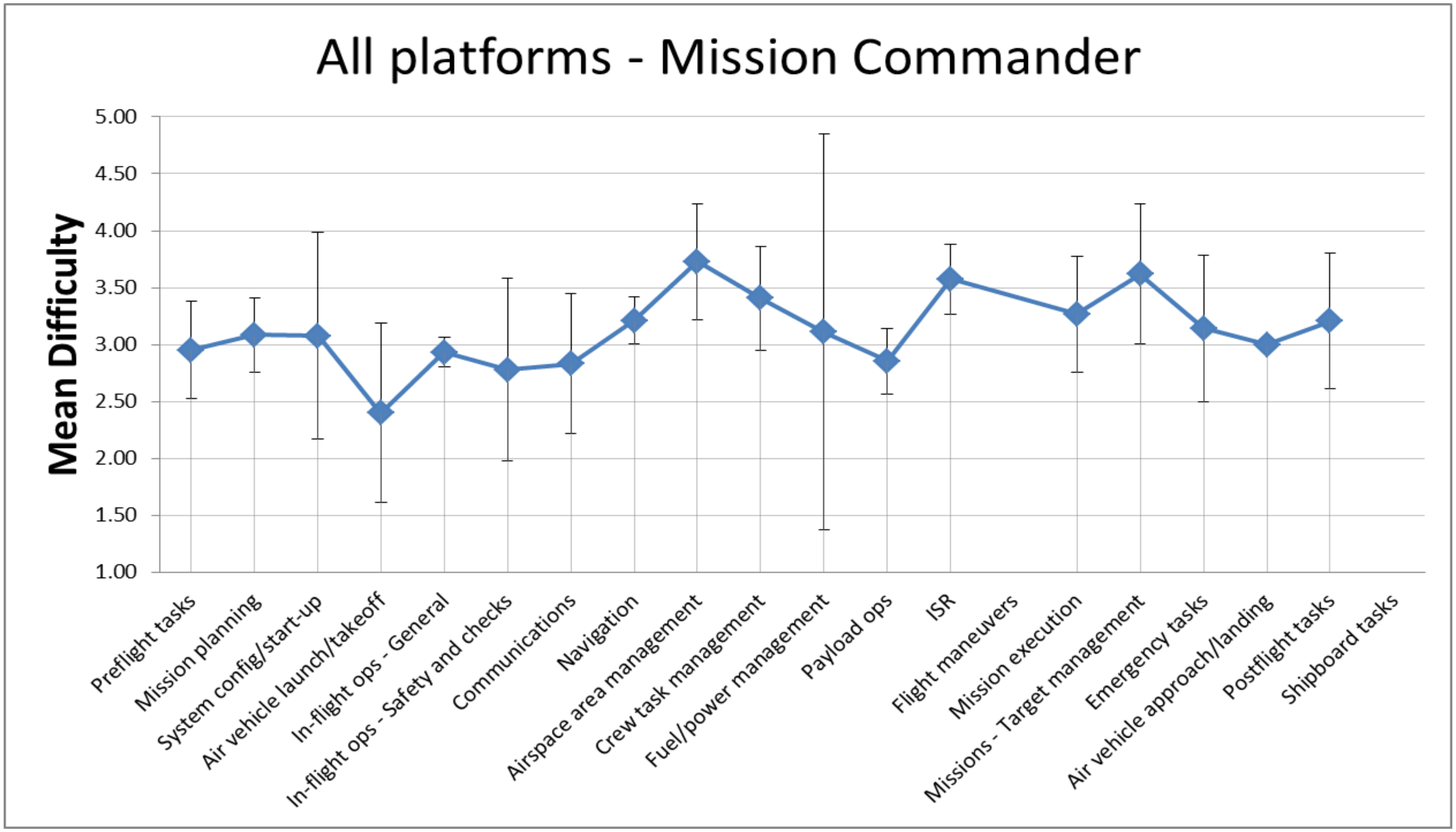


Figure 34: Task cluster profiles for BAMS-D – TACCO – Mean task difficulty

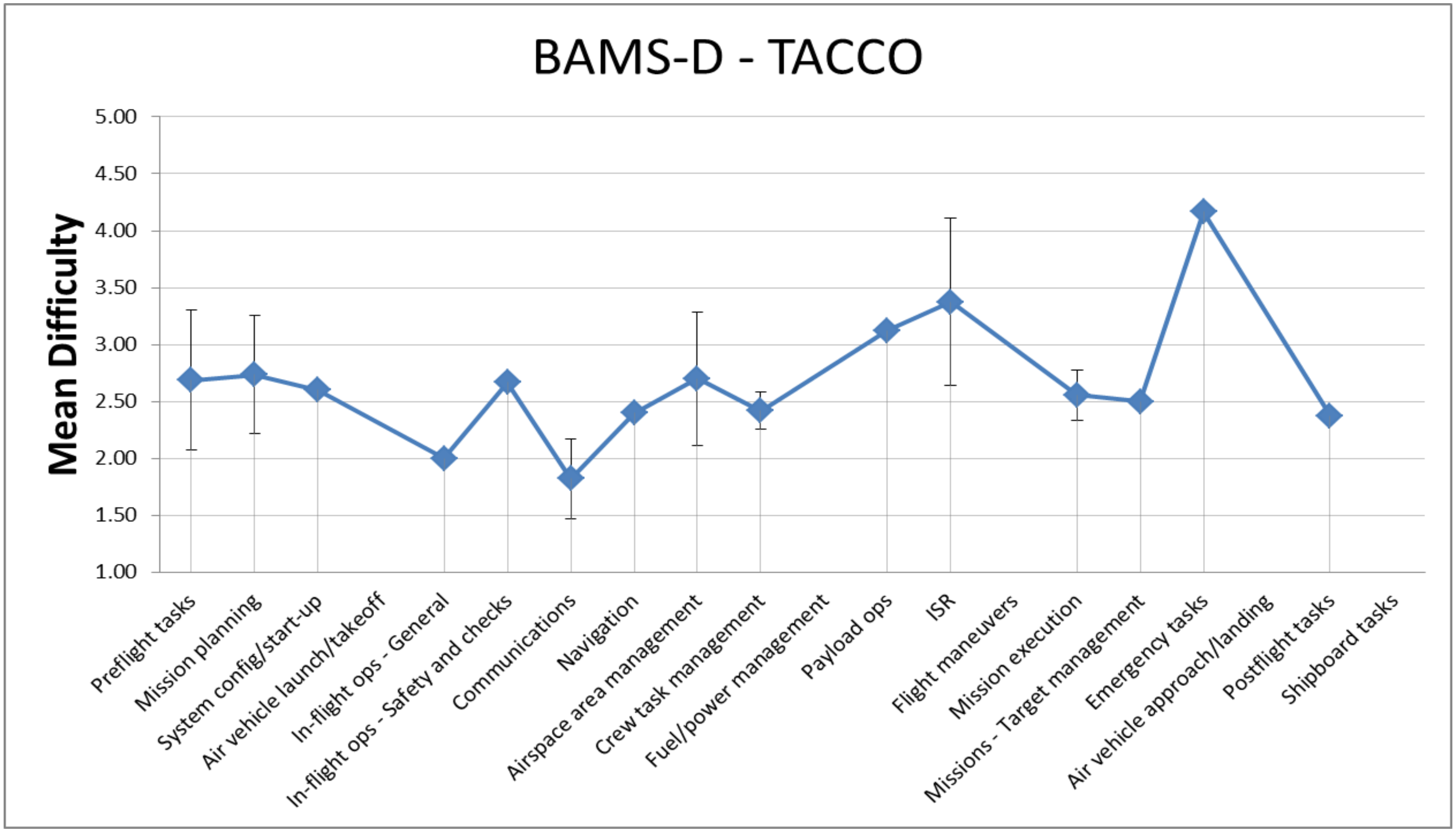


Figure 35: Task cluster profiles for BAMS – TACCO – Mean task difficulty

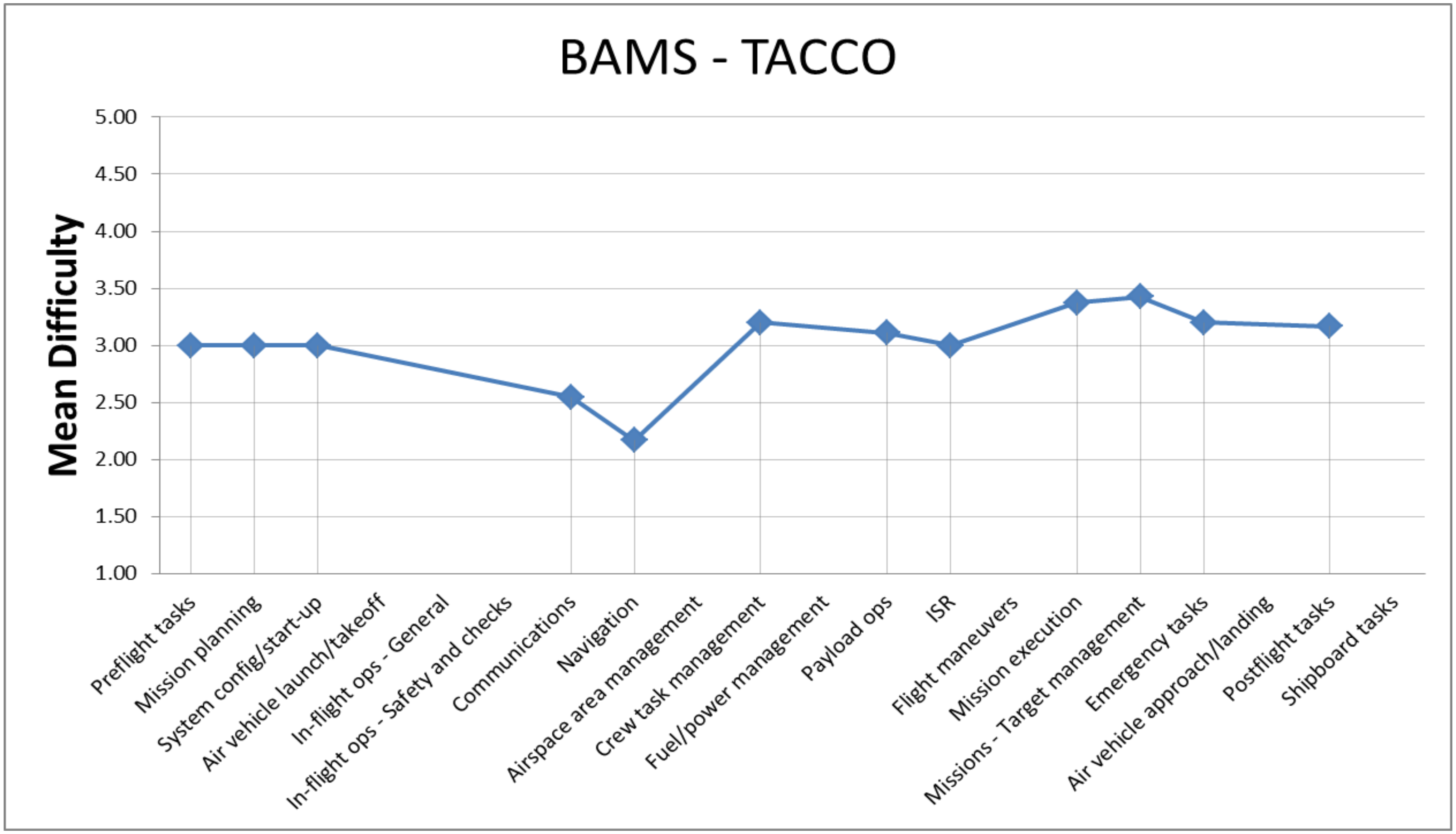
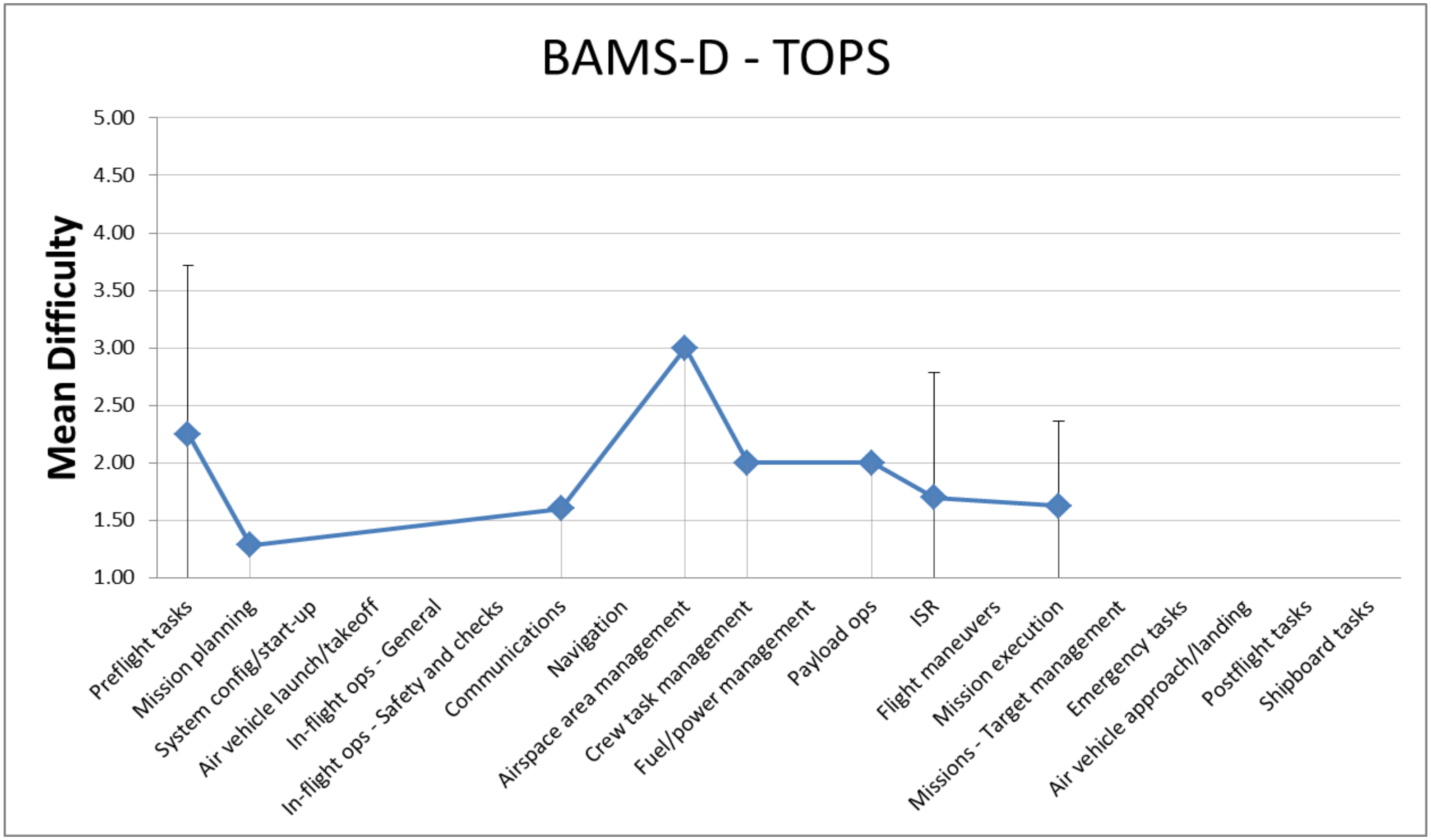


Figure 36: Task cluster profiles for BAMS-D – TOPS – Mean task difficulty



Figures 37: Task cluster profiles for Raven – Air vehicle operator/Pilot – Mean task frequency

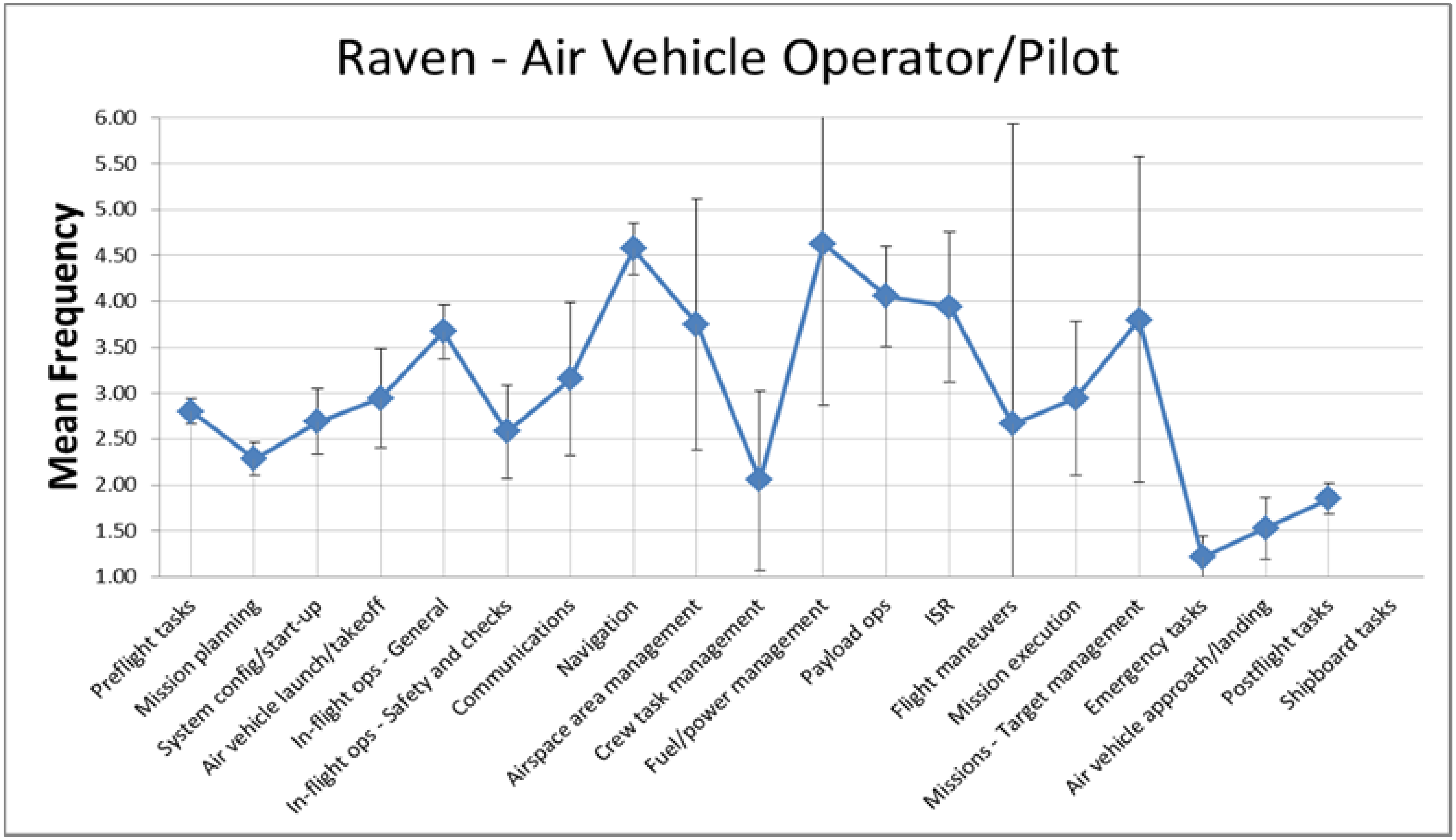


Figure 38: Task cluster profiles for Shadow – Air vehicle operator/Pilot – Mean task frequency

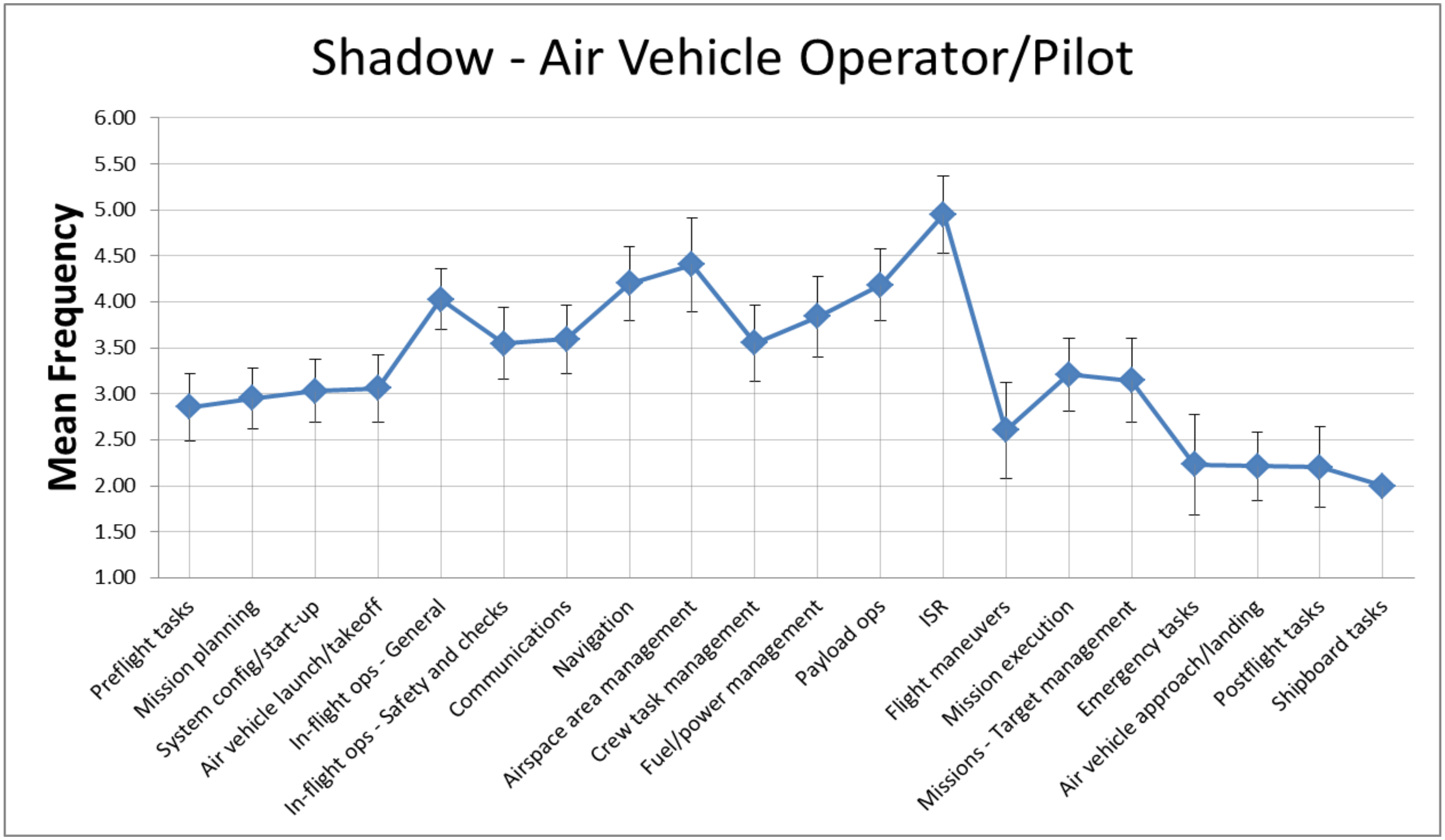


Figure 39: Task cluster profiles for Fire Scout – Air vehicle operator/Pilot – Mean task frequency

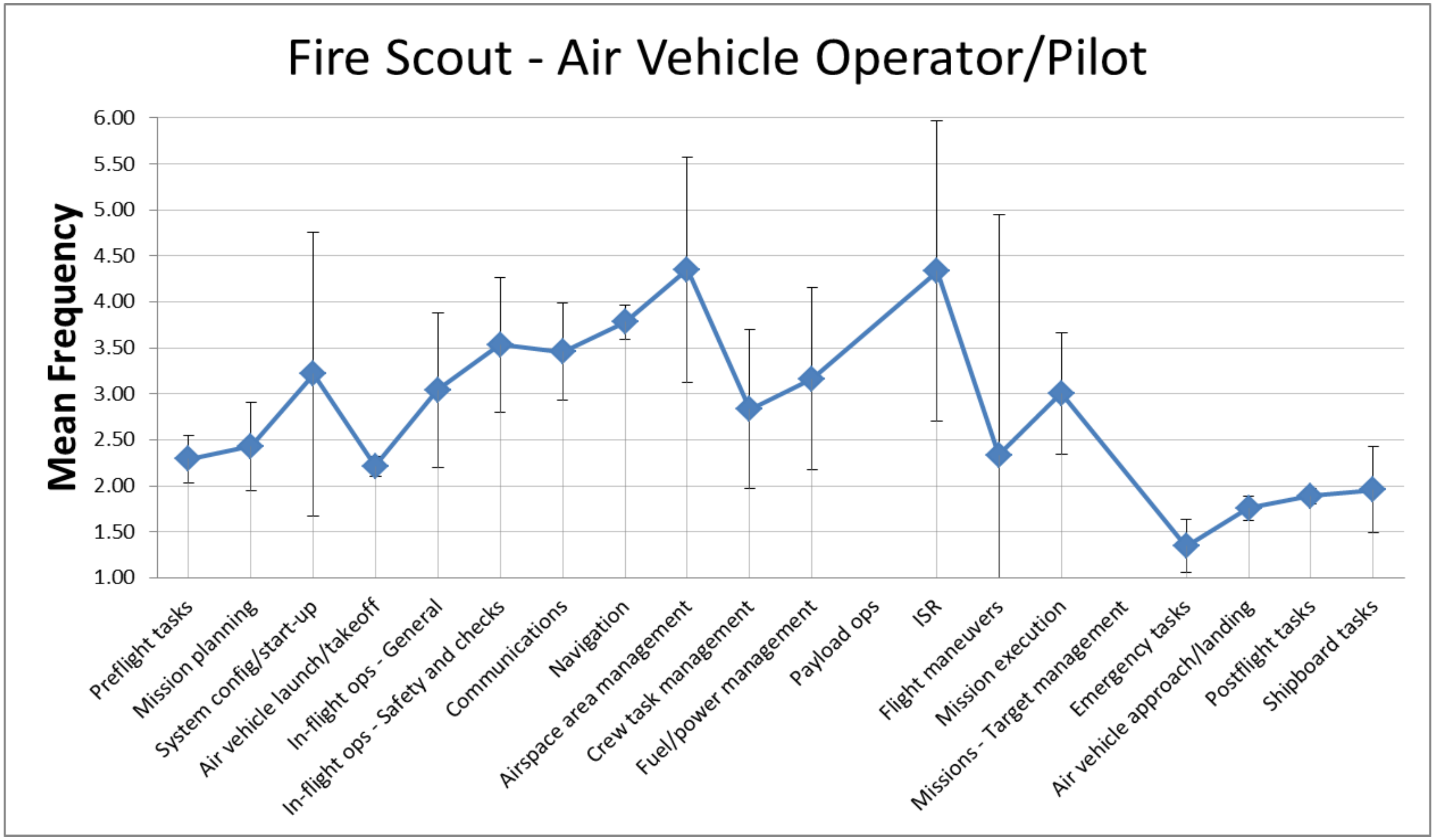


Figure 40: Task cluster profiles for BAMS-D – Air vehicle operator/Pilot – Mean task frequency

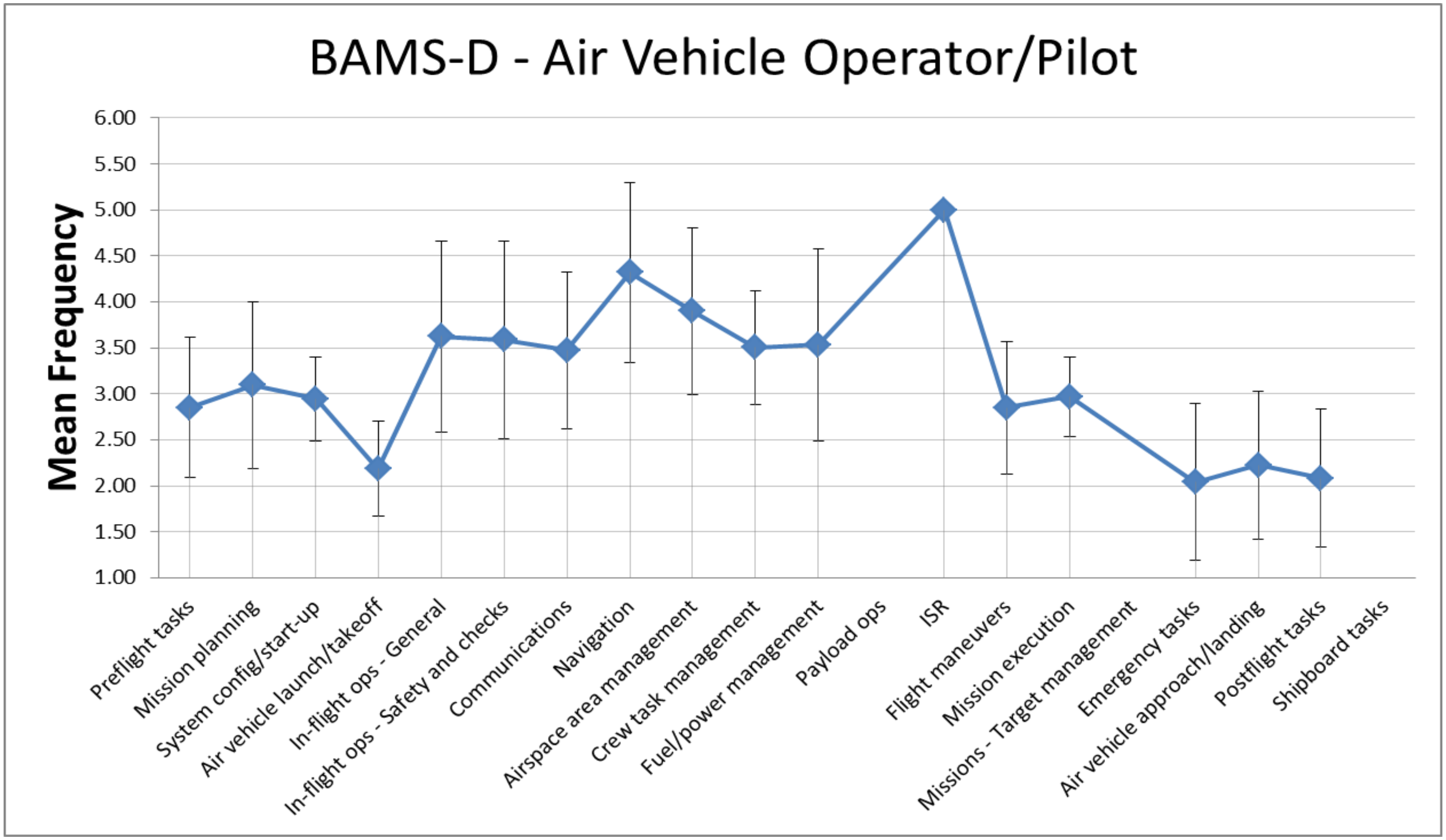


Figure 41: Task cluster profiles for BAMS – Air vehicle operator/Pilot – Mean task frequency

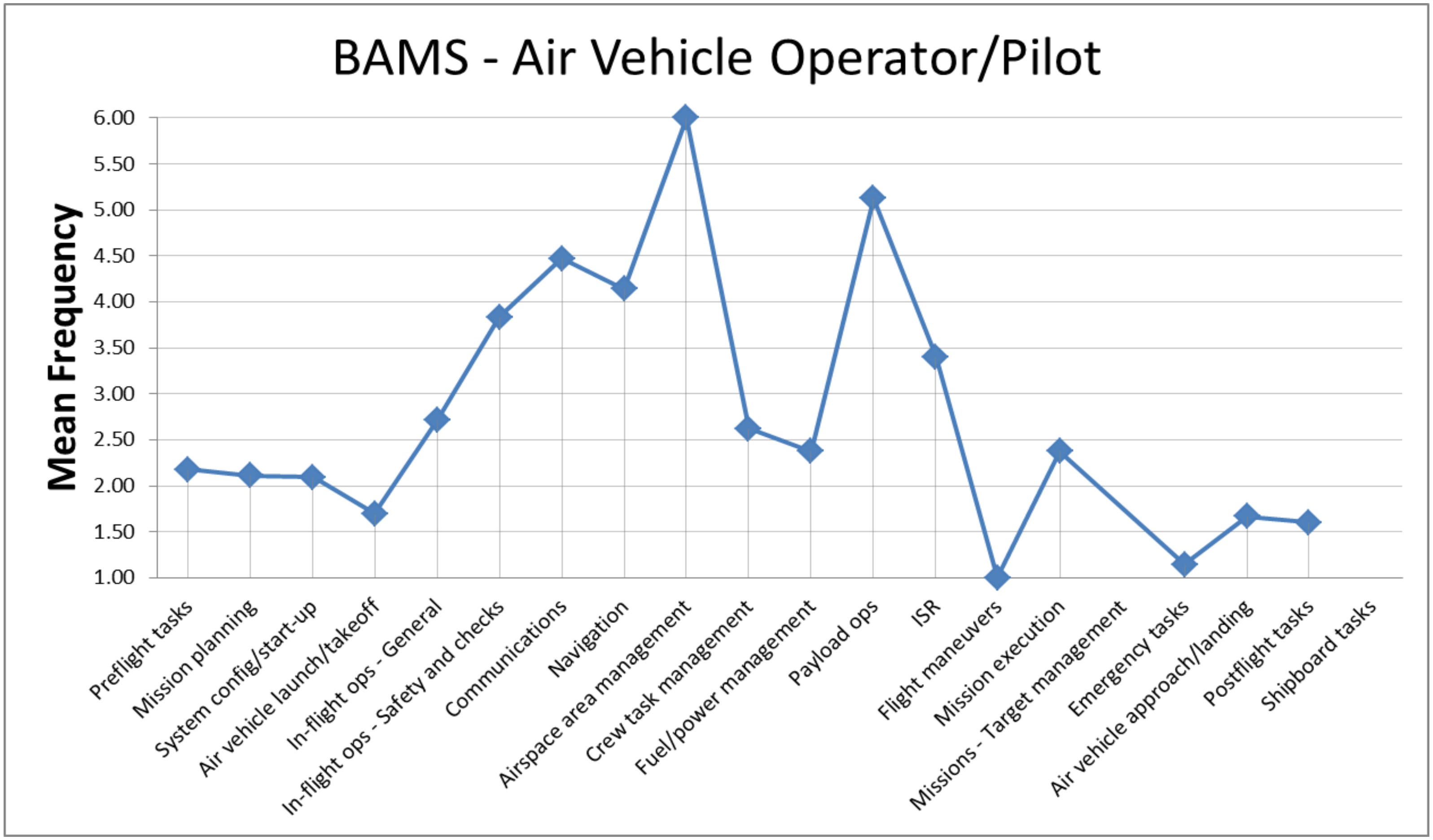


Figure 42: Task cluster profiles for all platforms – Air vehicle operator/Pilot – Mean task frequency

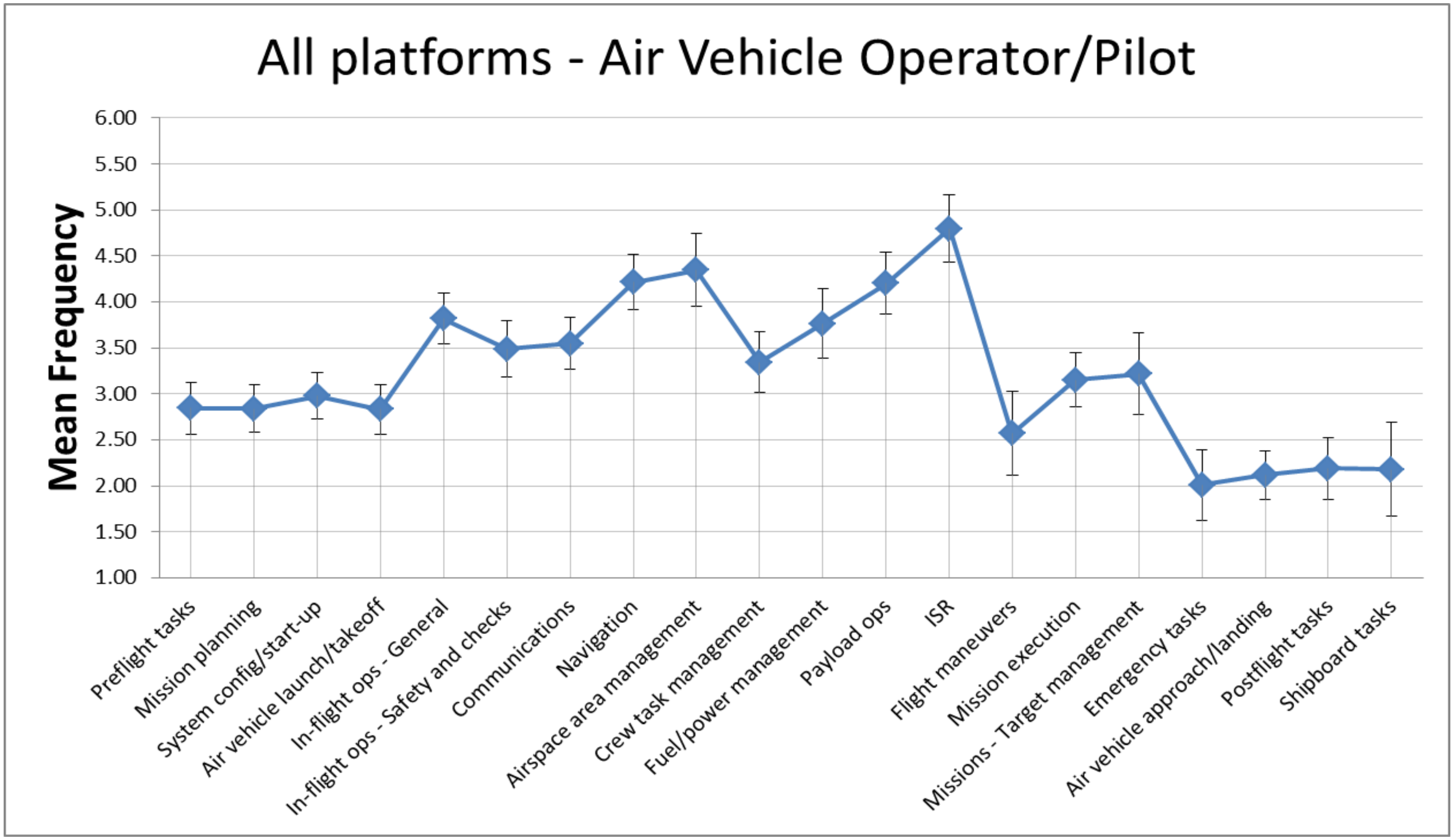


Figure 43: Task cluster profiles for Raven – Sensor/Payload operator – Mean task frequency

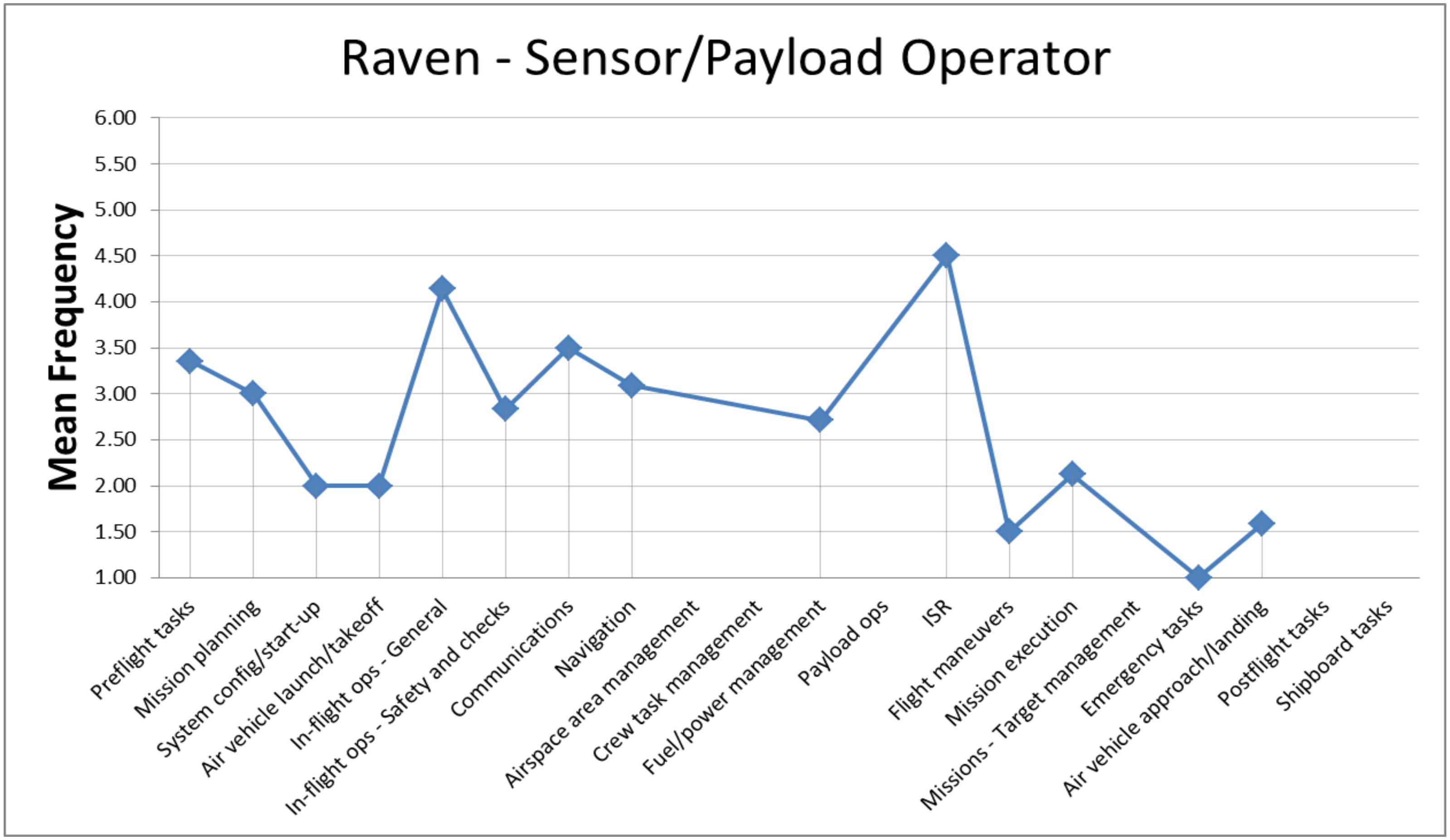


Figure 44: Task cluster profiles for Shadow – Sensor/Payload operator – Mean task frequency

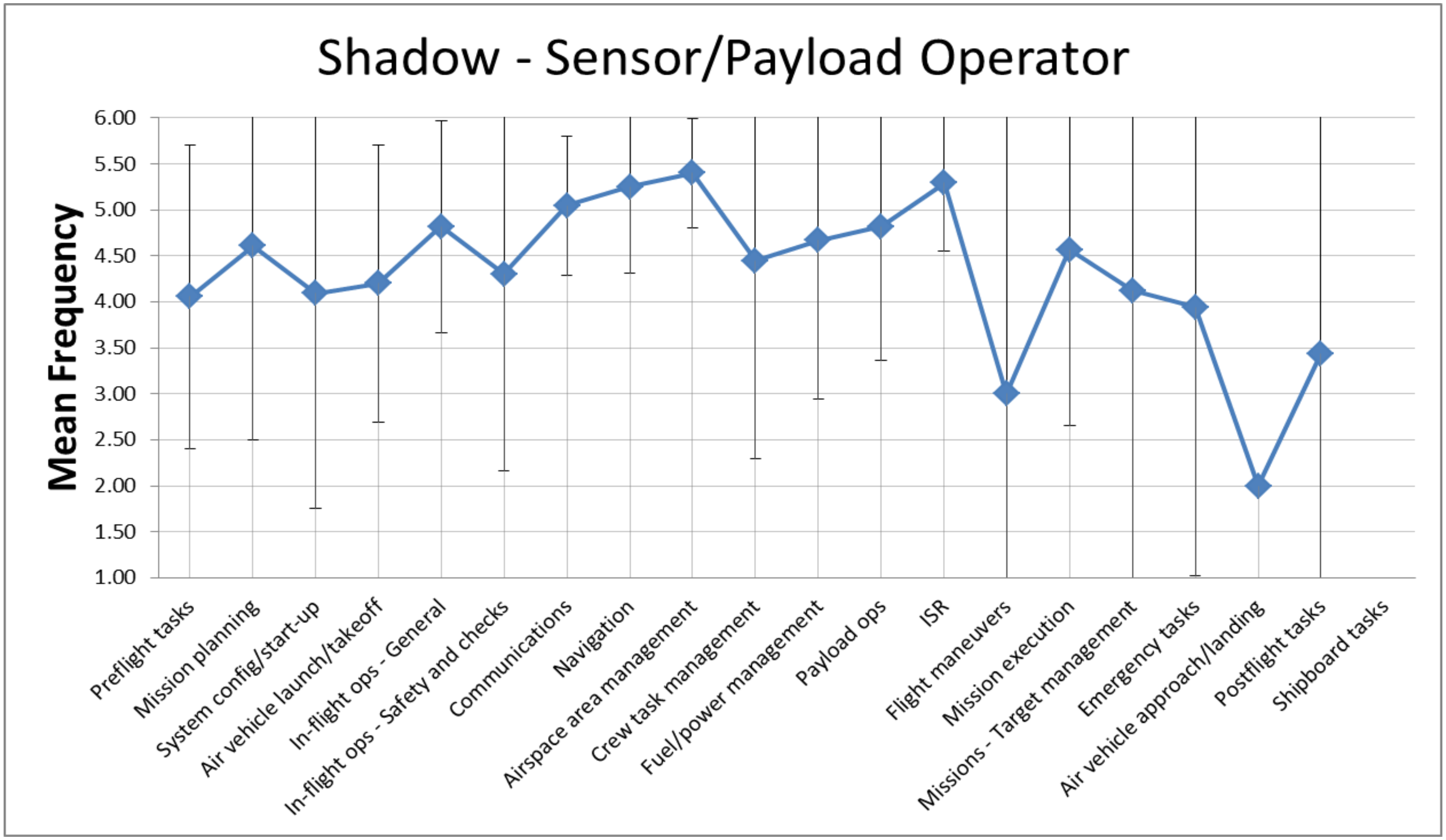


Figure 45: Task cluster profiles for BAMS-D – Sensor/Payload operator – Mean task frequency

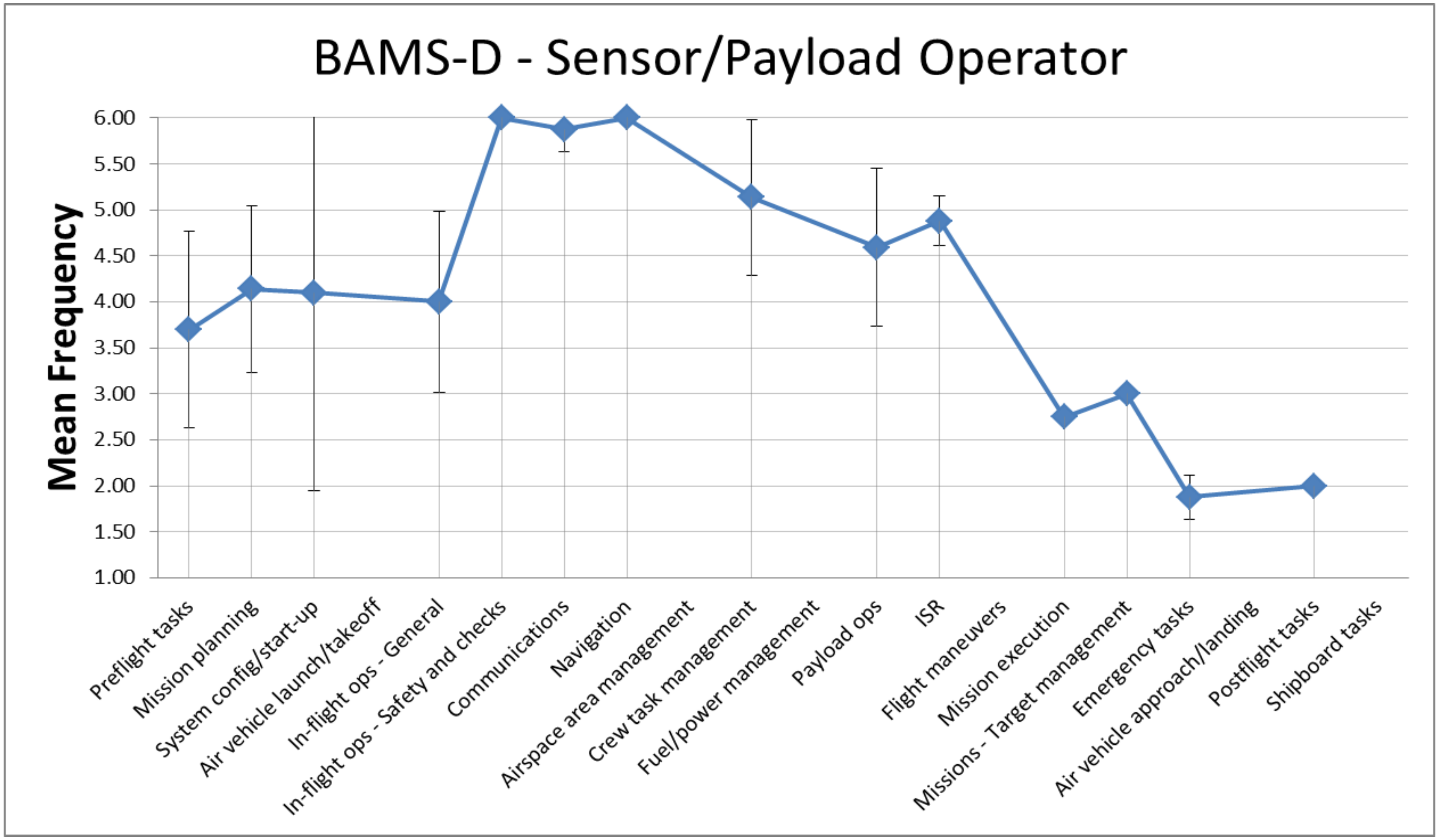


Figure 46: Task cluster profiles for BAMS – Sensor/Payload operator – Mean task frequency

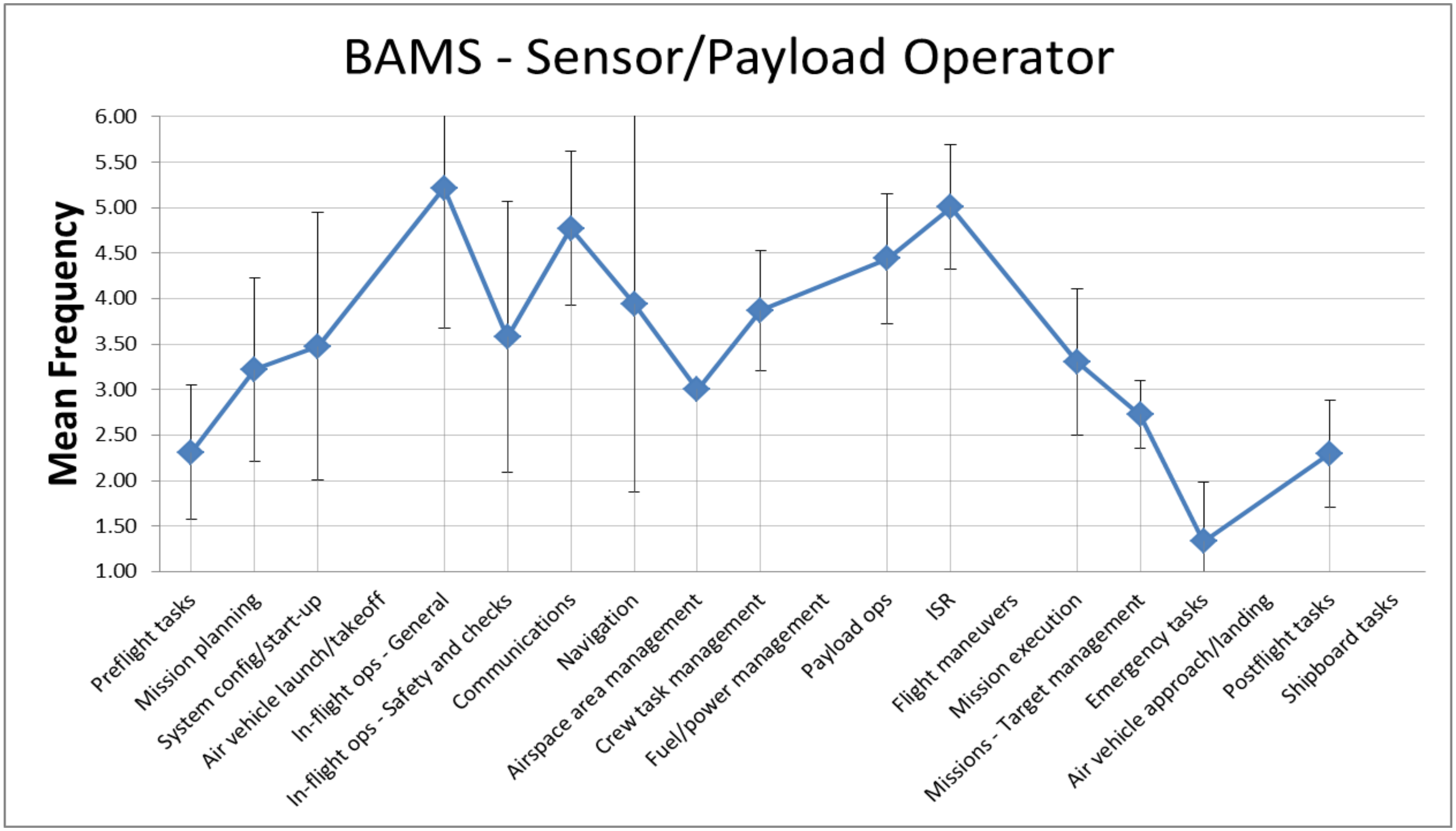


Figure 47: Task cluster profiles for all platforms – Sensor/Payload operator – Mean task frequency

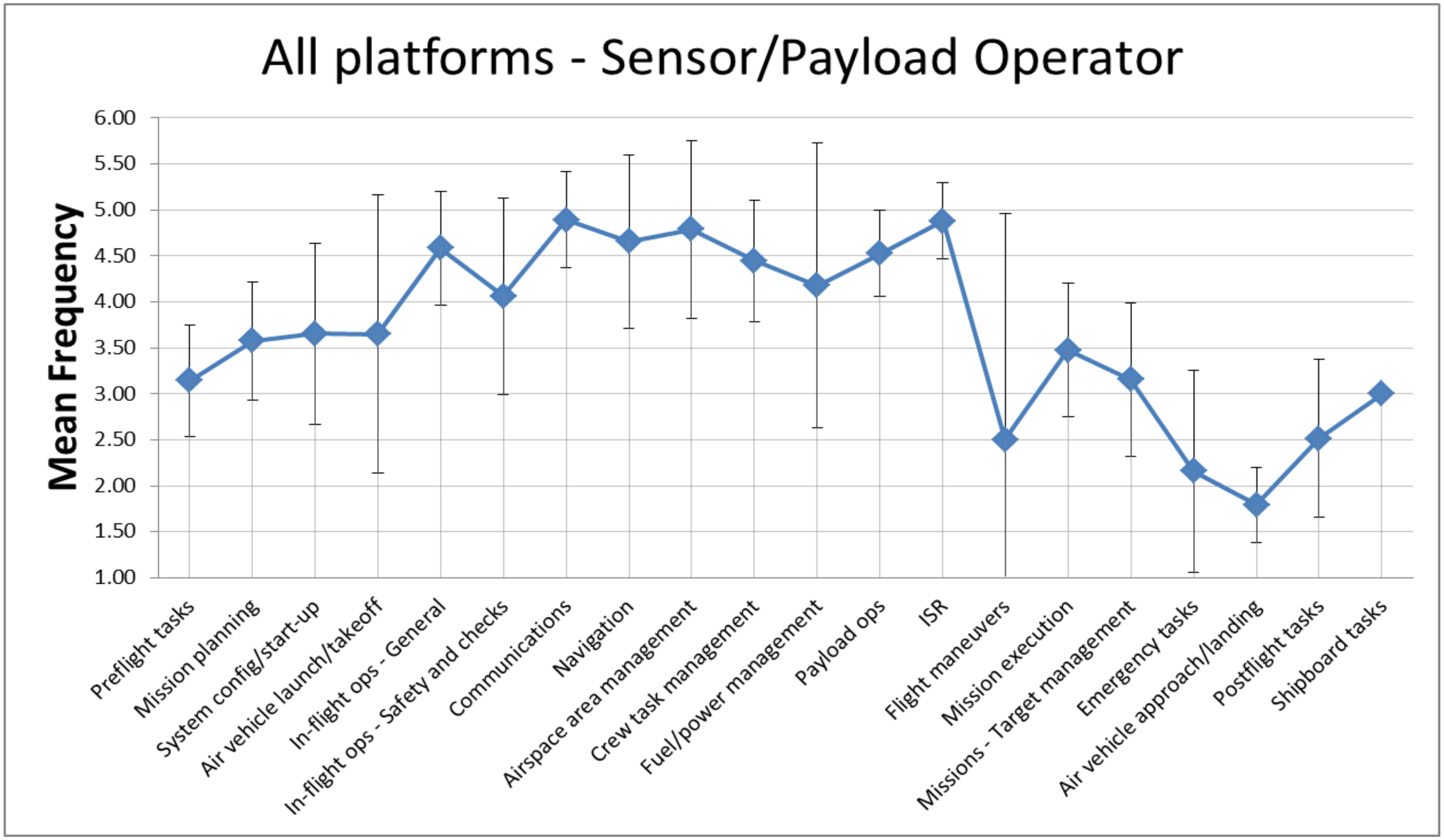


Figure 48: Task cluster profiles for ScanEagle – Mission commander – Mean task frequency

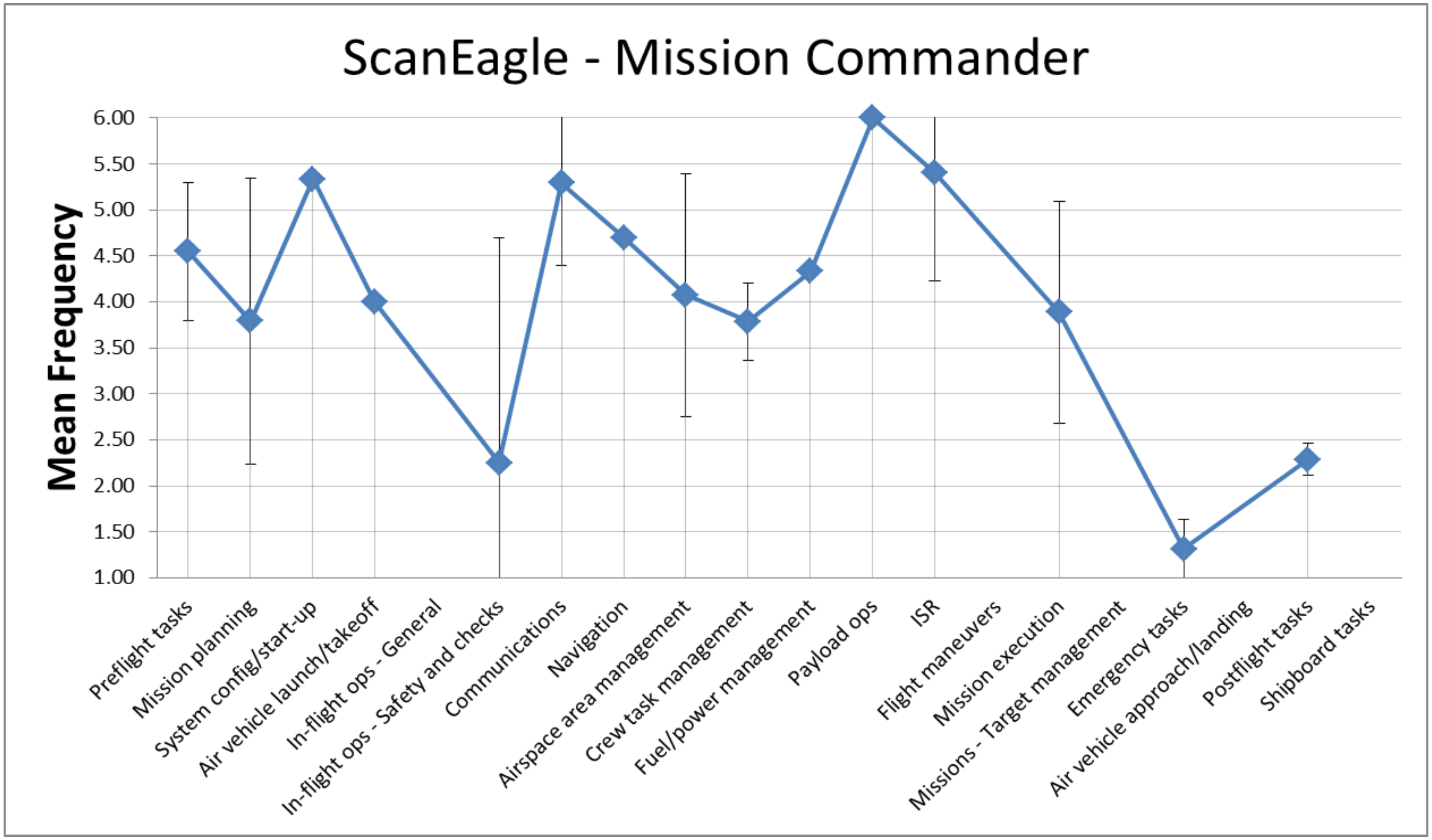


Figure 49: Task cluster profiles for BAMS-D – Mission commander – Mean task frequency

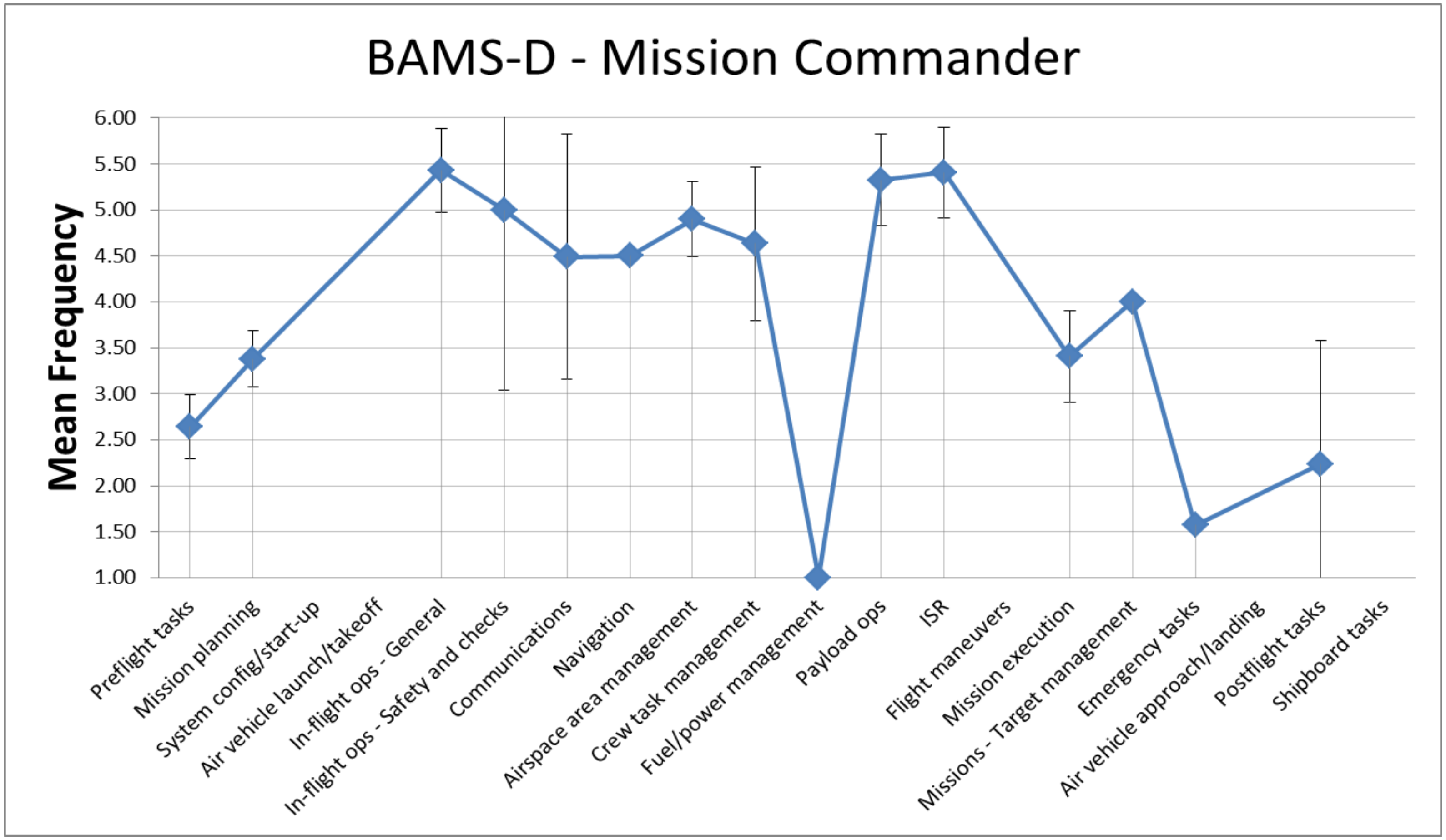


Figure 50: Task cluster profiles for BAMS – Mission commander – Mean task frequency

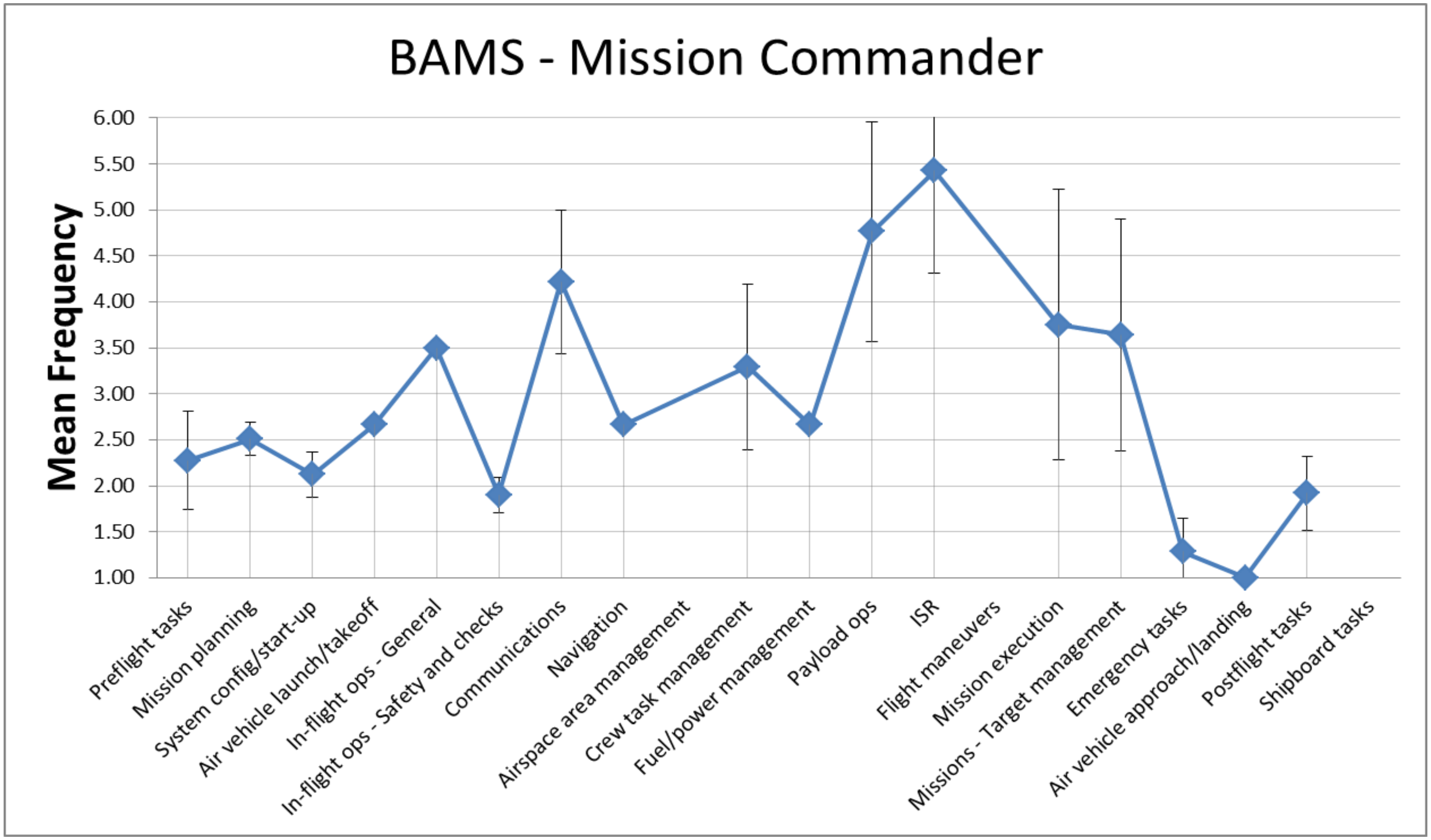


Figure 51: Task cluster profiles for all platforms – Mission commander – Mean task frequency

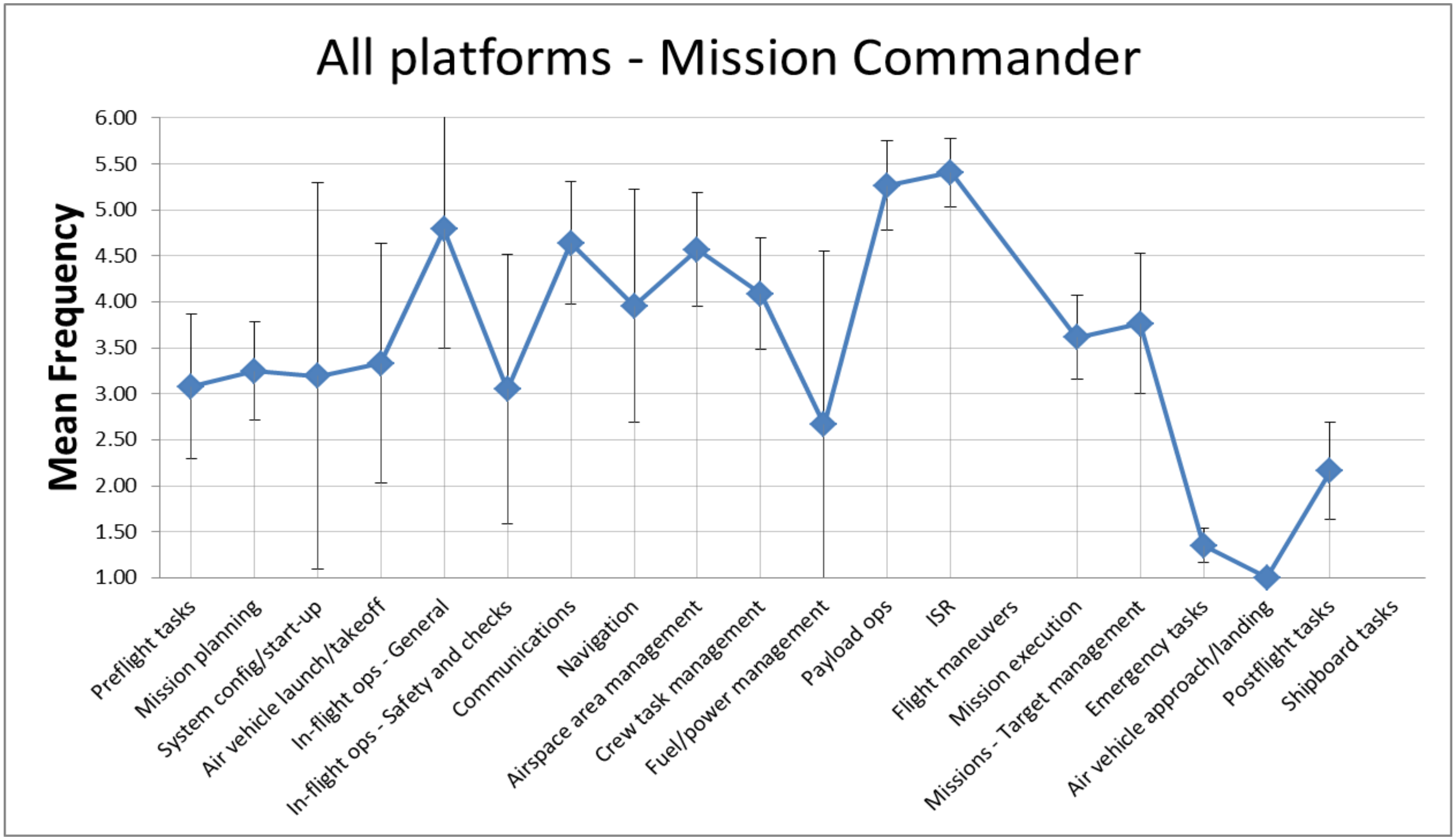


Figure 52: Task cluster profiles for BAMS-D – TACCO – Mean task frequency

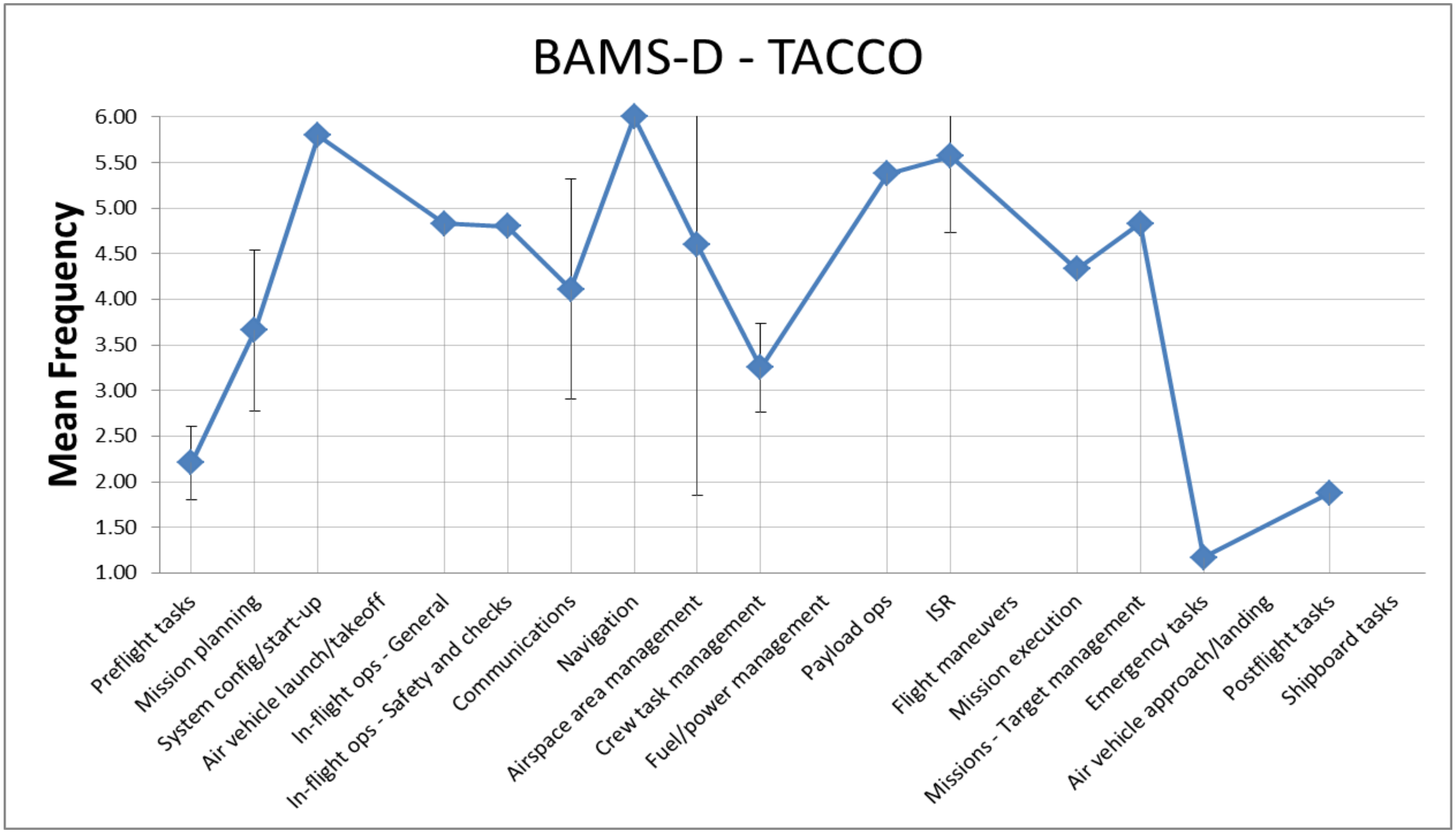


Figure 53: Task cluster profiles for BAMS – TACCO – Mean task frequency

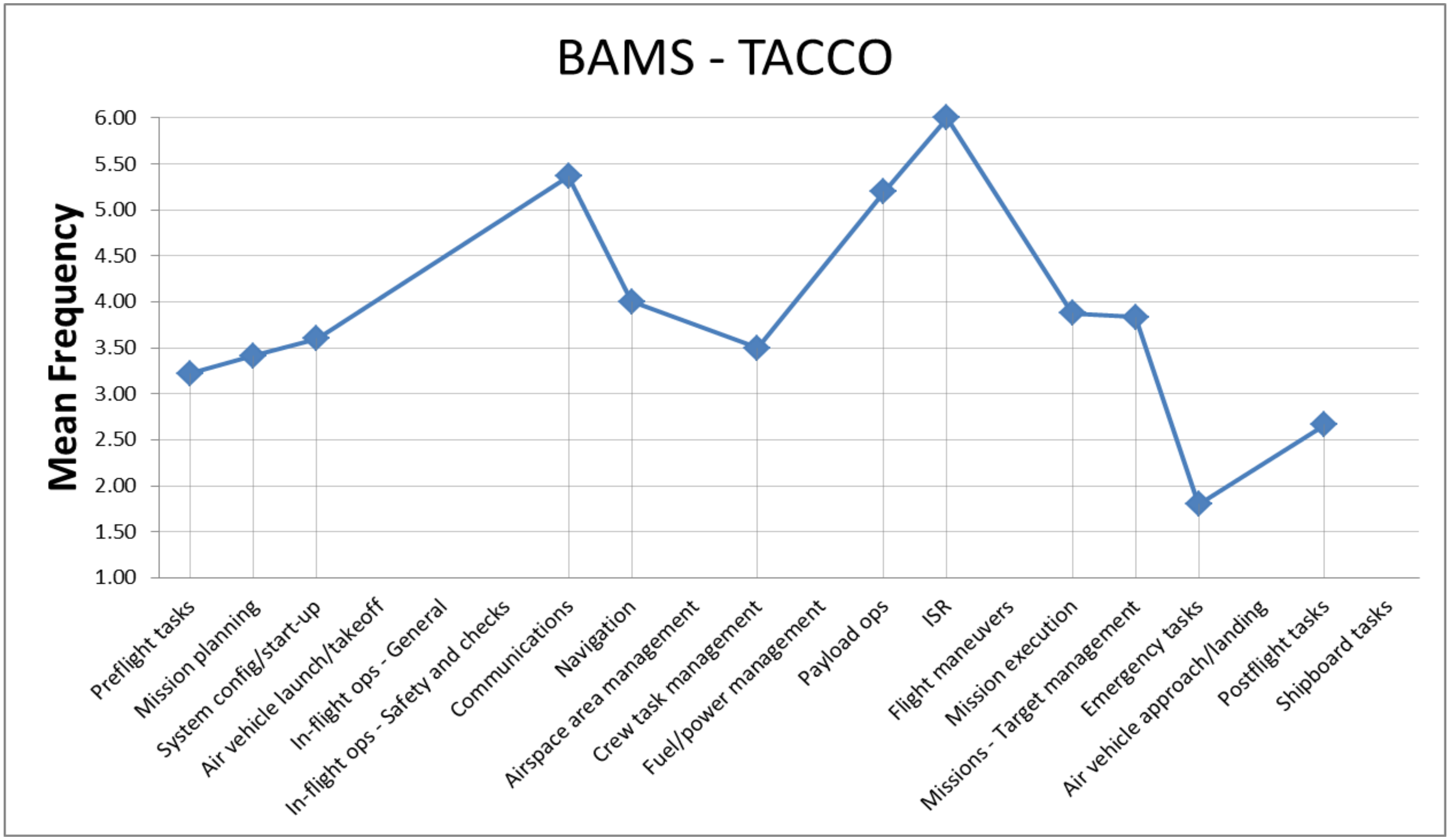
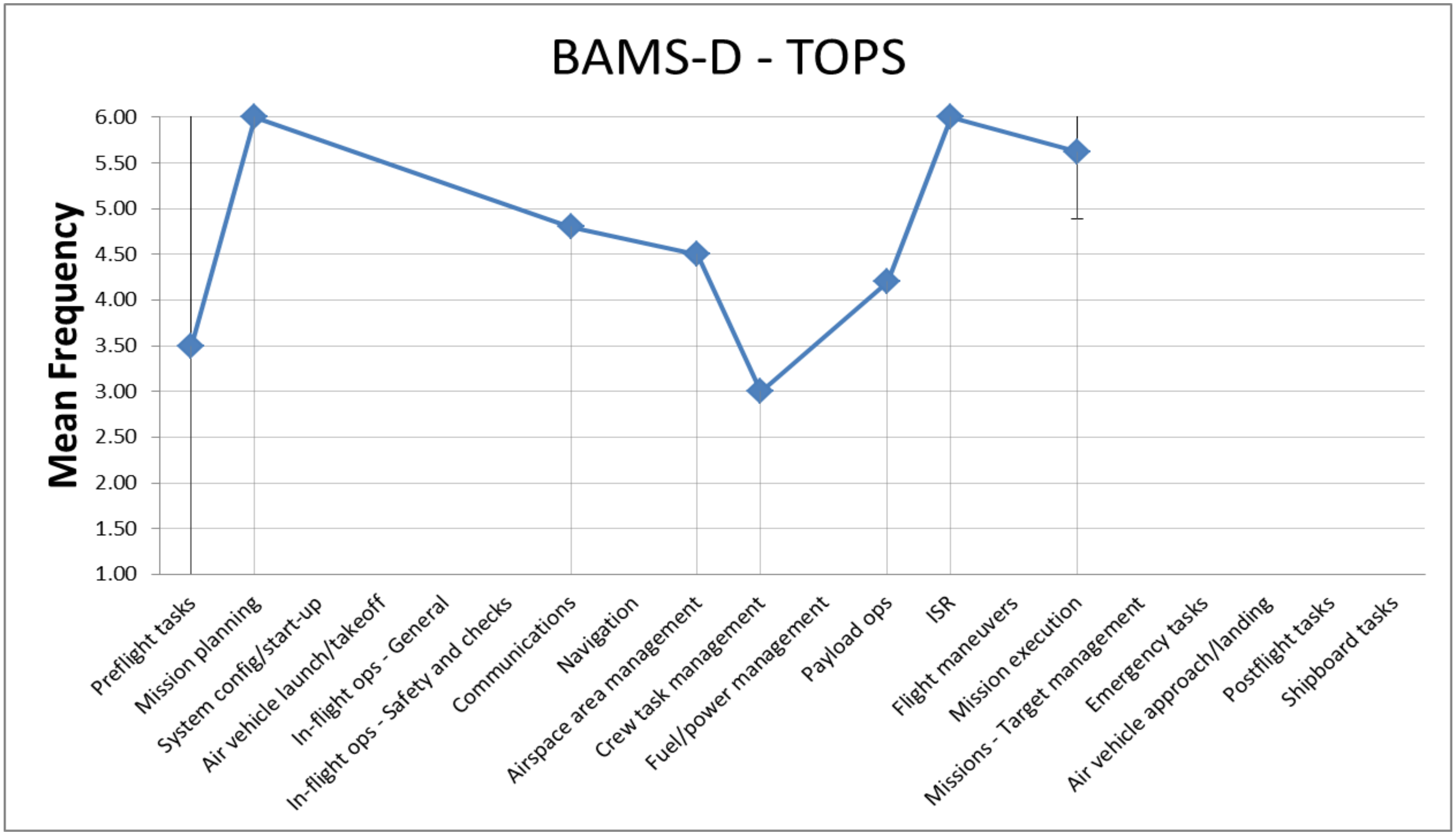


Figure 54: Task cluster profiles for BAMS-D – TOPS – Mean task frequency



Figures 55: Task cluster profiles for Raven – Air vehicle operator/Pilot – Mean required mastery for a qualified operator

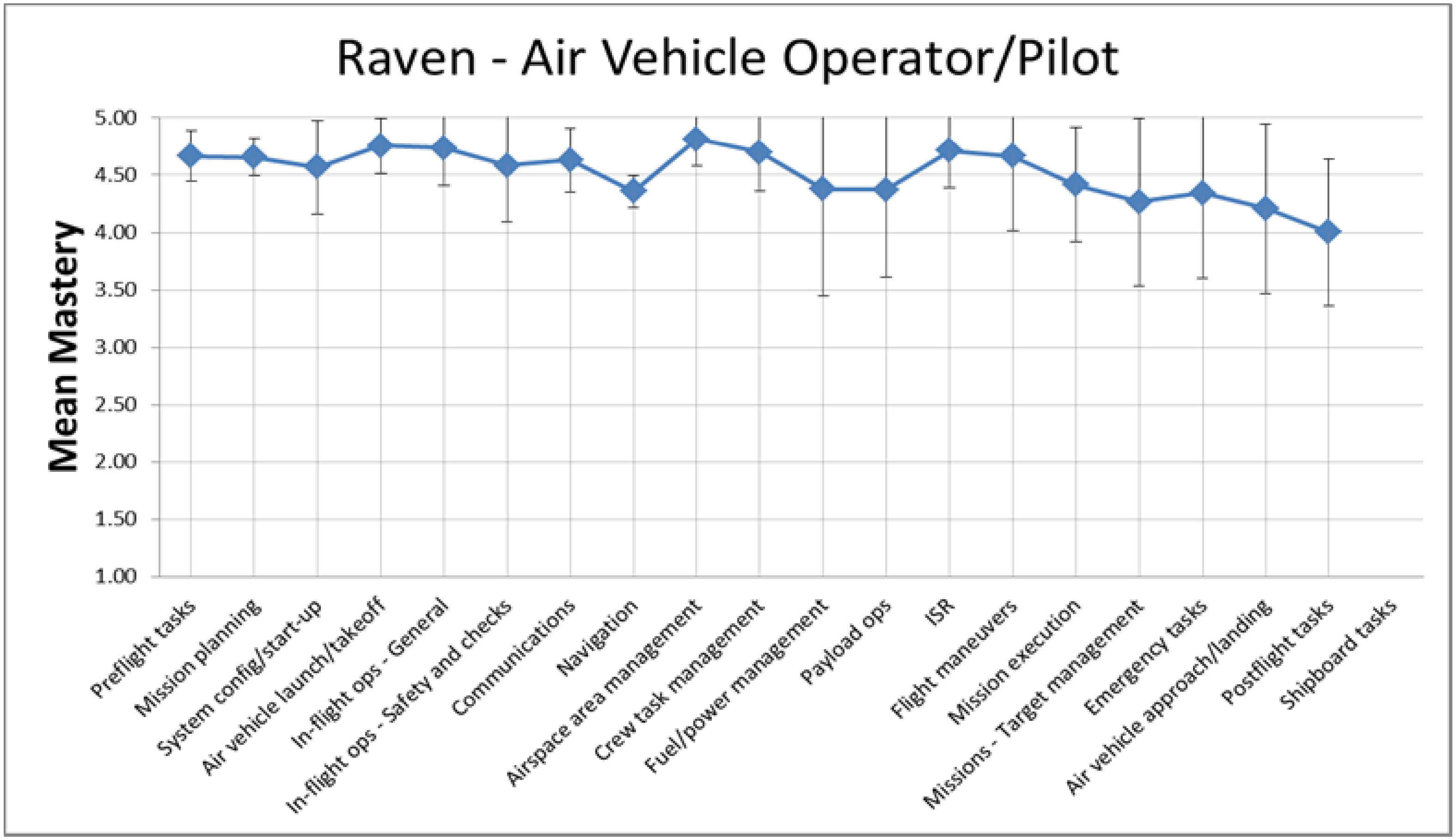


Figure 56: Task cluster profiles for Shadow – Air vehicle operator/Pilot – Mean required mastery for a qualified operator

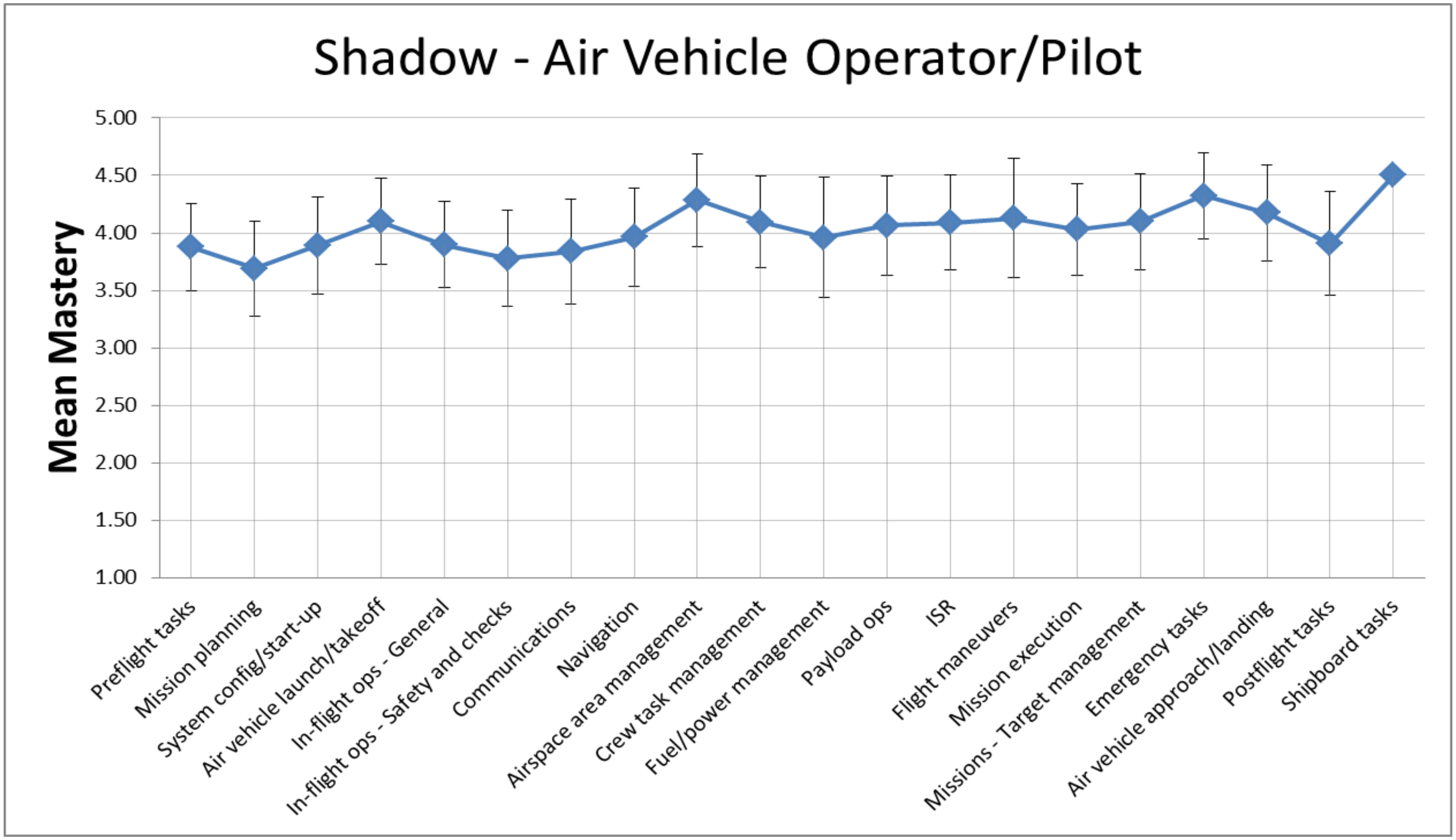


Figure 57: Task cluster profiles for Fire Scout – Air vehicle operator/Pilot – Mean required mastery for a qualified operator

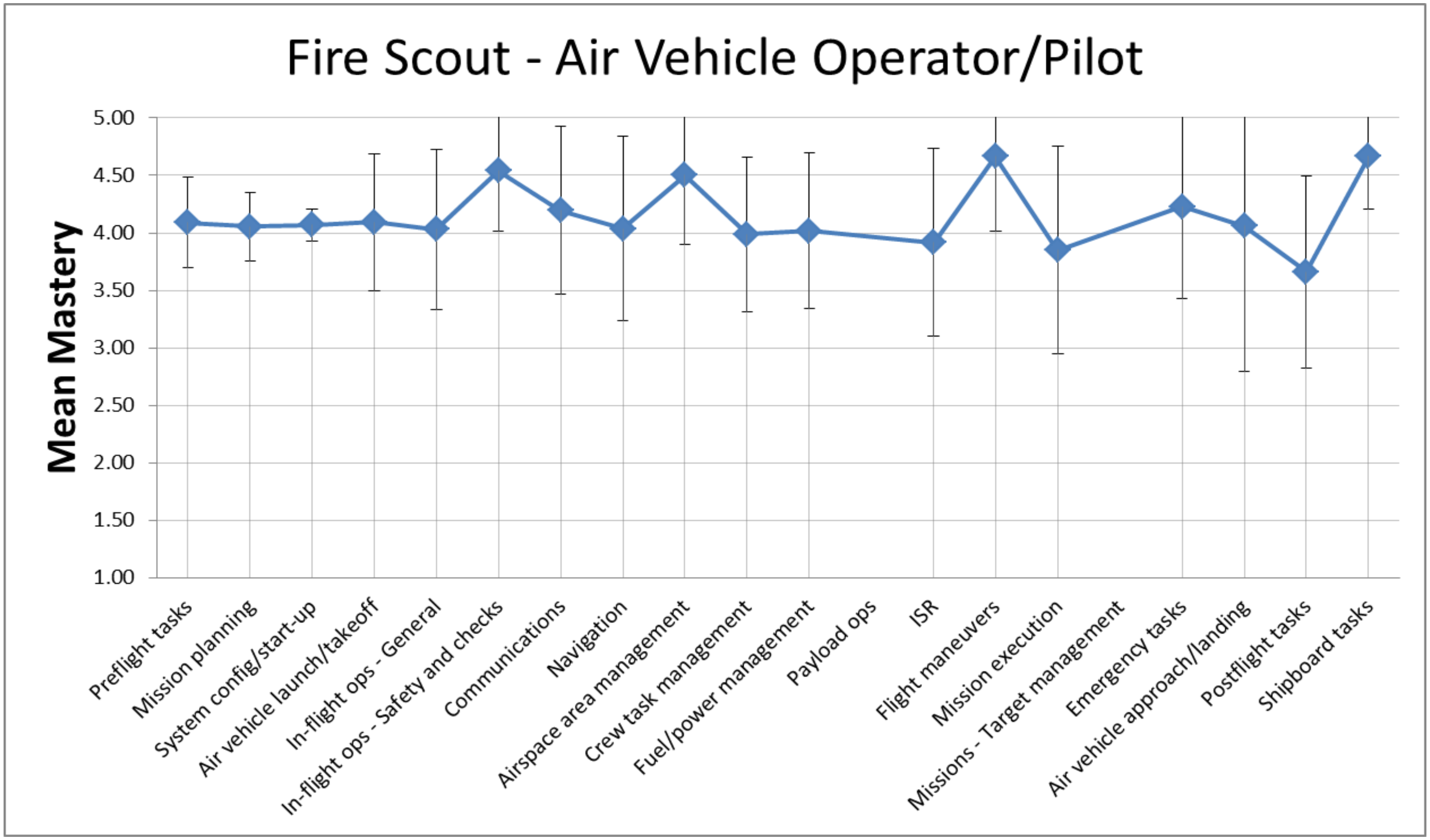


Figure 58: Task cluster profiles for BAMS-D – Air vehicle operator/Pilot – Mean required mastery for a qualified operator

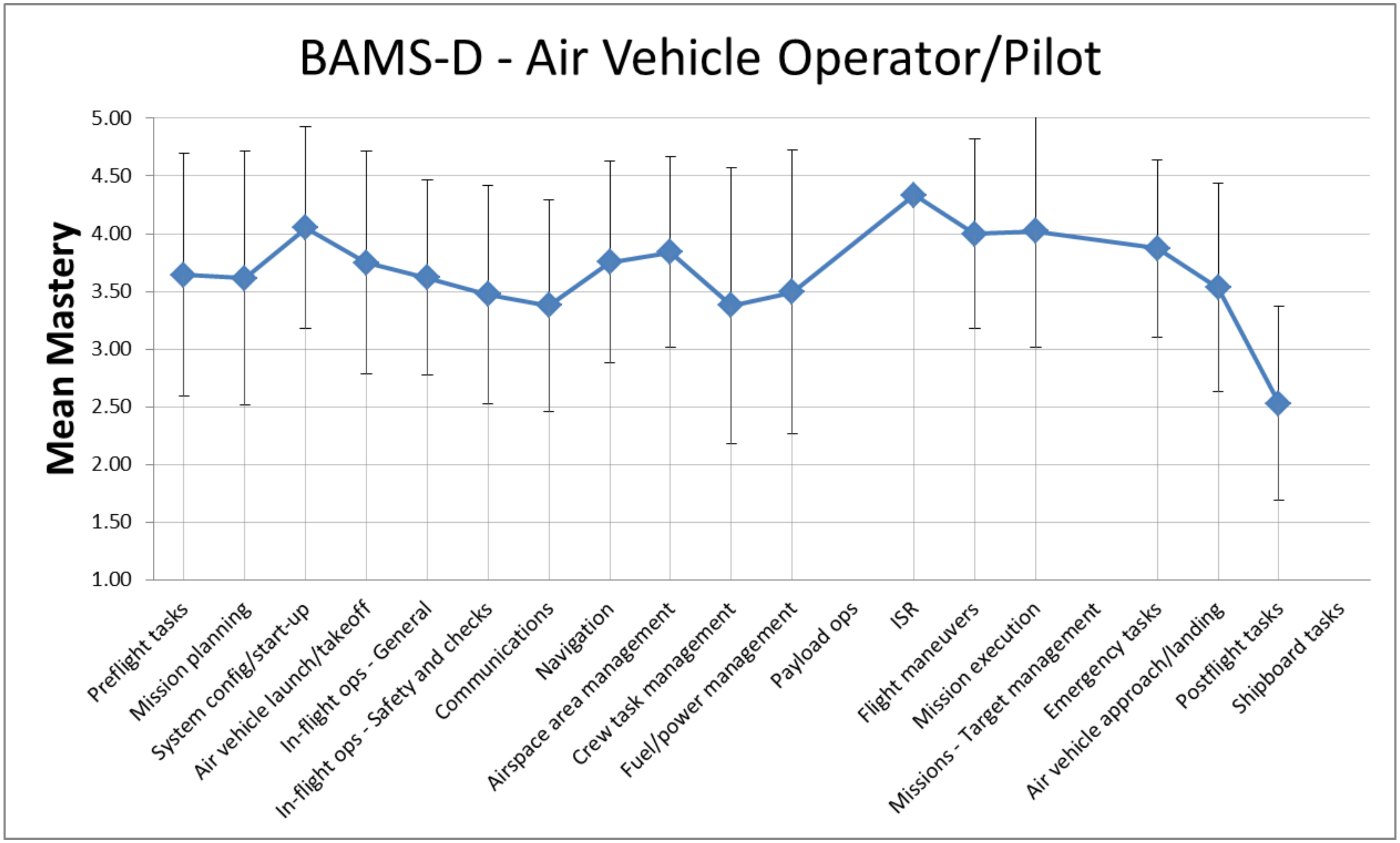


Figure 59: Task cluster profiles for BAMS – Air vehicle operator/Pilot – Mean required mastery for a qualified operator

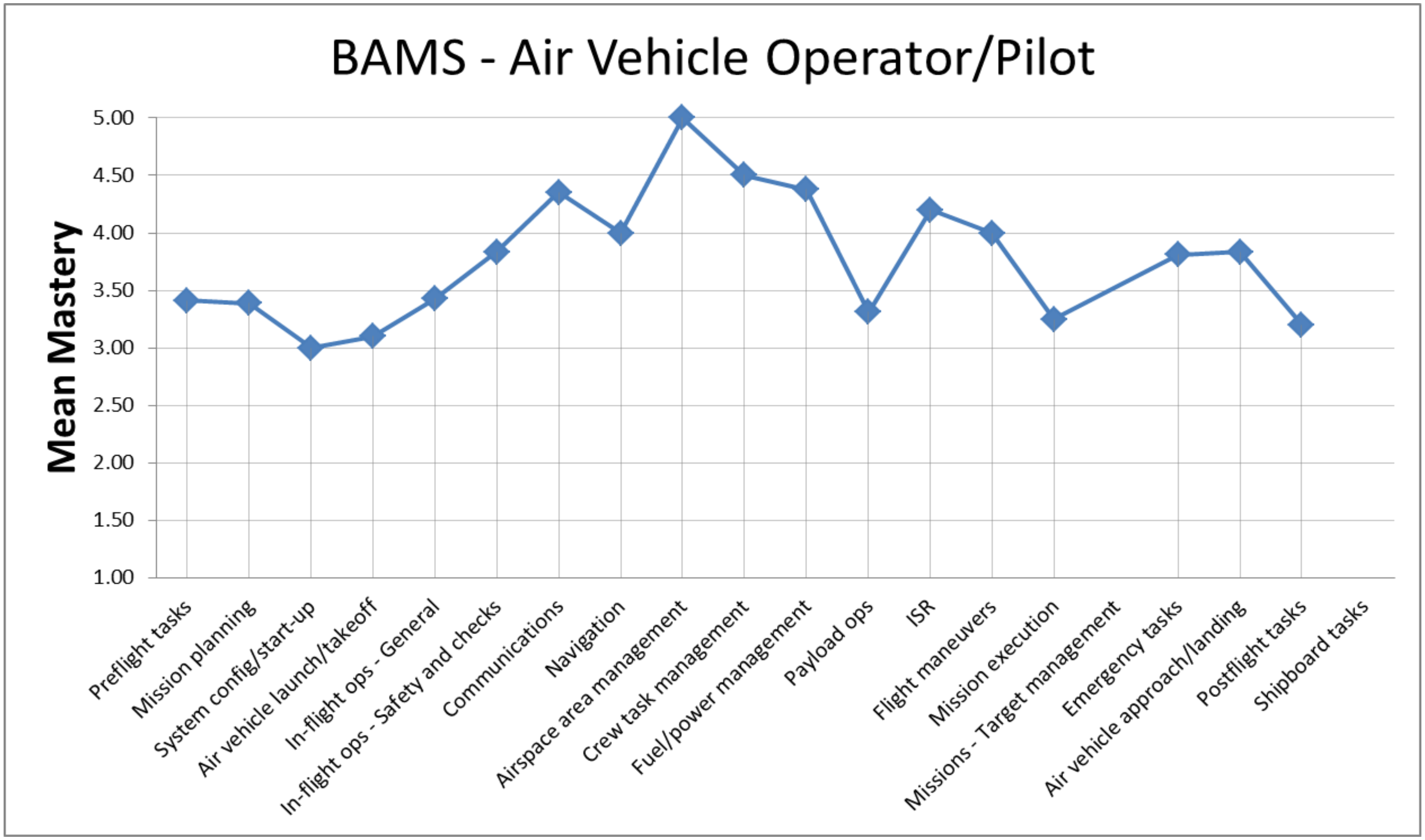


Figure 60: Task cluster profiles for all platforms – Air vehicle operator/Pilot – mean required mastery for a qualified operator

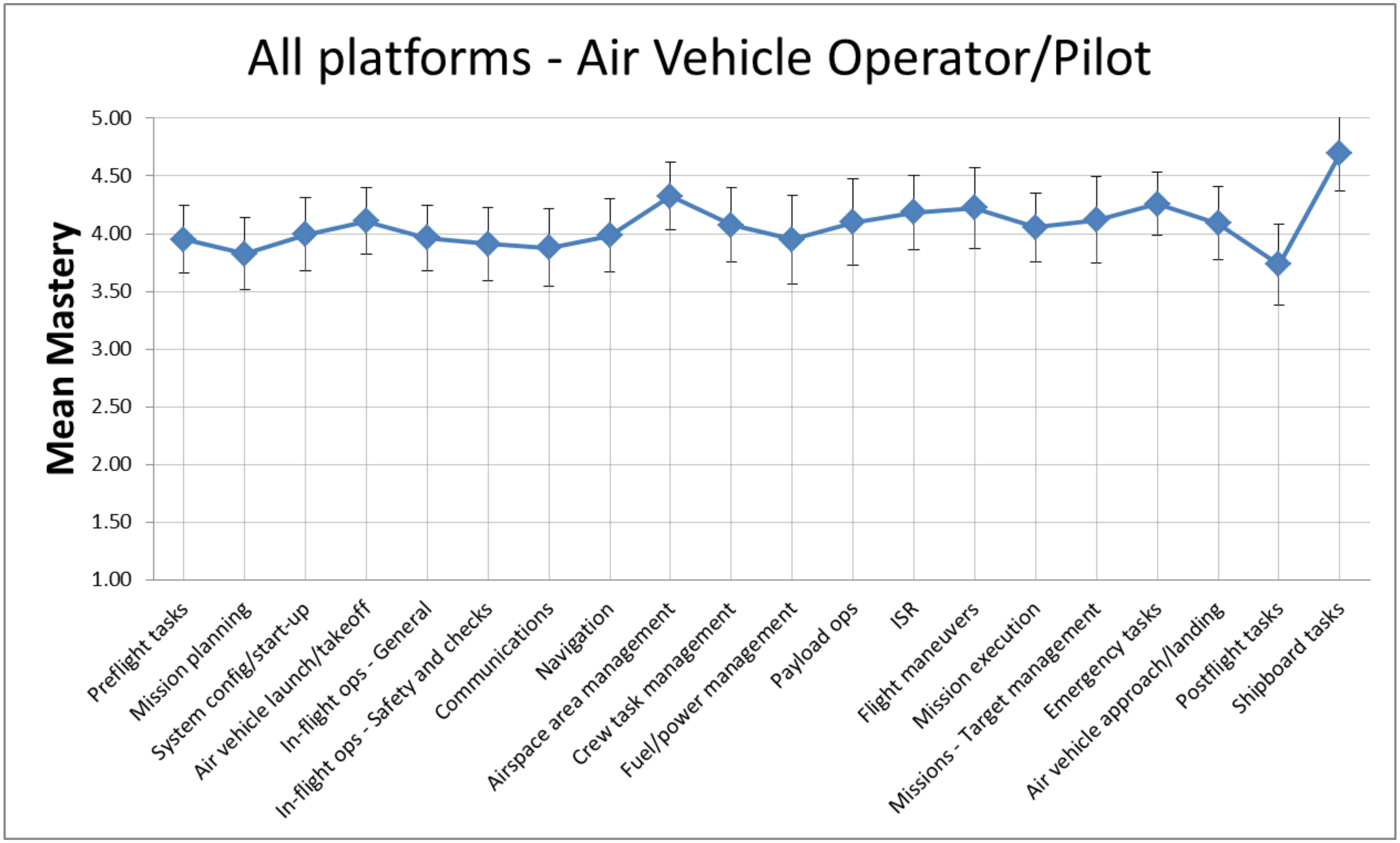


Figure 61: Task cluster profiles for Raven – Sensor/Payload operator – Mean required mastery for a qualified operator

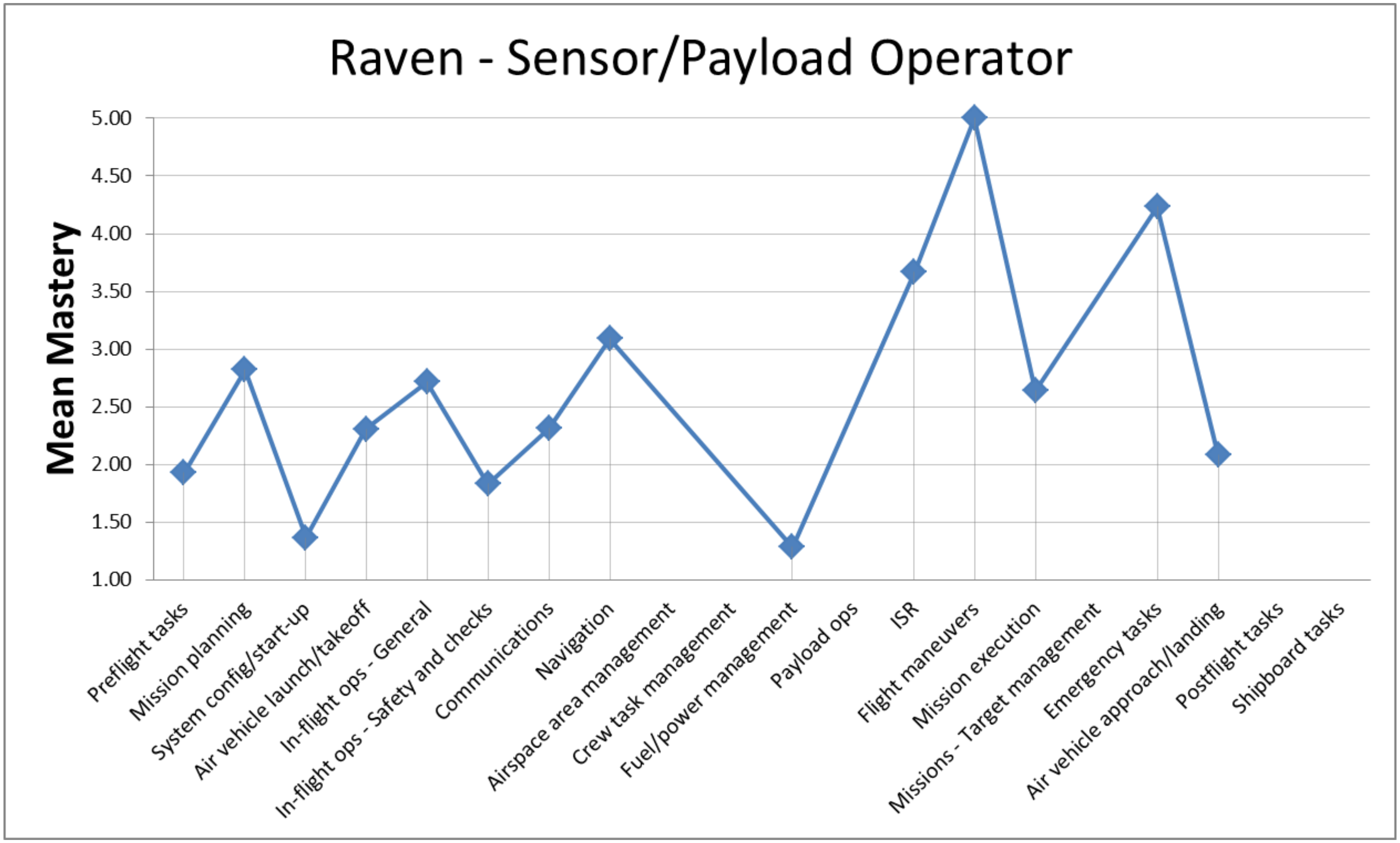


Figure 62: Task cluster profiles for Shadow – Sensor/Payload operator – Mean required mastery for a qualified operator

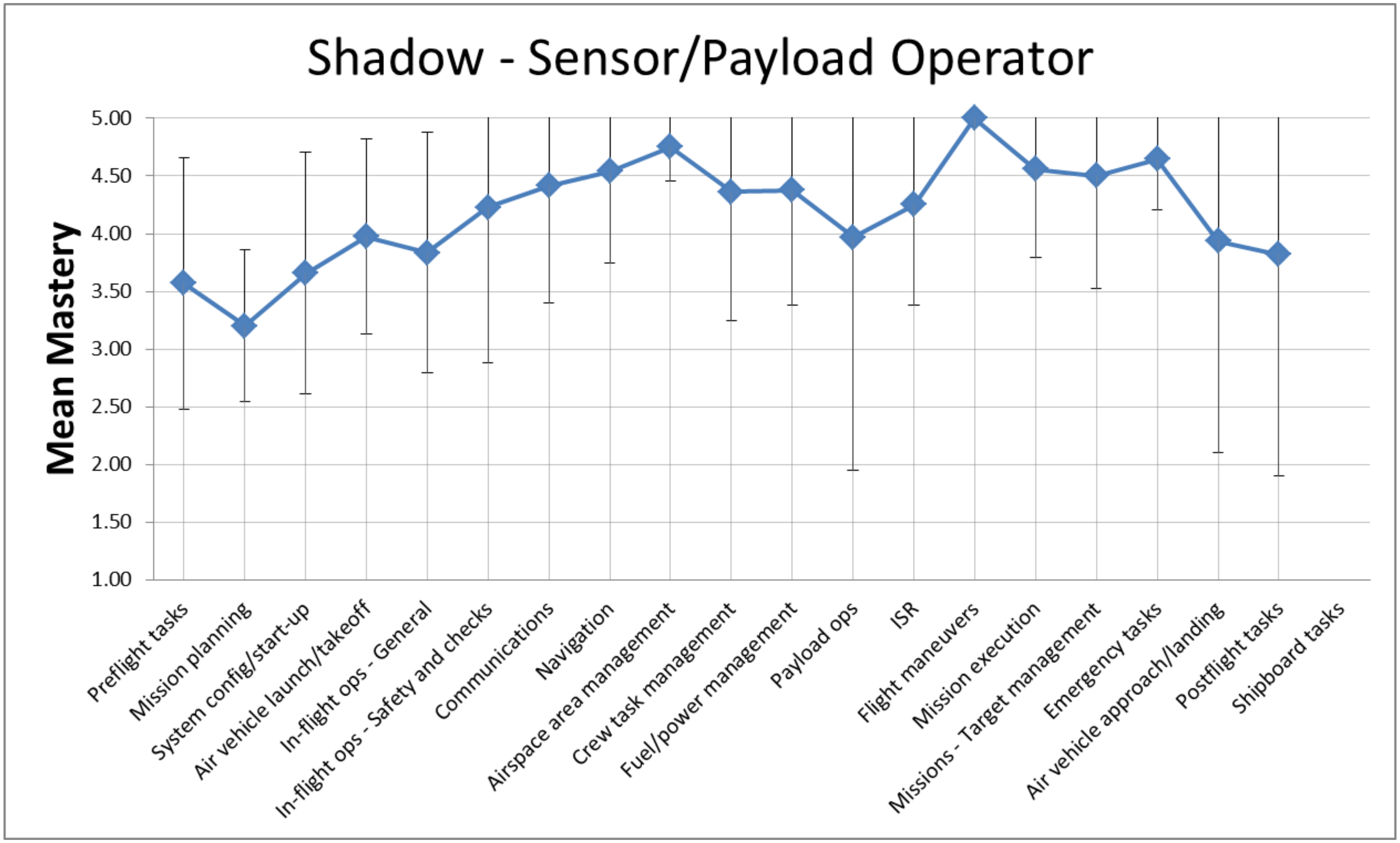


Figure 63: Task cluster profiles for BAMS-D – Sensor/Payload operator – Mean required mastery for a qualified operator

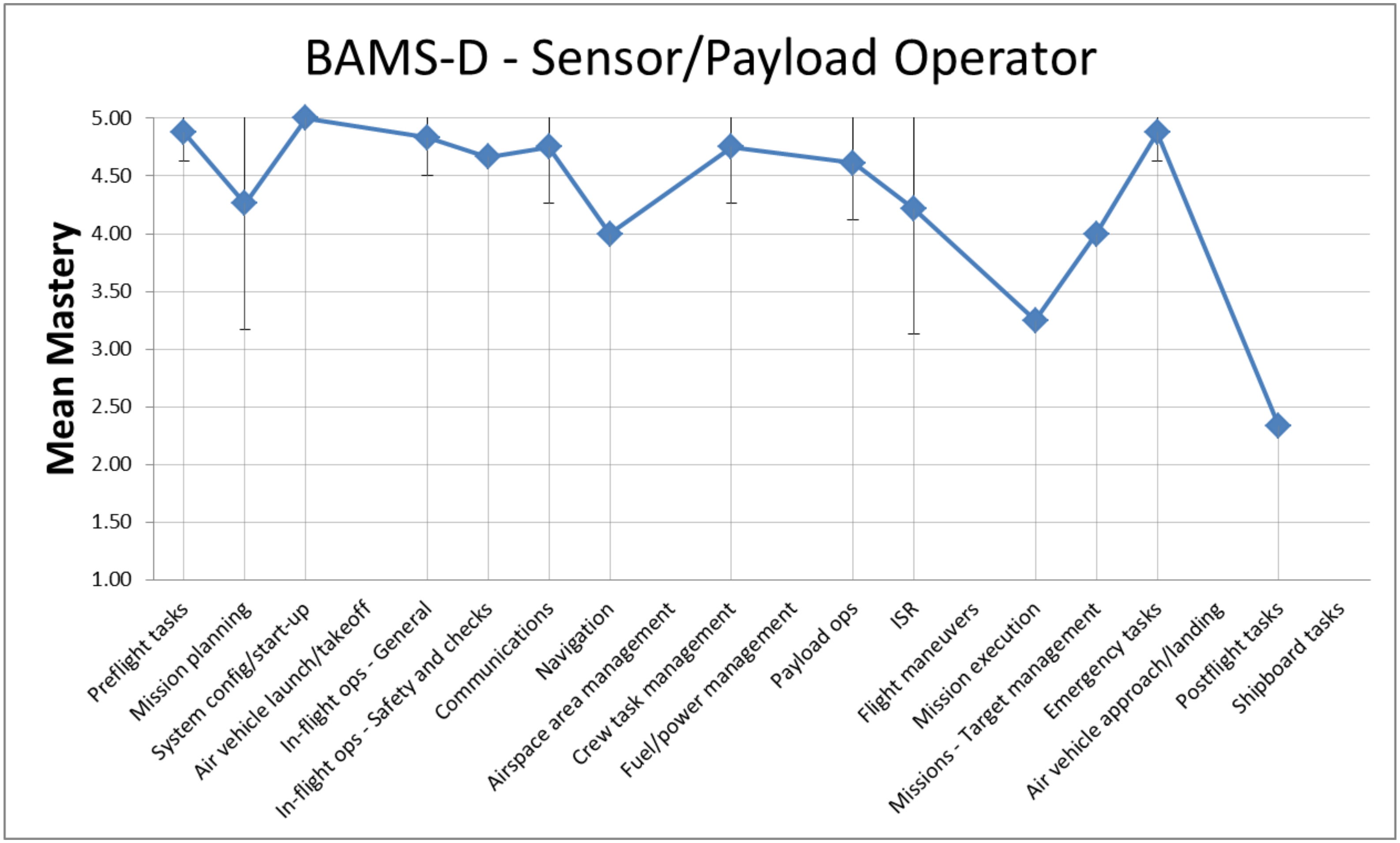


Figure 64: Task cluster profiles for BAMS – Sensor/Payload operator – Mean required mastery for a qualified operator

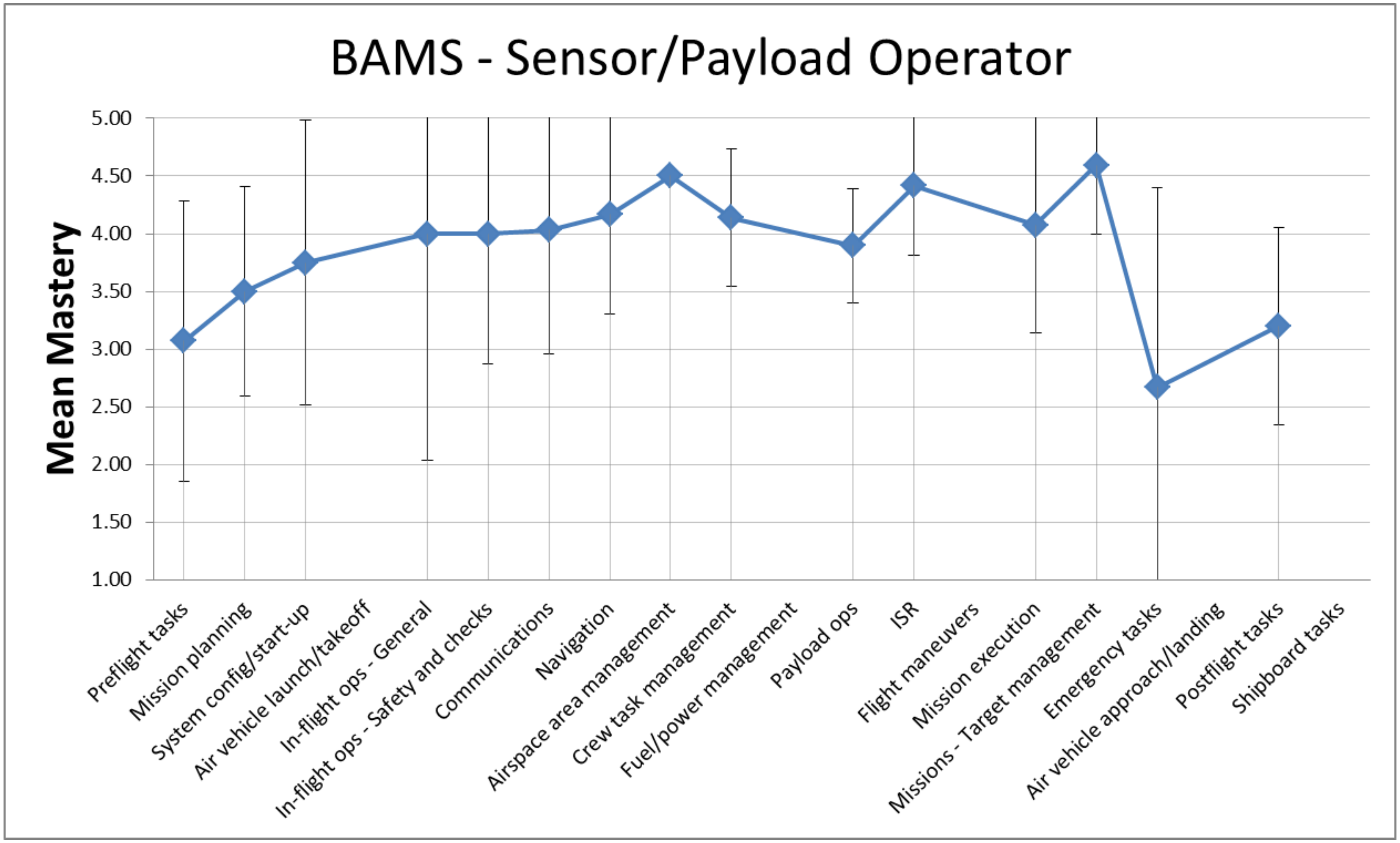


Figure 65: Task cluster profiles for all platforms – Sensor/Payload operator – Mean required mastery for a qualified operator

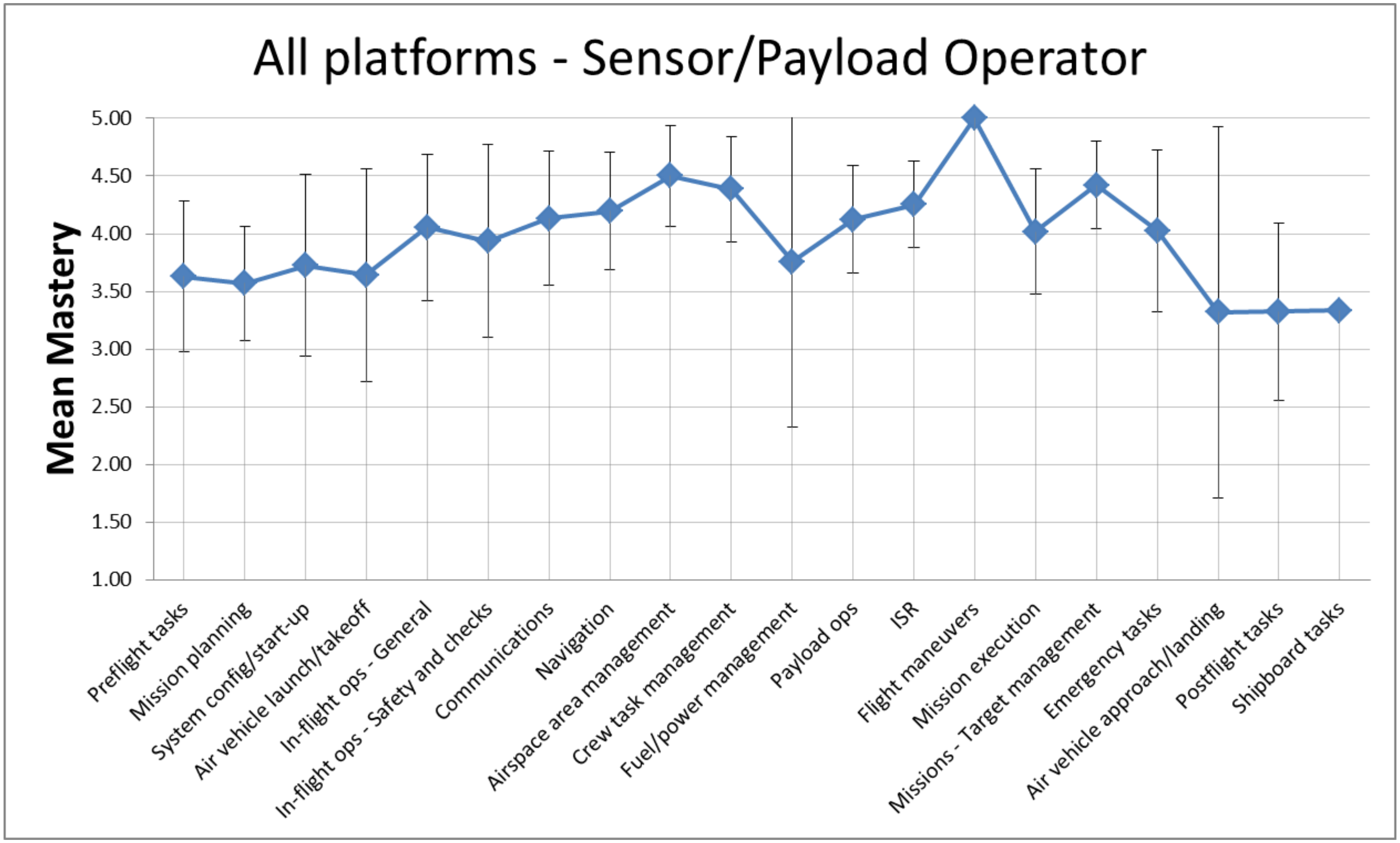


Figure 66: Task cluster profiles for ScanEagle – Mission commander – Mean required mastery for a qualified operator

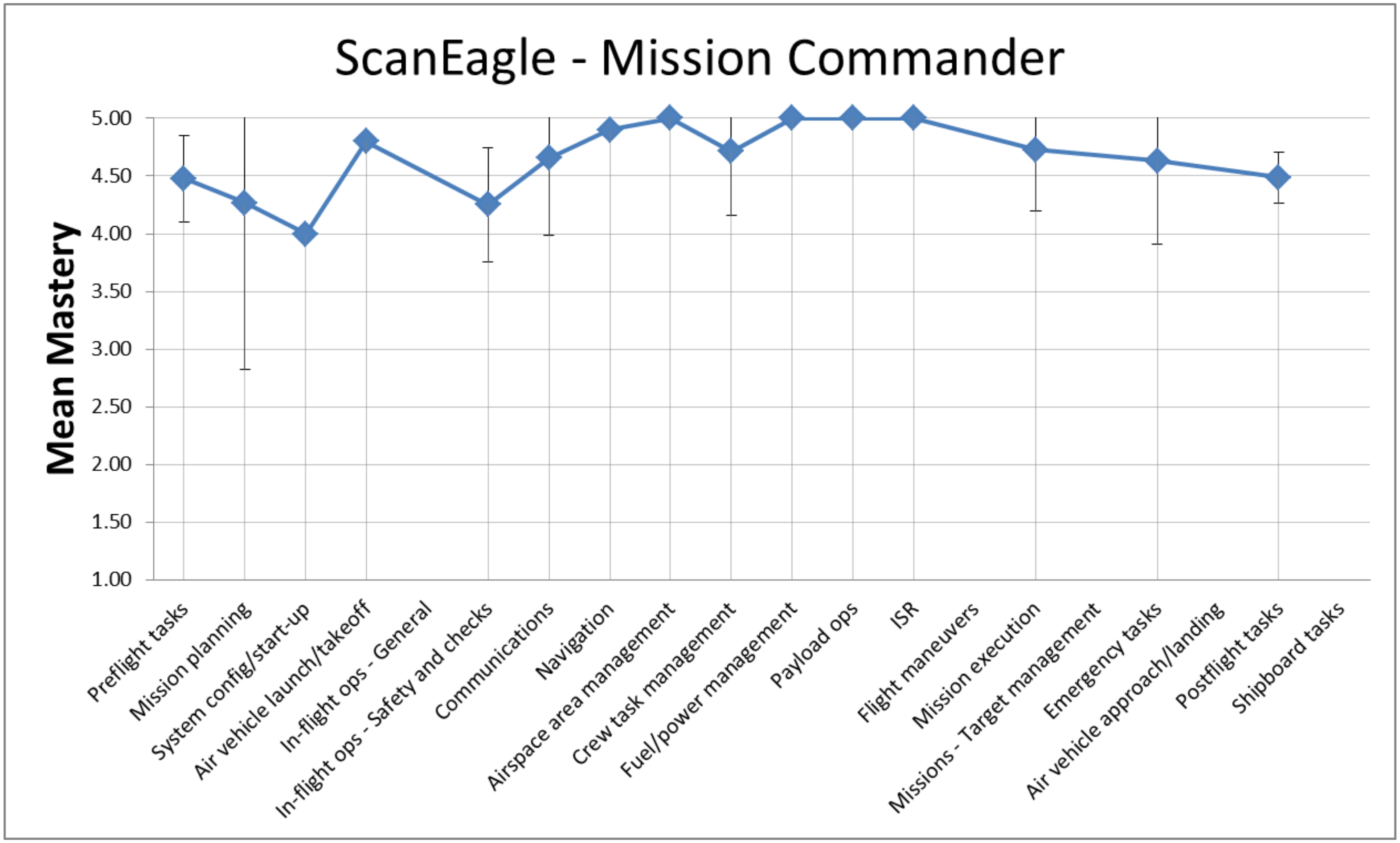


Figure 67: Task cluster profile for BAMS-D – Mission commander – mean required mastery for a qualified operator

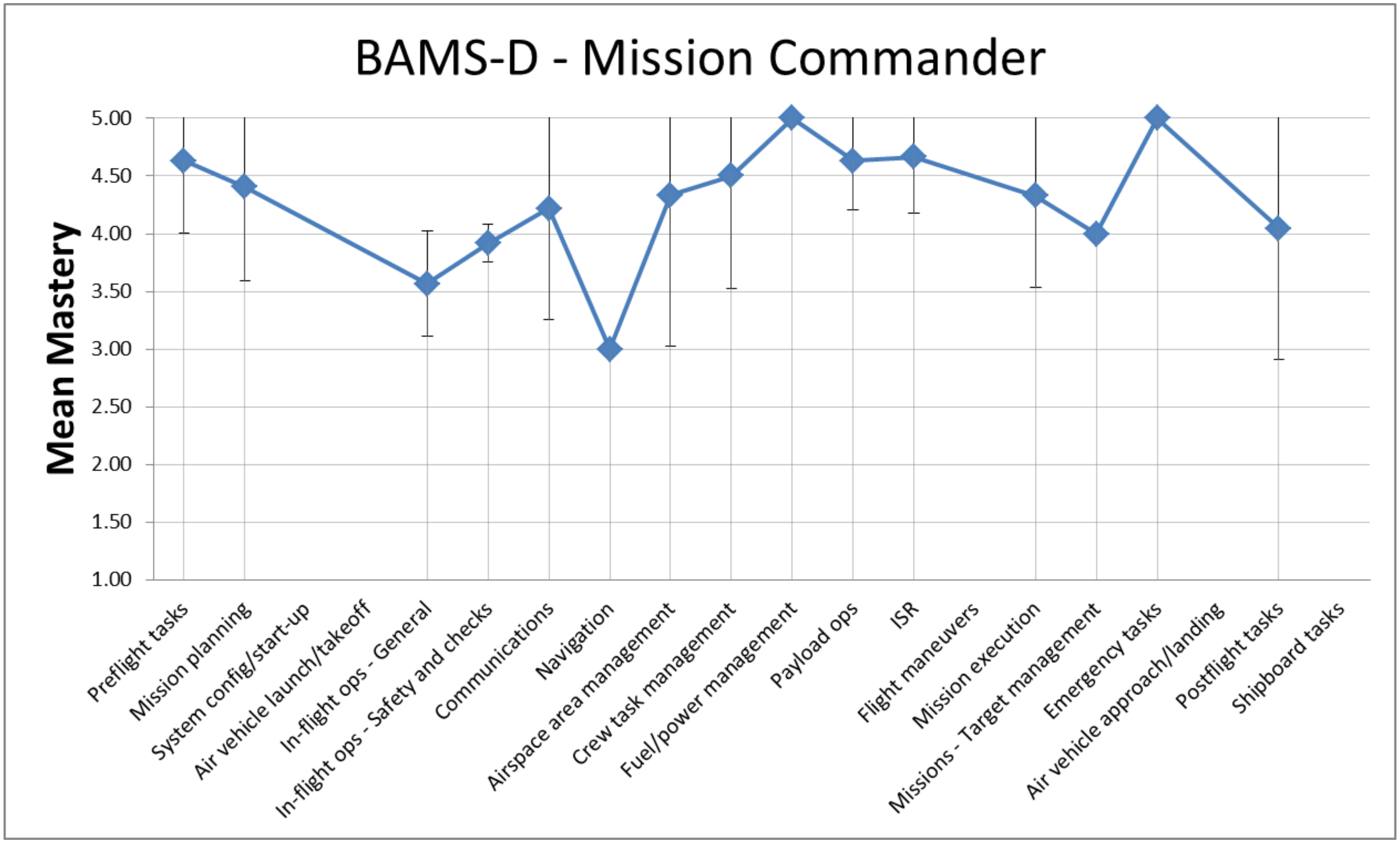


Figure 68: Task cluster profiles for BAMS – Mission commander – Mean required mastery for a qualified operator

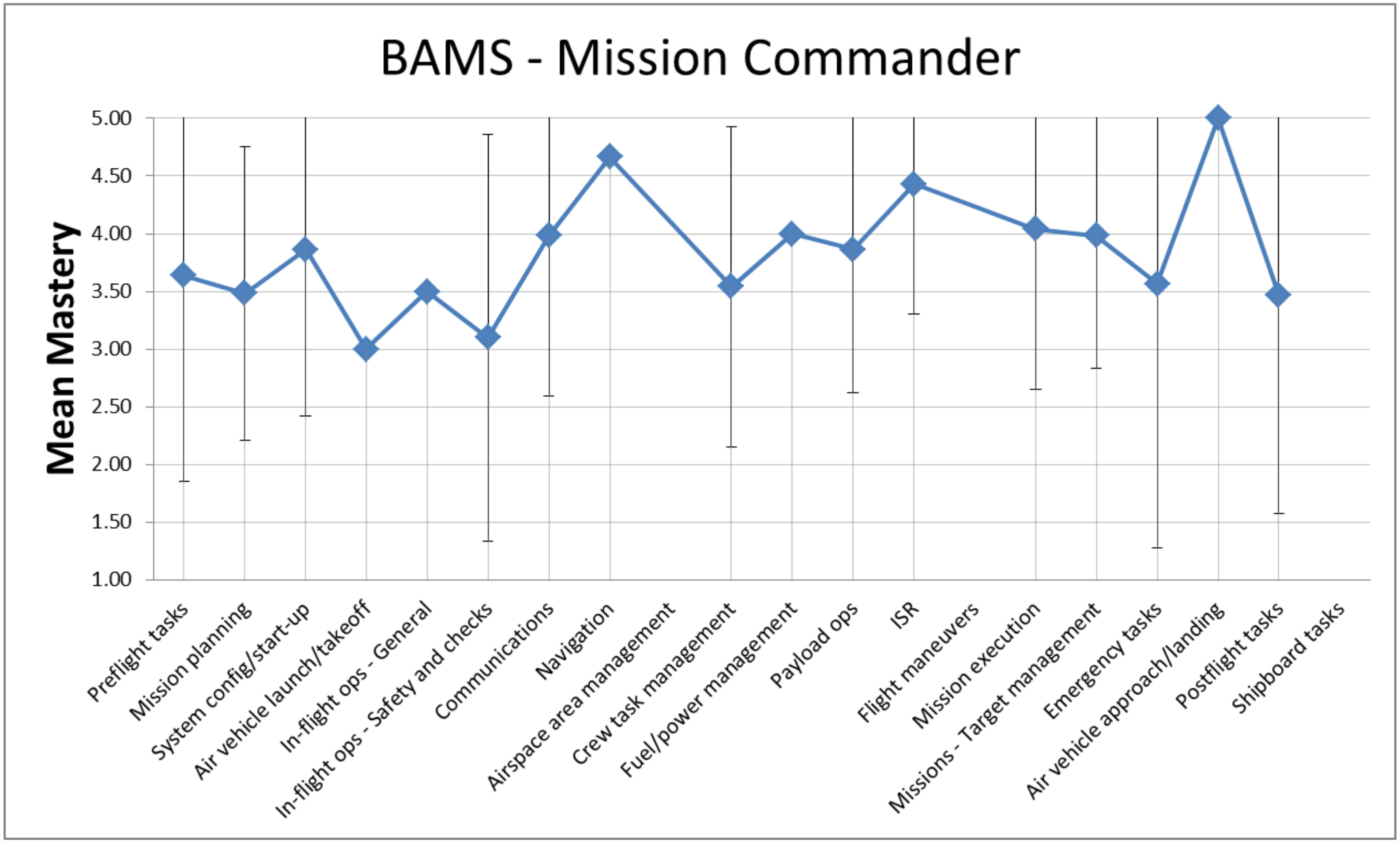


Figure 69: Task cluster profile for all platforms – Mission commander – Mean required mastery for a qualified operator

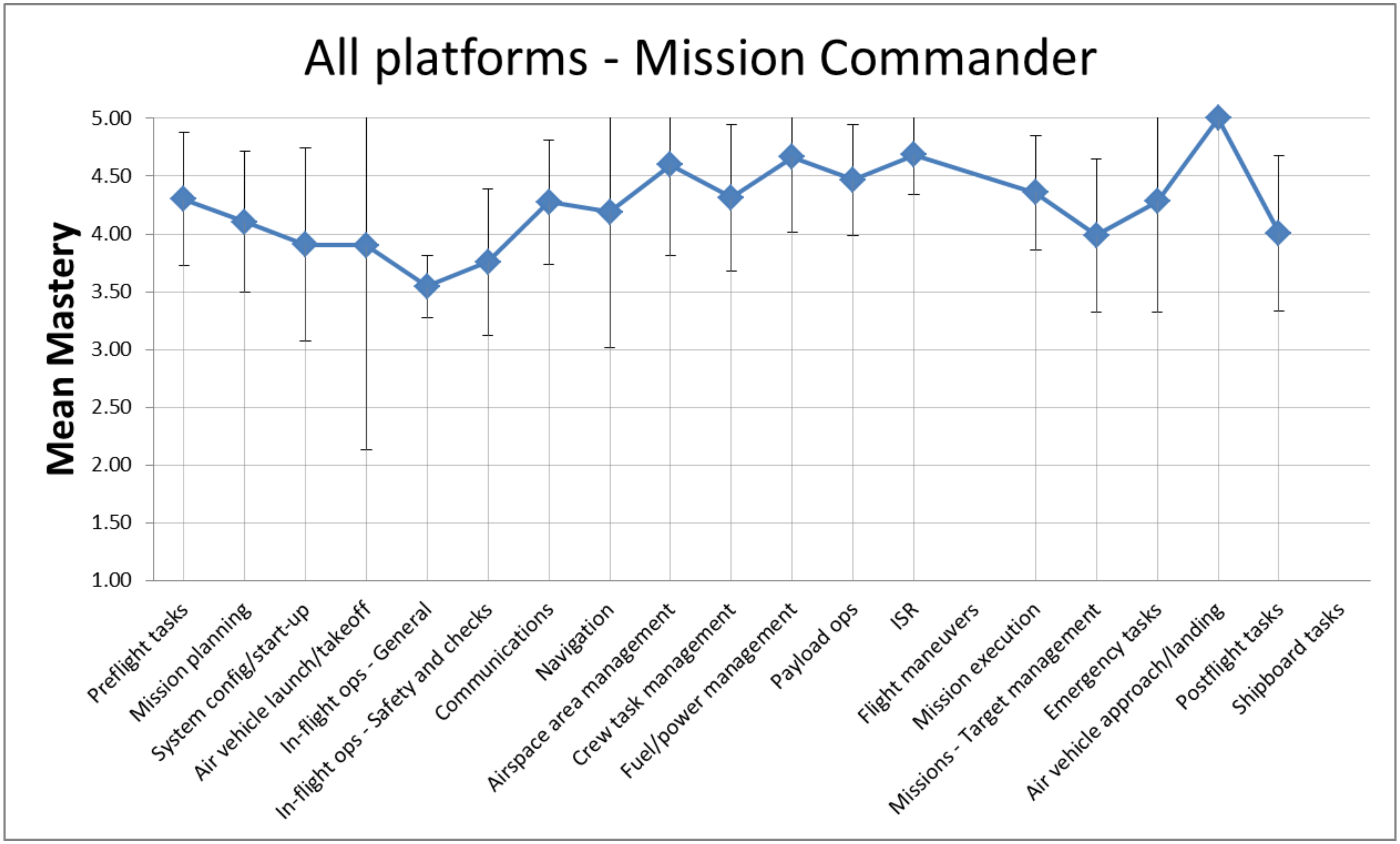


Figure 70: Task cluster profiles for BAMS-D- TACCO – mean required mastery for a qualified operator

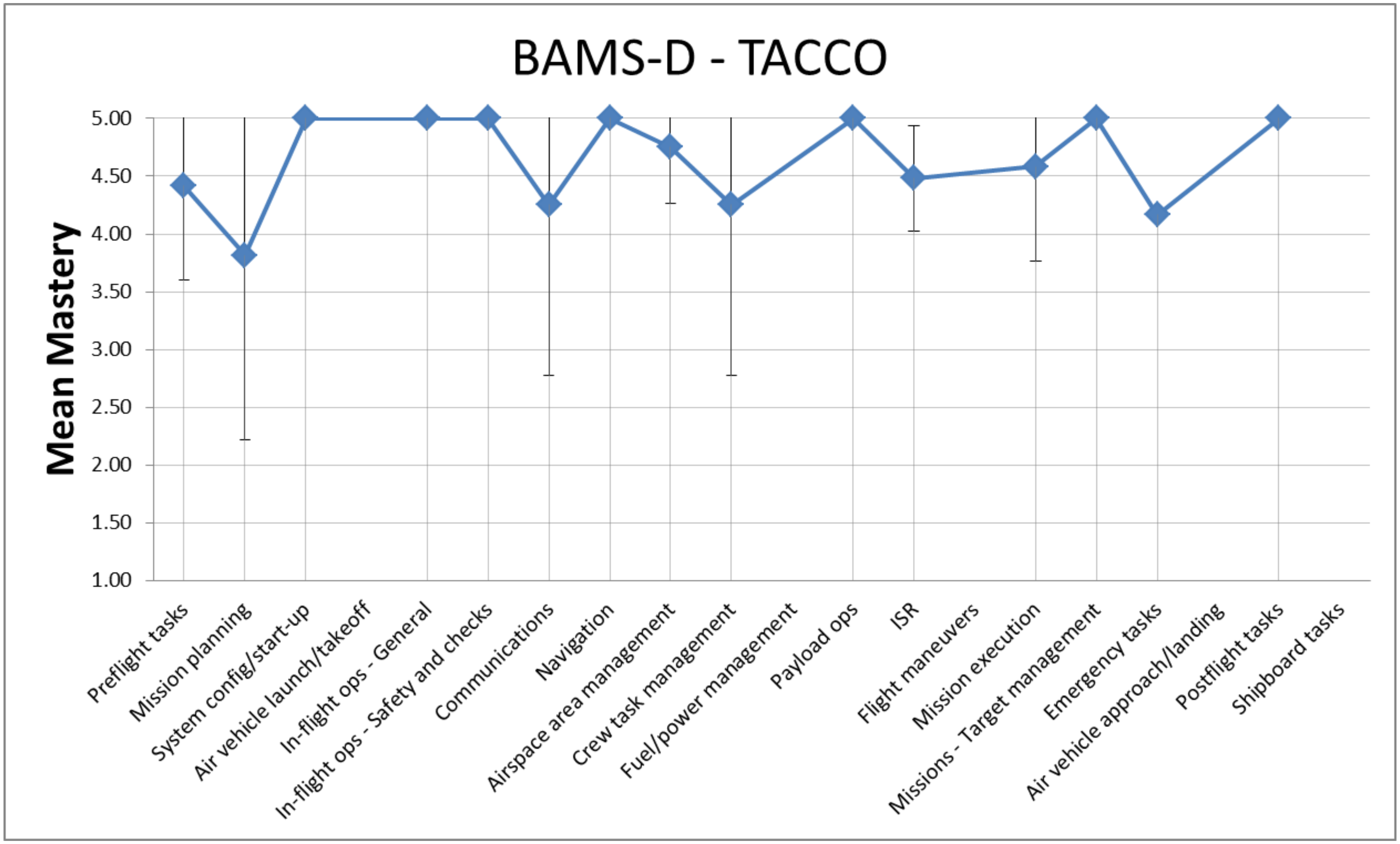


Figure 71: Task cluster profiles for BAMS – TACCO – Mean required mastery for a qualified operator

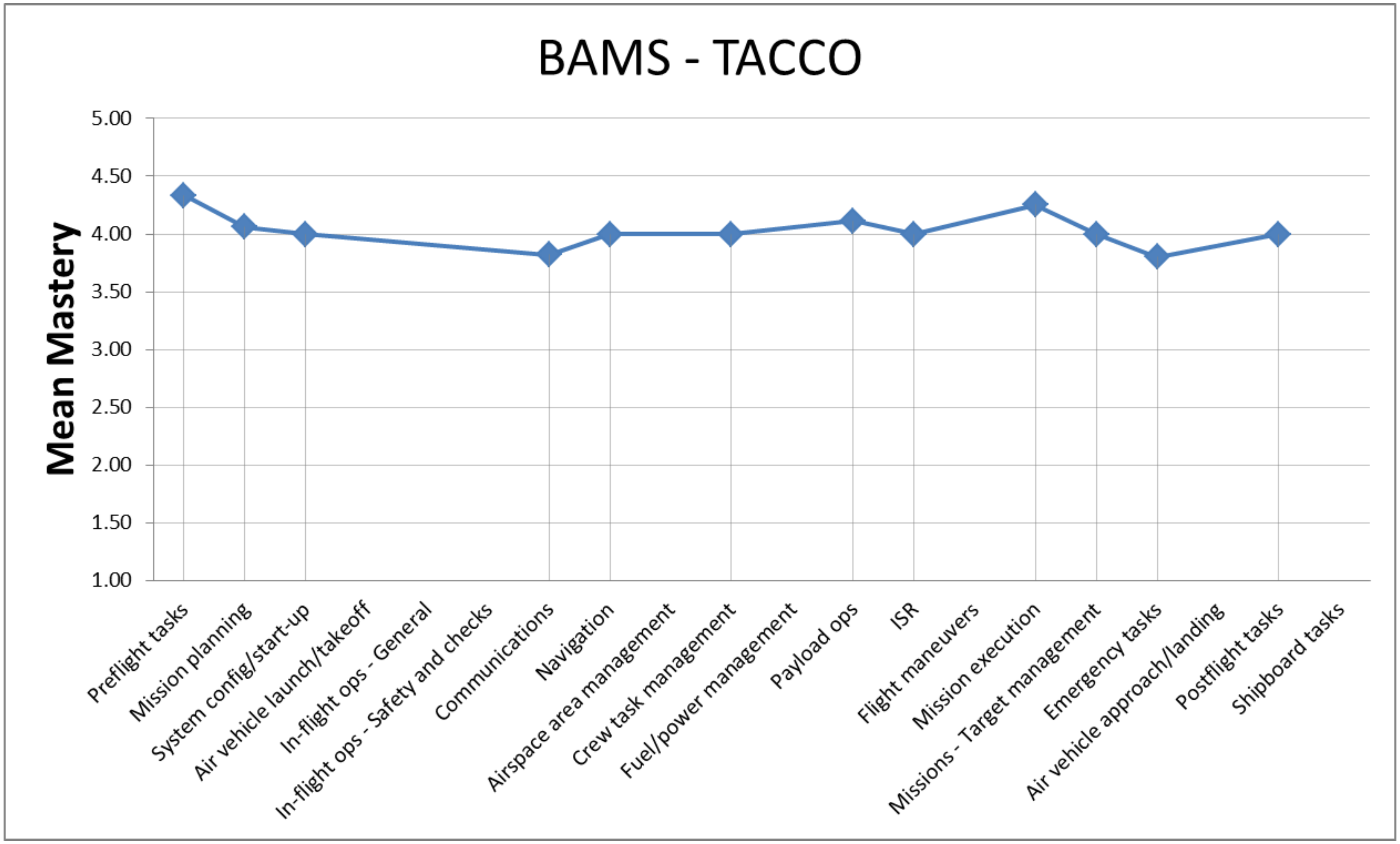
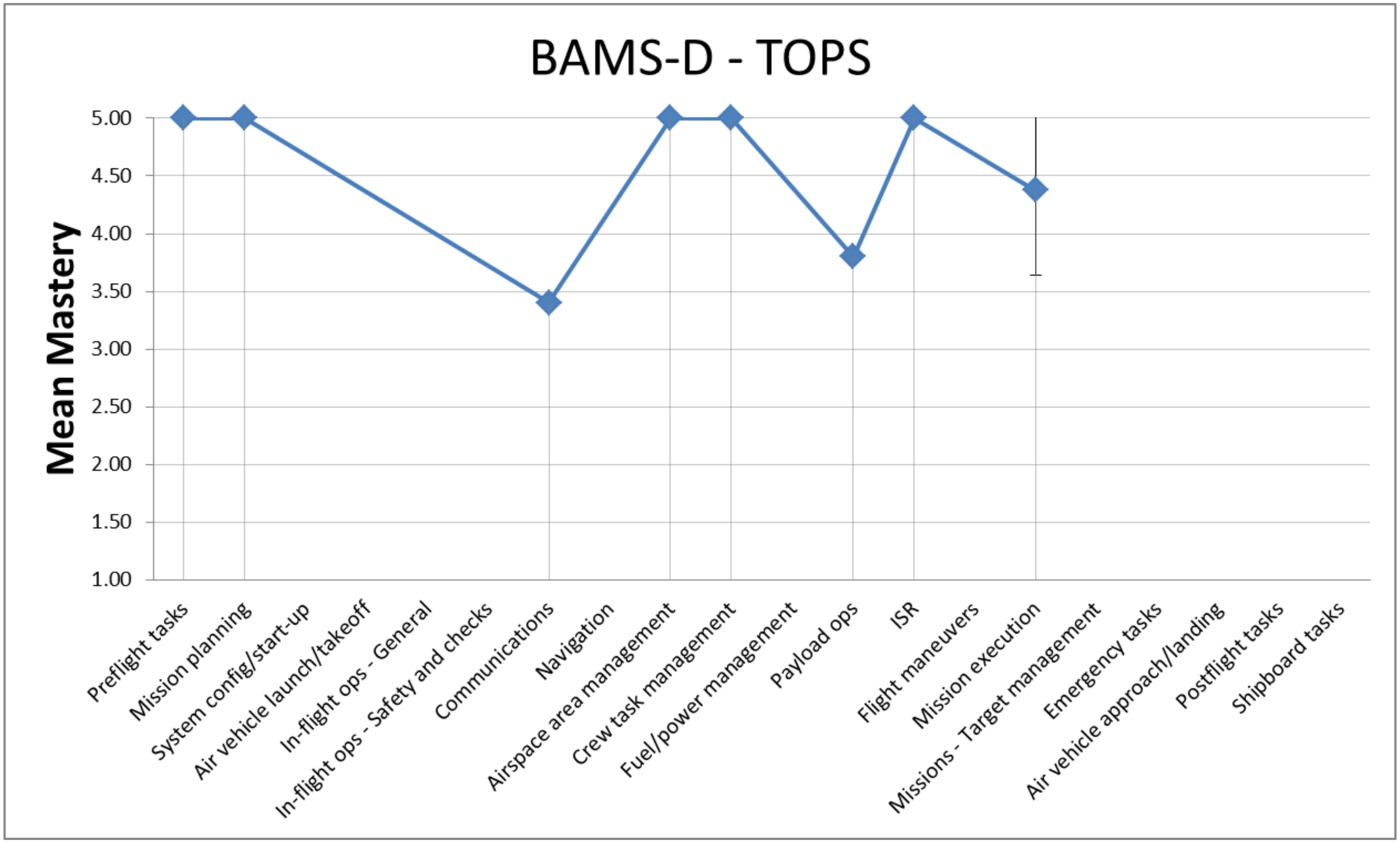


Figure 72: Task cluster profiles for BAMS-D – TOPS – Mean required mastery for a qualified operator



KSAO Profiles by Platform and Position

Additionally, we generated a second set of interactive tables and figures (Figures 73 – 90) demonstrating KSAO profiles for each platform-position combination. First, we include a second set of interactive tables that provide rankings for each KSAO by each platform-position combination. These are structured in a manner analogous to the task ranking tables, allowing filtering of KSAO ranks for each platform-position combination. Second, we produced figures showing KSAO profiles for each platform-position combination. Individual KSAO ratings were averaged across all KSAOS within each of the 17 KSAO clusters, and then aggregated across respondents within each platform-position combination, and for each position (i.e., combining data across platforms). Results are shown in Figures 73 – 90.

Top KSAO categories, along with representative individual KSAOs within category that appear to be relevant across platforms and positions (means > 4.00) include:

- Conscientiousness
    - Dependability
    - Accountability
    - Self-Discipline
- Communication Skills
    - Oral Expression
    - Oral Comprehension
- Multitasking and Attentional Skills
    - Concentration/Selective Attention
    - Attention Allocation and Control
- Development Skills
    - Confidence
- Coping with Stress and Emergencies
    - Adaptability
    - Stress Tolerance
    - Handling Crisis and Emergency Situations
- Social/Interpersonal Skills
    - Assertiveness
    - Teamwork Skills
- Learning and Memory Skills
    - Learning Ability
    - Working Memory
    - Long-Term Memory
- Motivation
    - Initiative
    - Work Motivation
- Problem Solving/Reasoning Skills
    - Critical Thinking Skills
- Planning and Organizing Skills

- Attention to Detail
- Safety Consciousness
- Time Management Skills

Several other individual KSAOs were rated as important across platforms and positions as well as for platform-position combinations. Means for all KSAO categories were above the 3.00 range for the platform-collapsed AVO profile. The Sensor/Payload Operator profile followed a similar pattern with slightly lower means for only a few clusters. The Mission Commander profile was slightly more variable, with means for the Mathematical Ability, Mechanical Abilities, Physical and Psychomotor Abilities, Sensation Seeking, and Sensory/Perceptual Abilities clusters dipping below the 3.00 threshold.

Figures 73: KSAO cluster profiles for Raven – Air vehicle operator/Pilot – Mean KSAO Importance

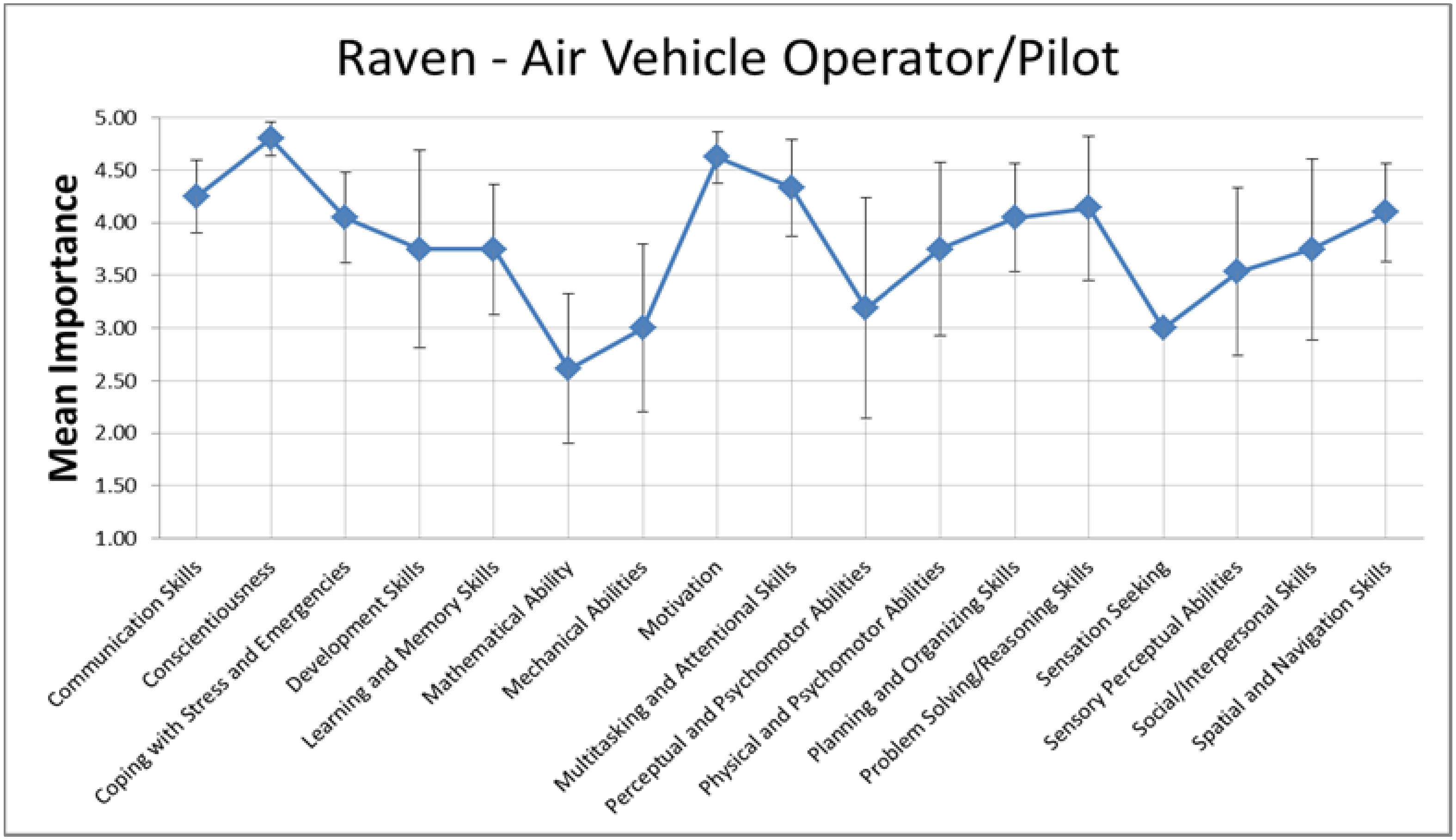


Figure 74: KSAO cluster profiles for Shadow – Air vehicle operator/Pilot – Mean KSAO Importance

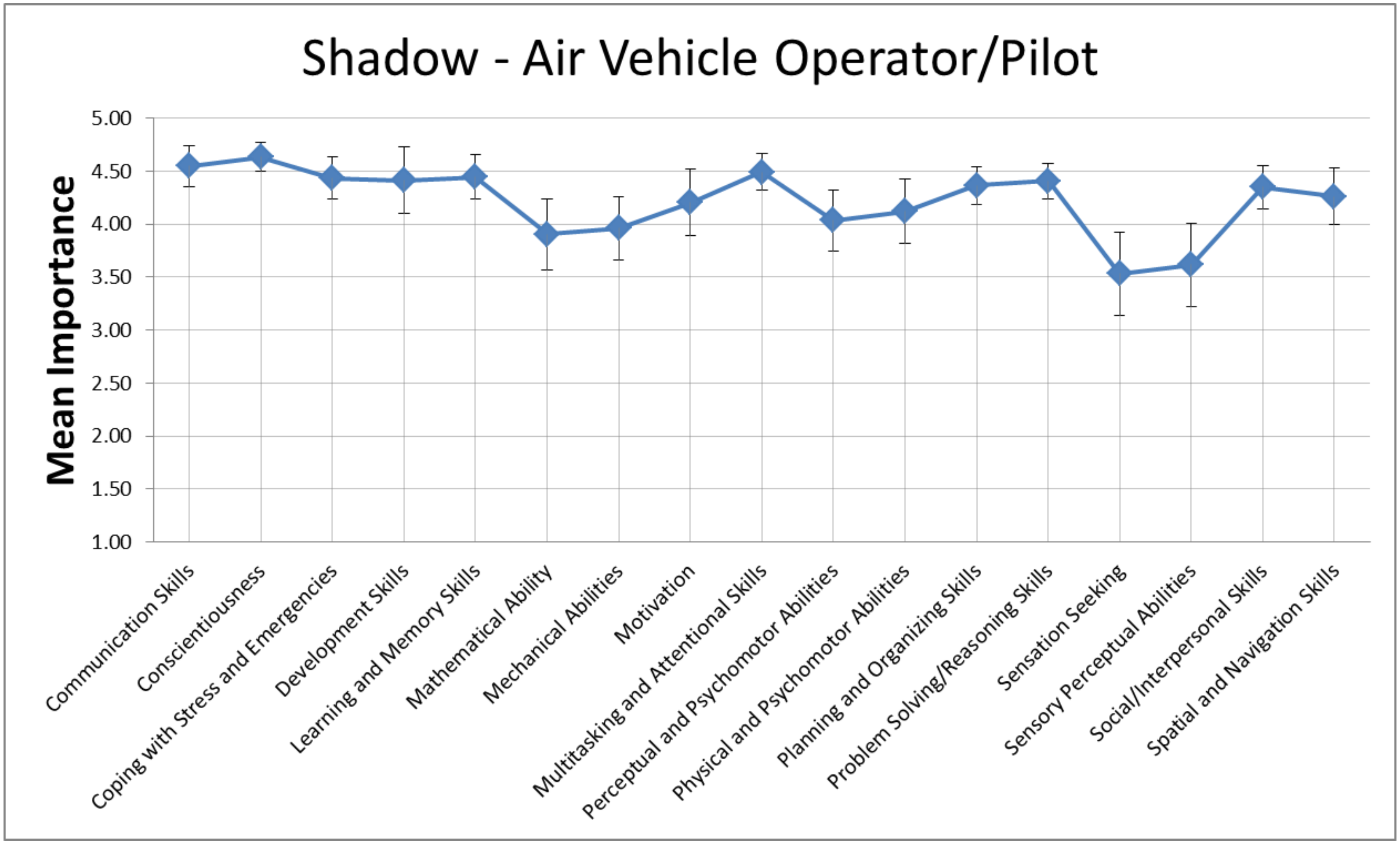


Figure 75: KSAO cluster profiles for Fire Scout – Air vehicle operator/Pilot – Mean KSAO Importance

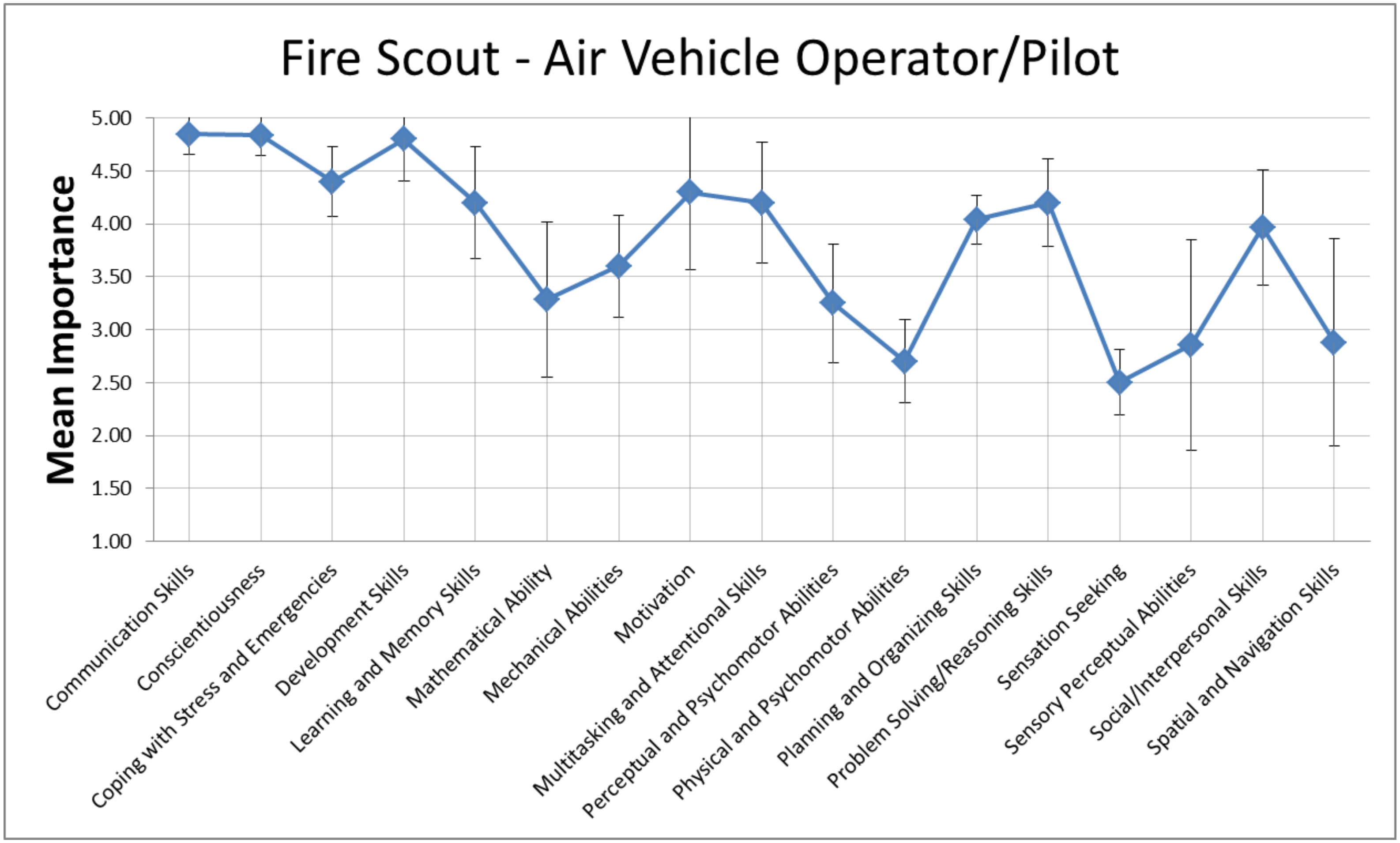


Figure 76: KSAO cluster profiles for BAMS-D – Air vehicle operator/Pilot – Mean KSAO Importance

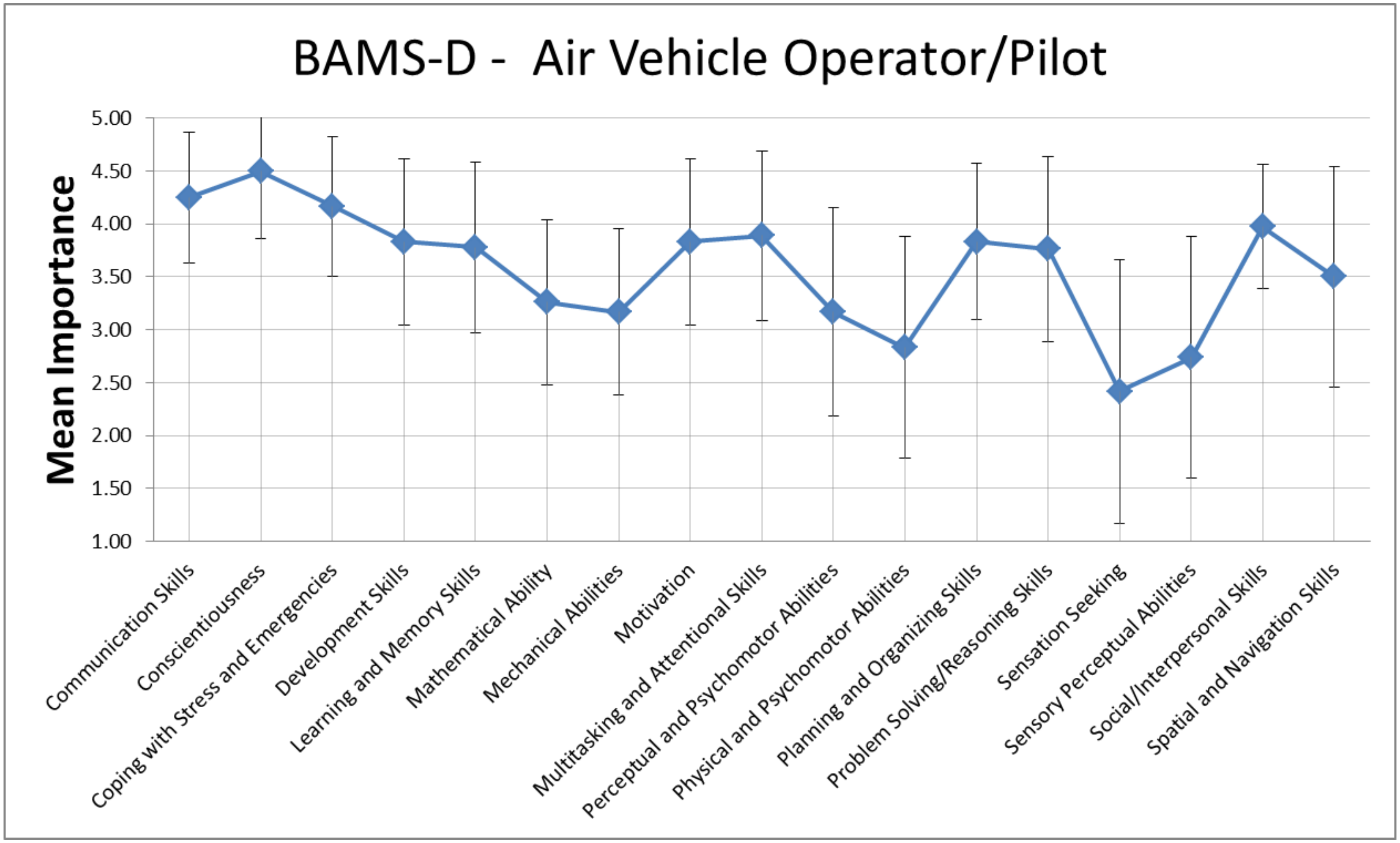


Figure 77: KSAO cluster profiles for BAMS – Air vehicle operator/Pilot – Mean KSAO Importance

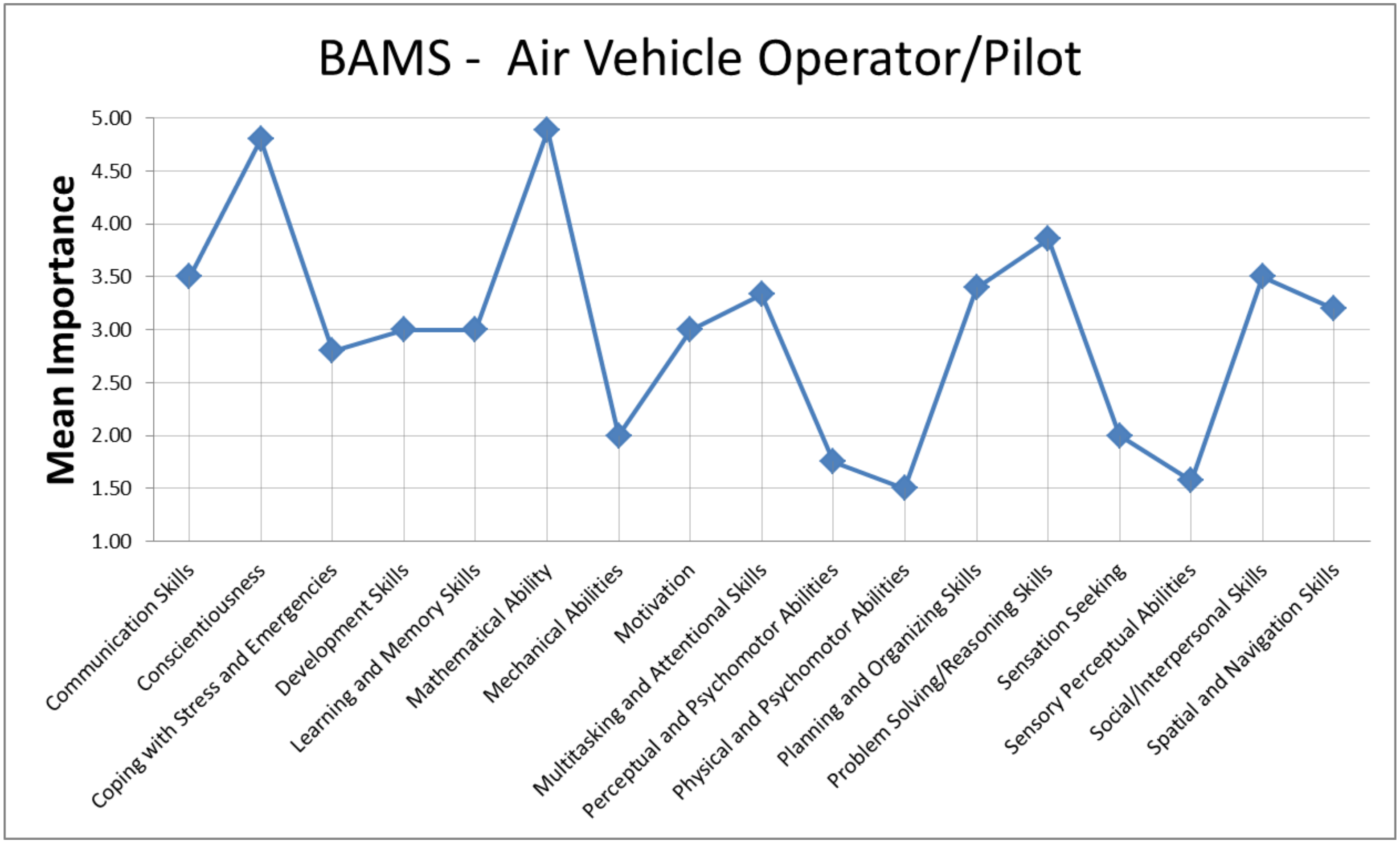


Figure 78: KSAO cluster profiles for all platforms – Air vehicle operator/Pilot – Mean KSAO Importance

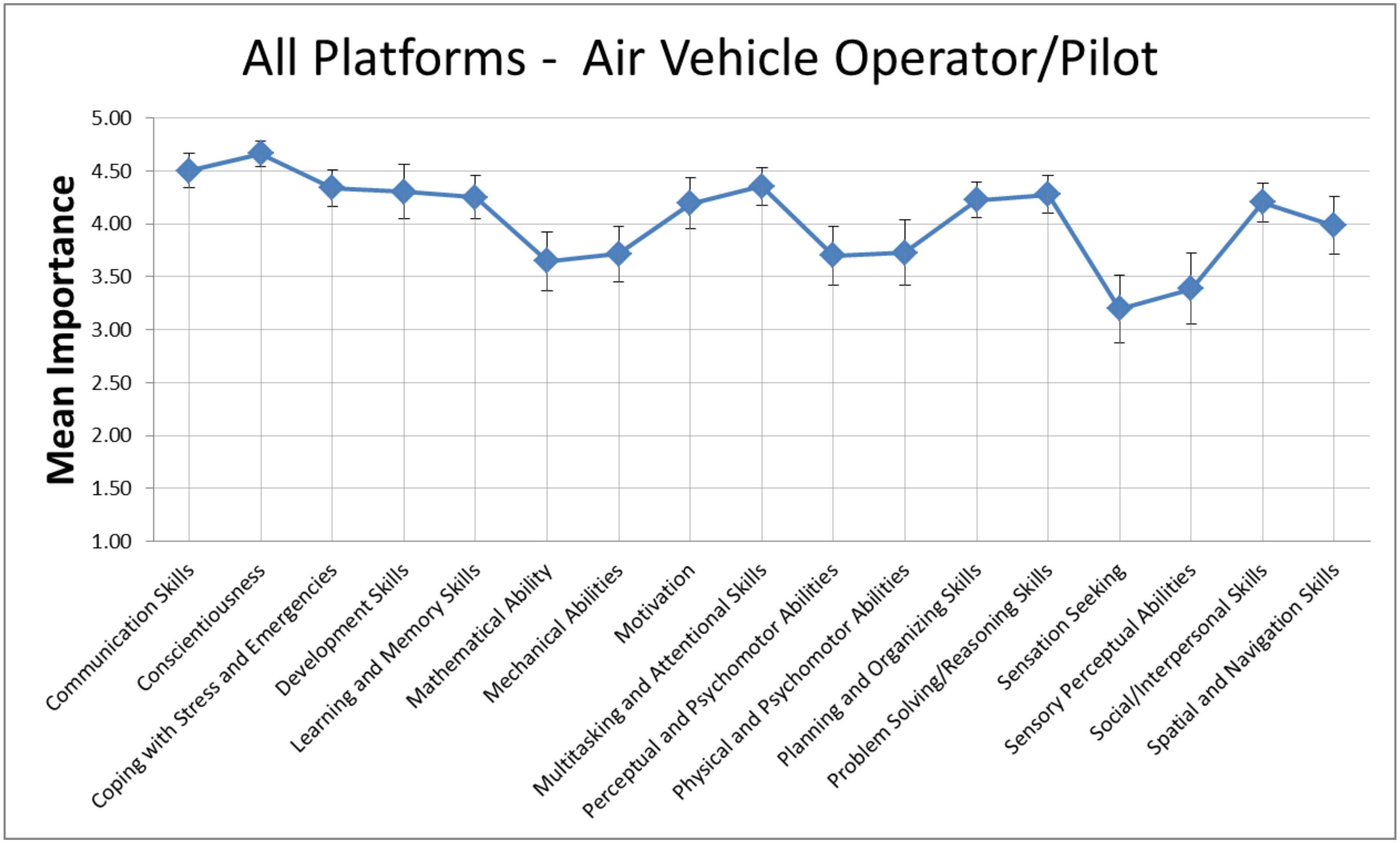


Figure 79: KSAO cluster profiles for Raven – Sensor/Payload operator – Mean KSAO Importance

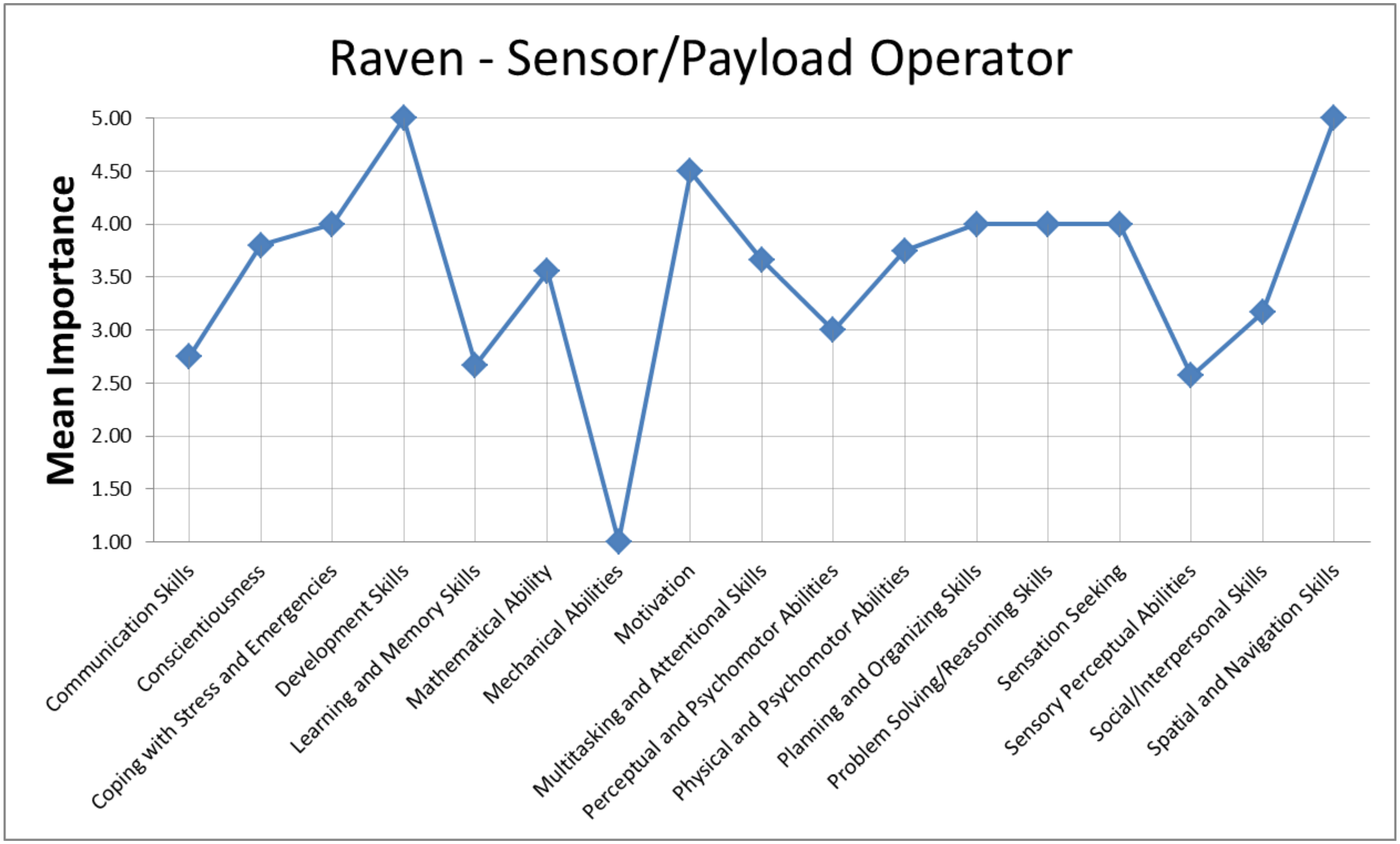


Figure 80: KSAO cluster profiles for Shadow – Sensor/Payload operator – Mean KSAO Importance

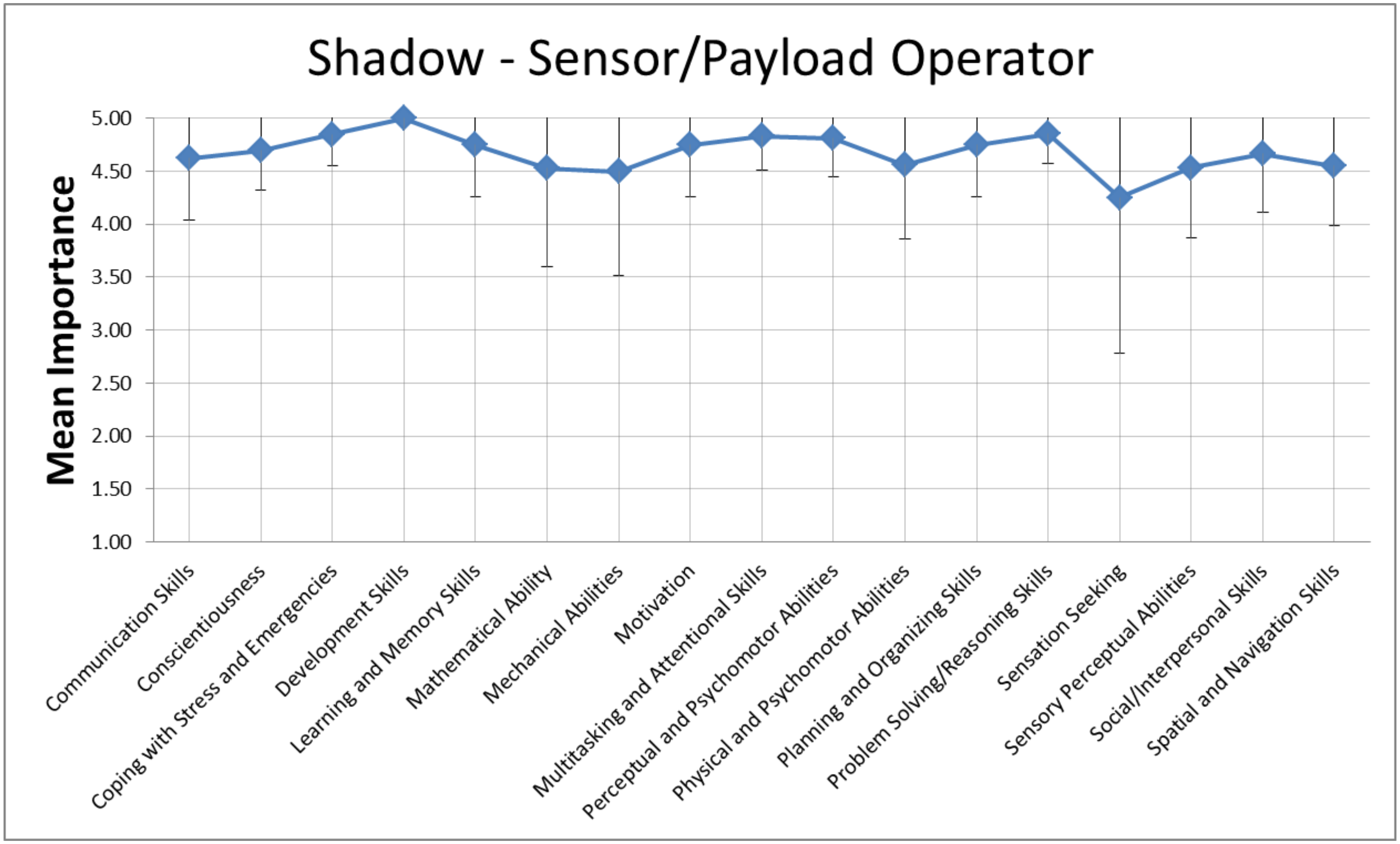


Figure 81: KSAO cluster profiles for BAMS-D – Sensor/Payload operator – Mean KSAO Importance

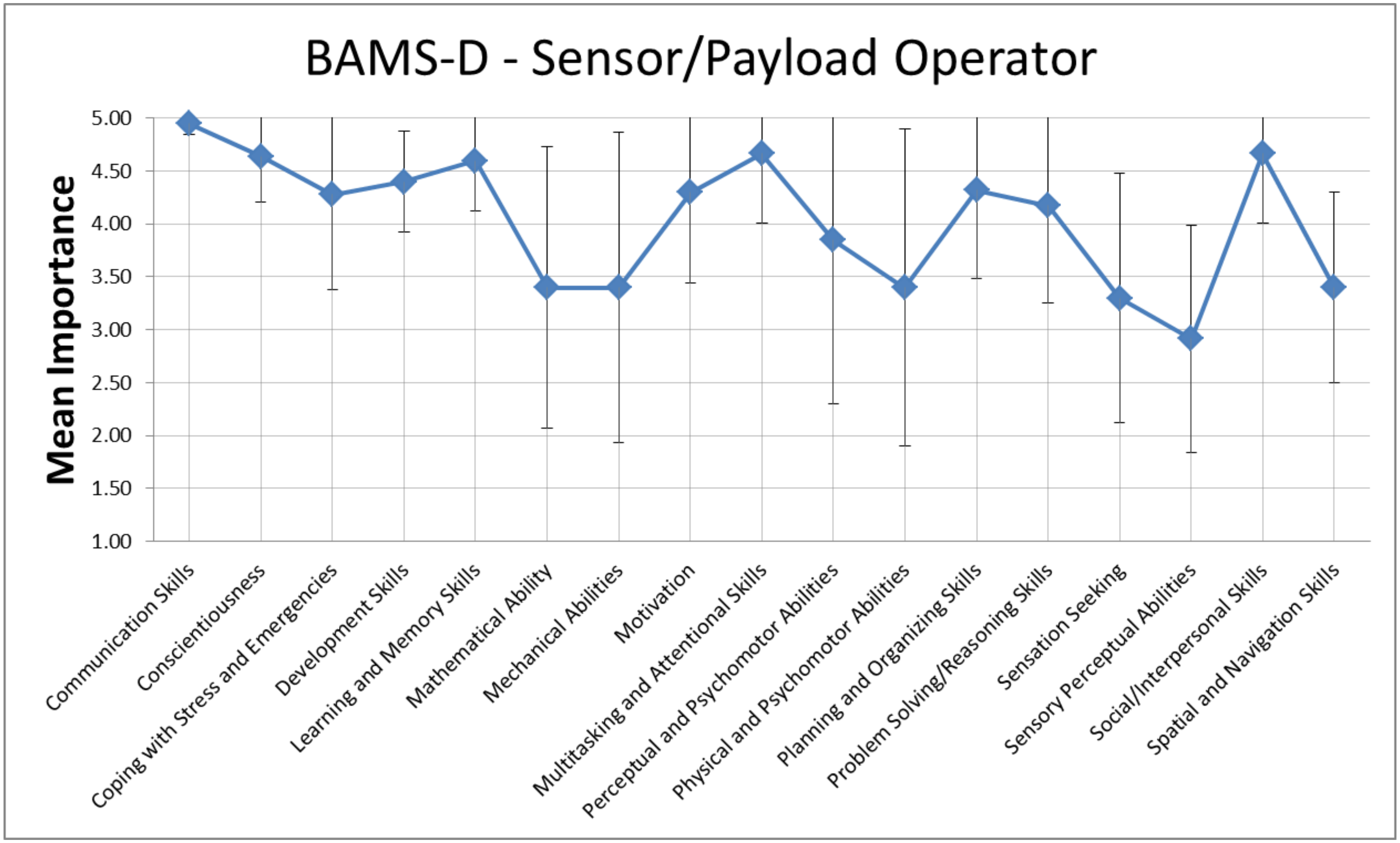


Figure 82: KSAO cluster profiles for BAMS – Sensor/Payload operator – mean KSAO Importance

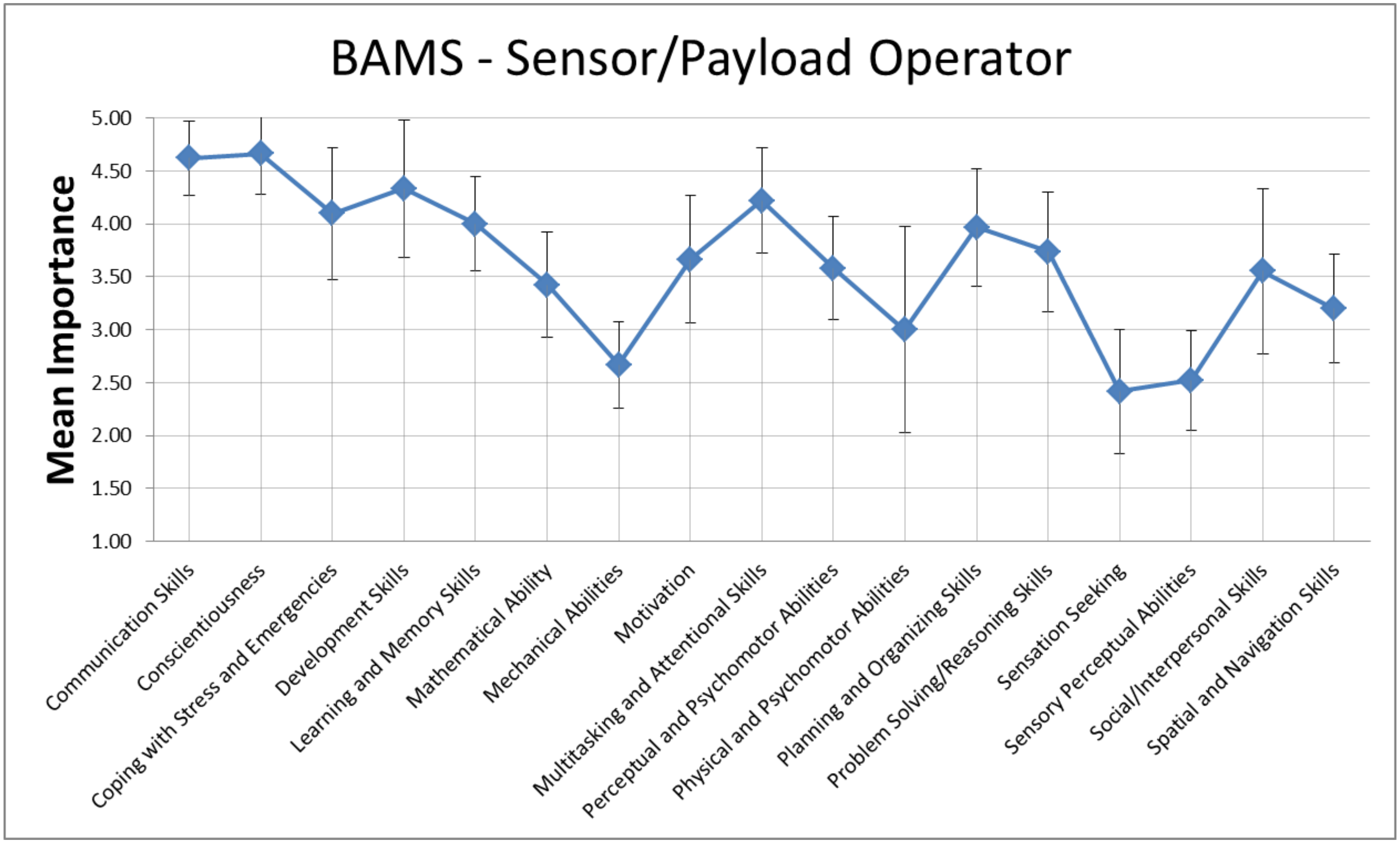


Figure 83: KSAO cluster profiles for all platforms – Sensor/Payload operator – Mean KSAO Importance

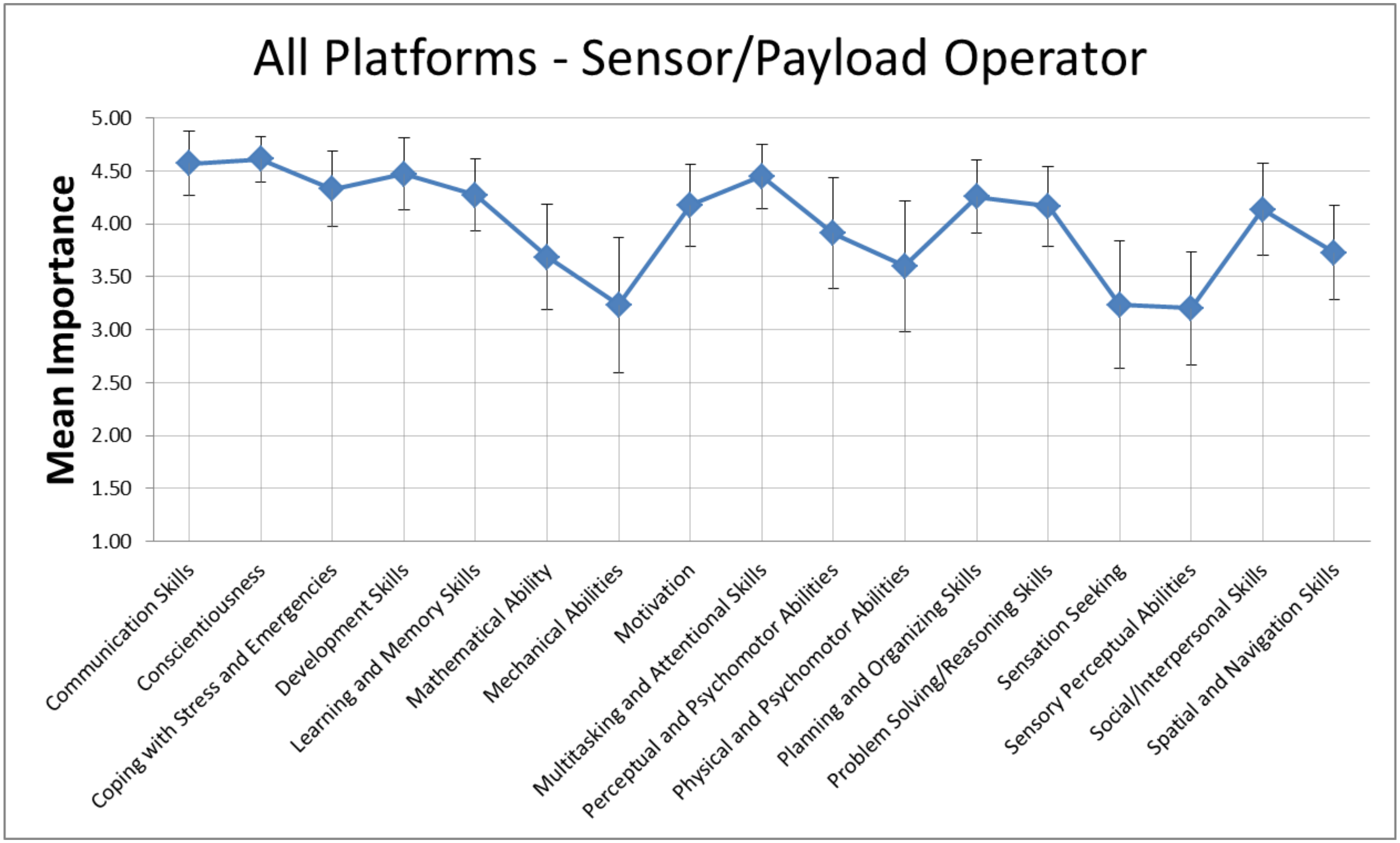


Figure 84: KSAO cluster profiles for ScanEagle – Mission commander – Mean KSAO Importance

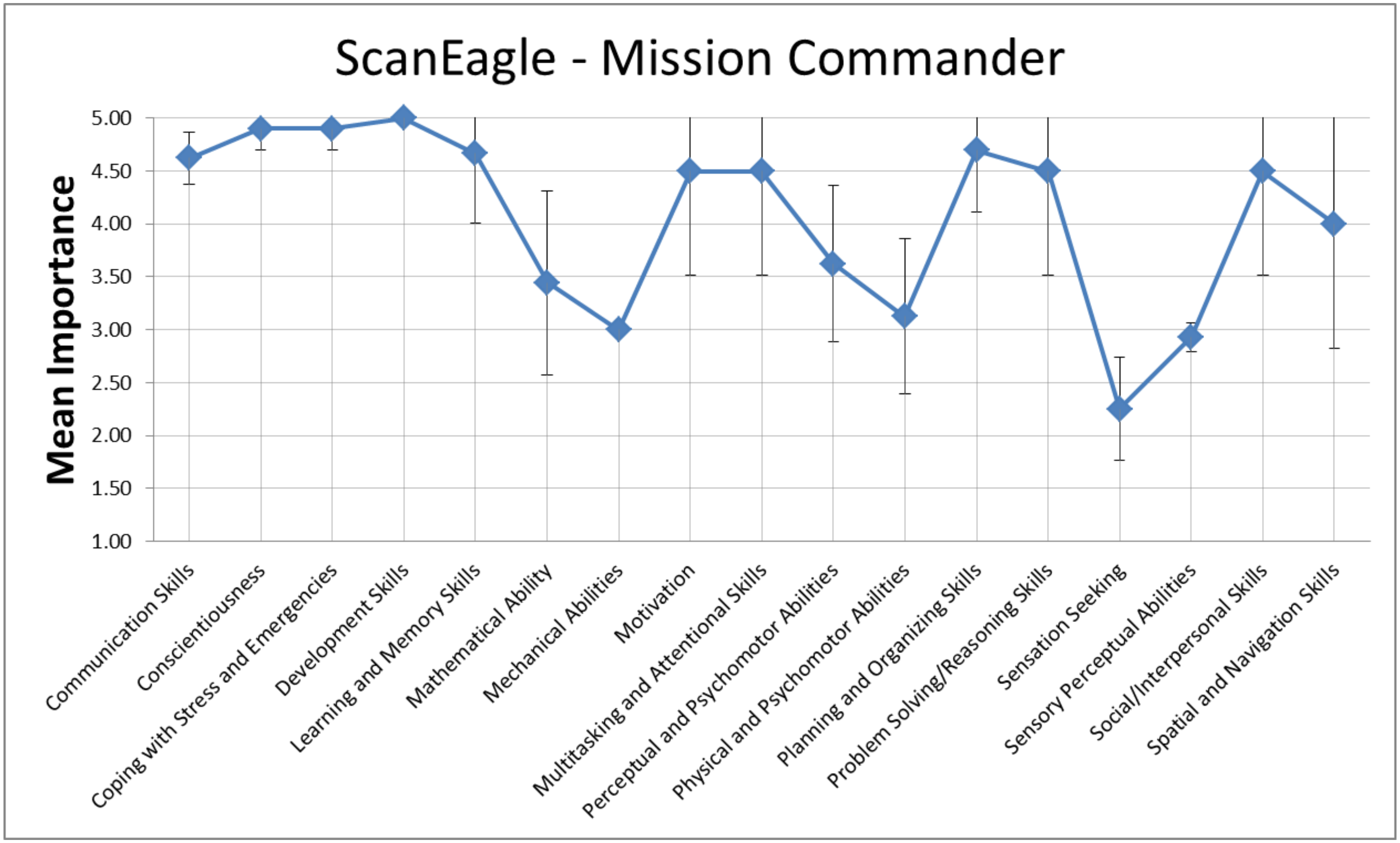


Figure 85: KSAO cluster profiles for BAMS-D – Mission commander – mean KSAO Importance

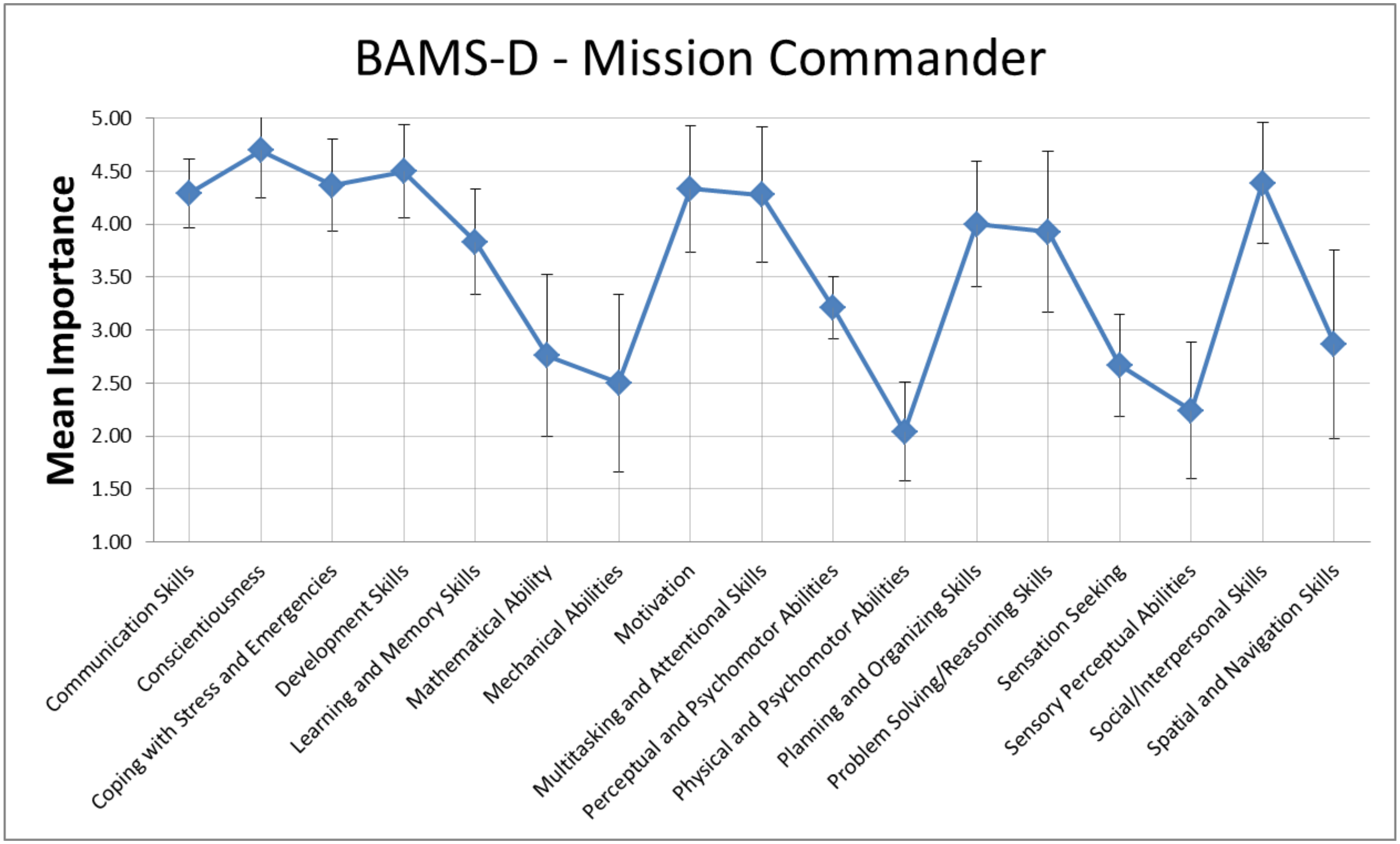


Figure 86: KSAO cluster profiles for BAMS – Mission commander – Mean KSAO Importance

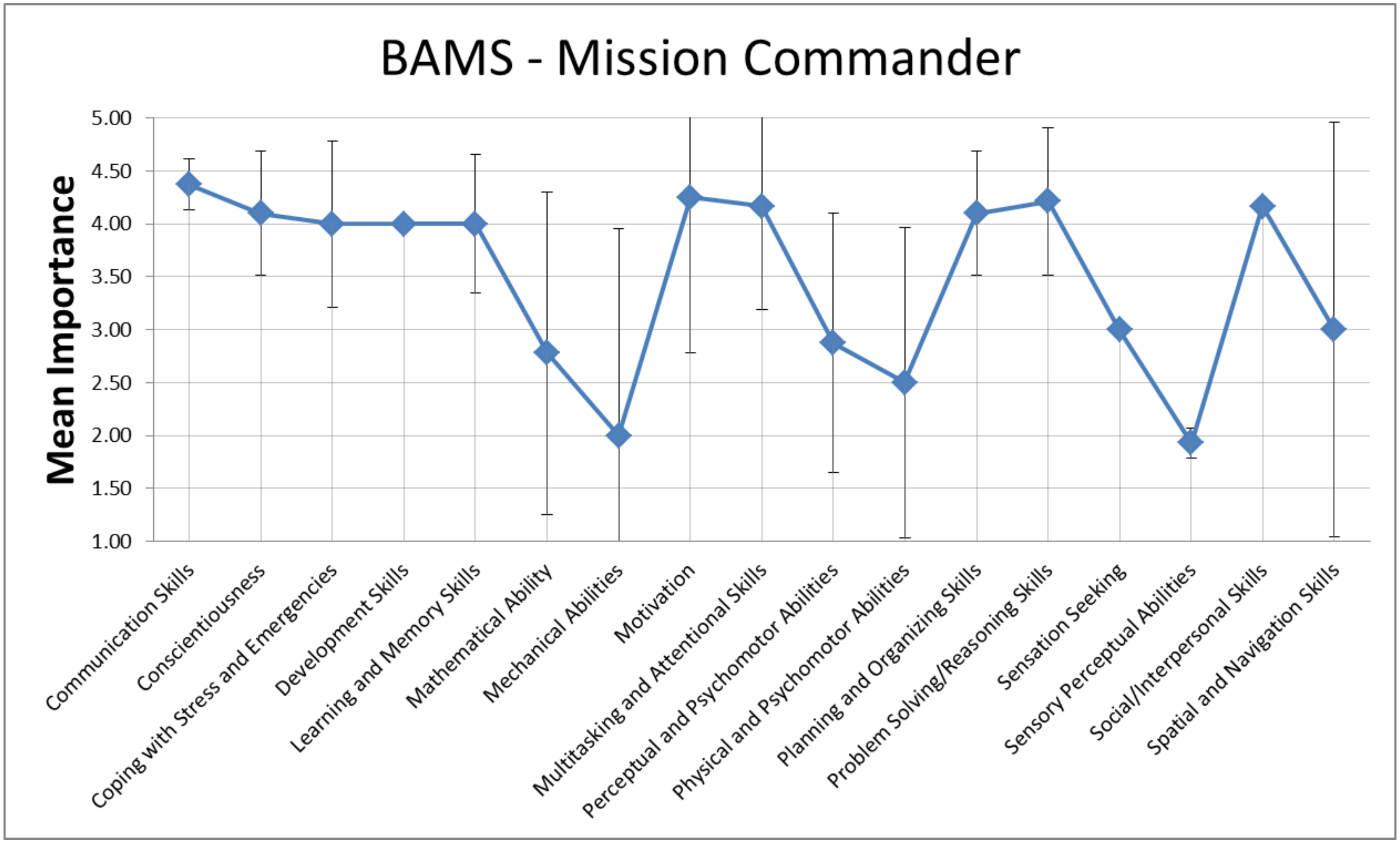


Figure 87: KSAO cluster profiles for all platforms – Mission commander – Mean KSAO Importance

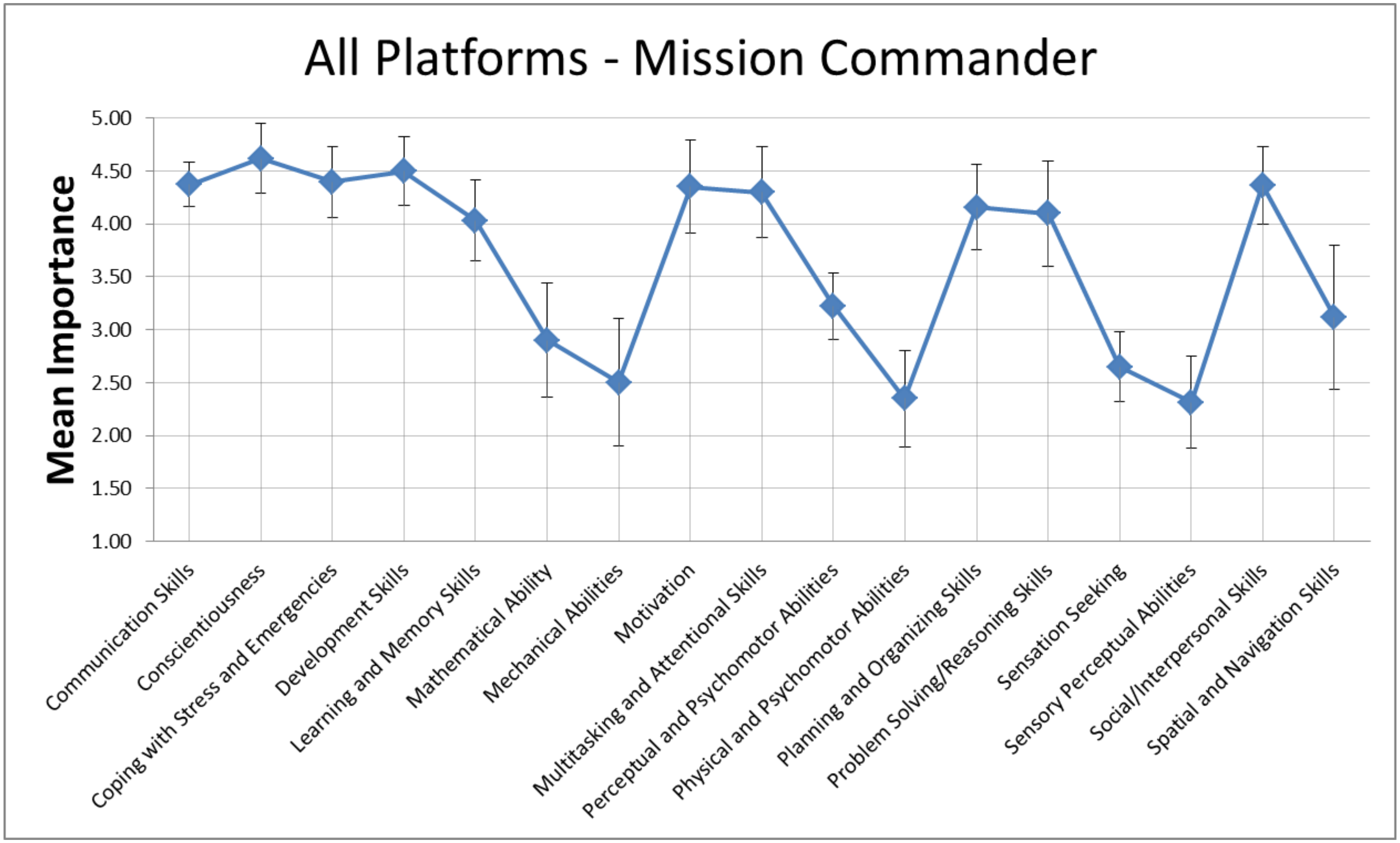


Figure 88: KSAO cluster profiles for BAMS-D – TACCO – Mean KSAO Importance

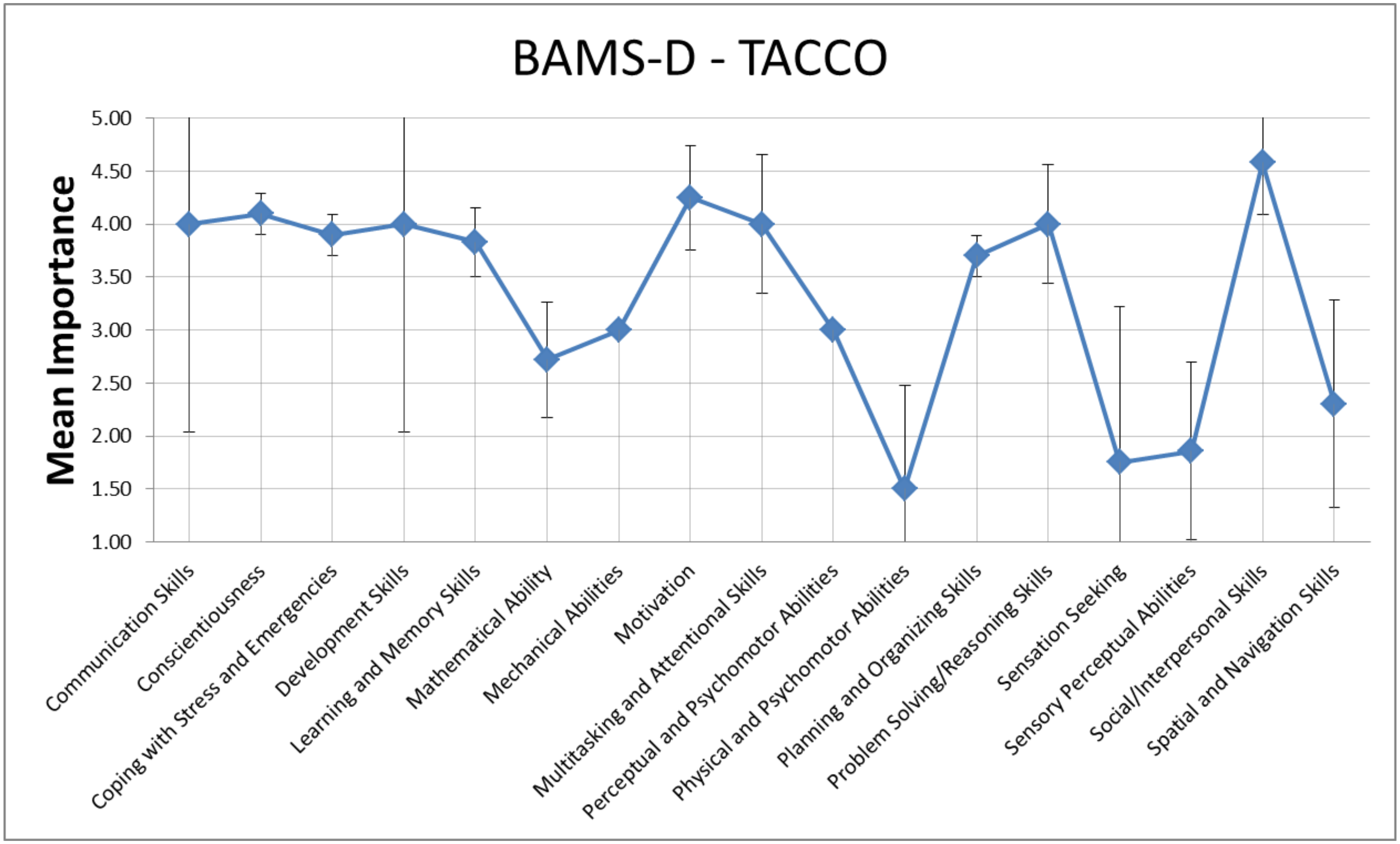


Figure 89: KSAO cluster profiles for BAMS – TACCO – Mean KSAO Importance

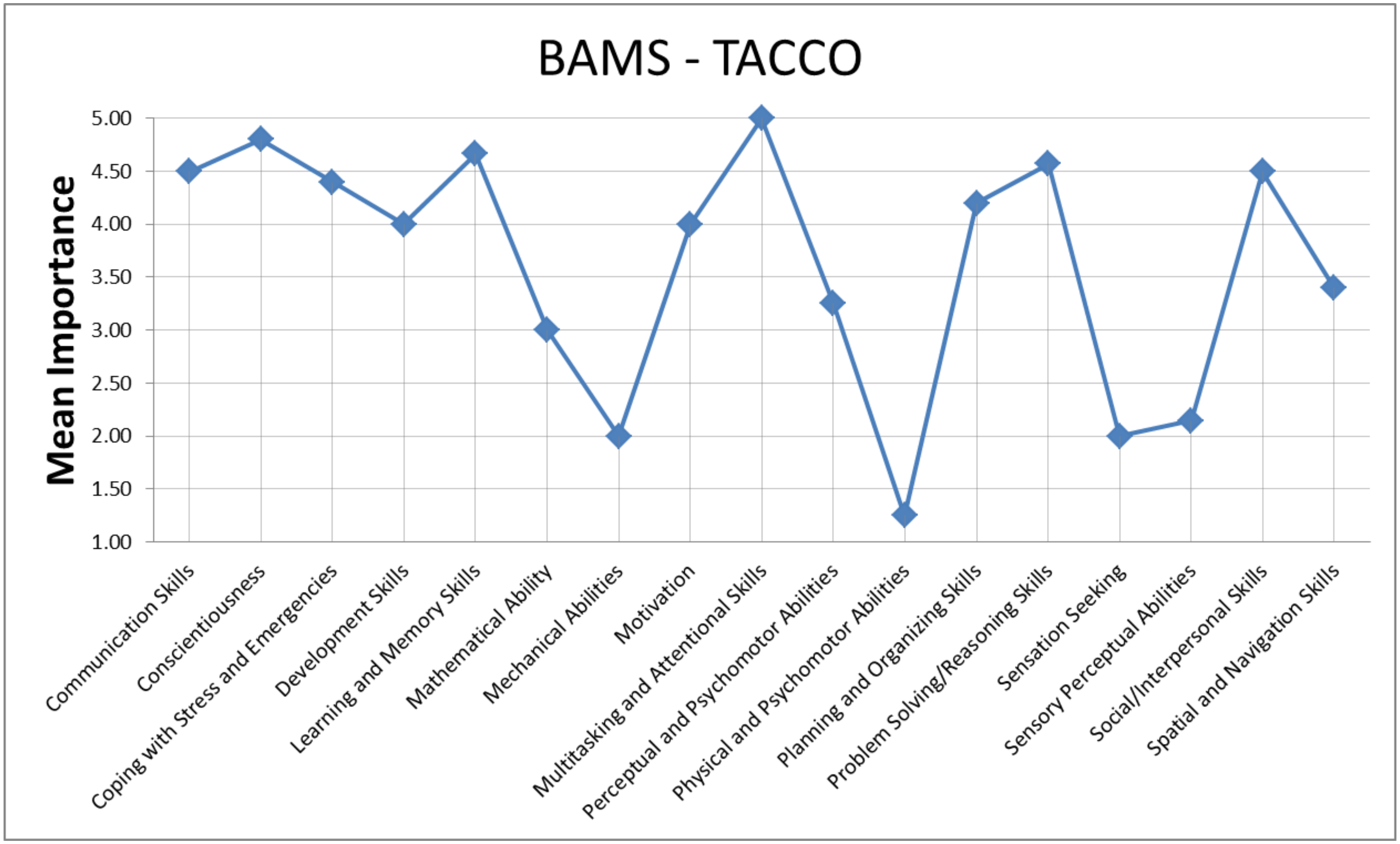
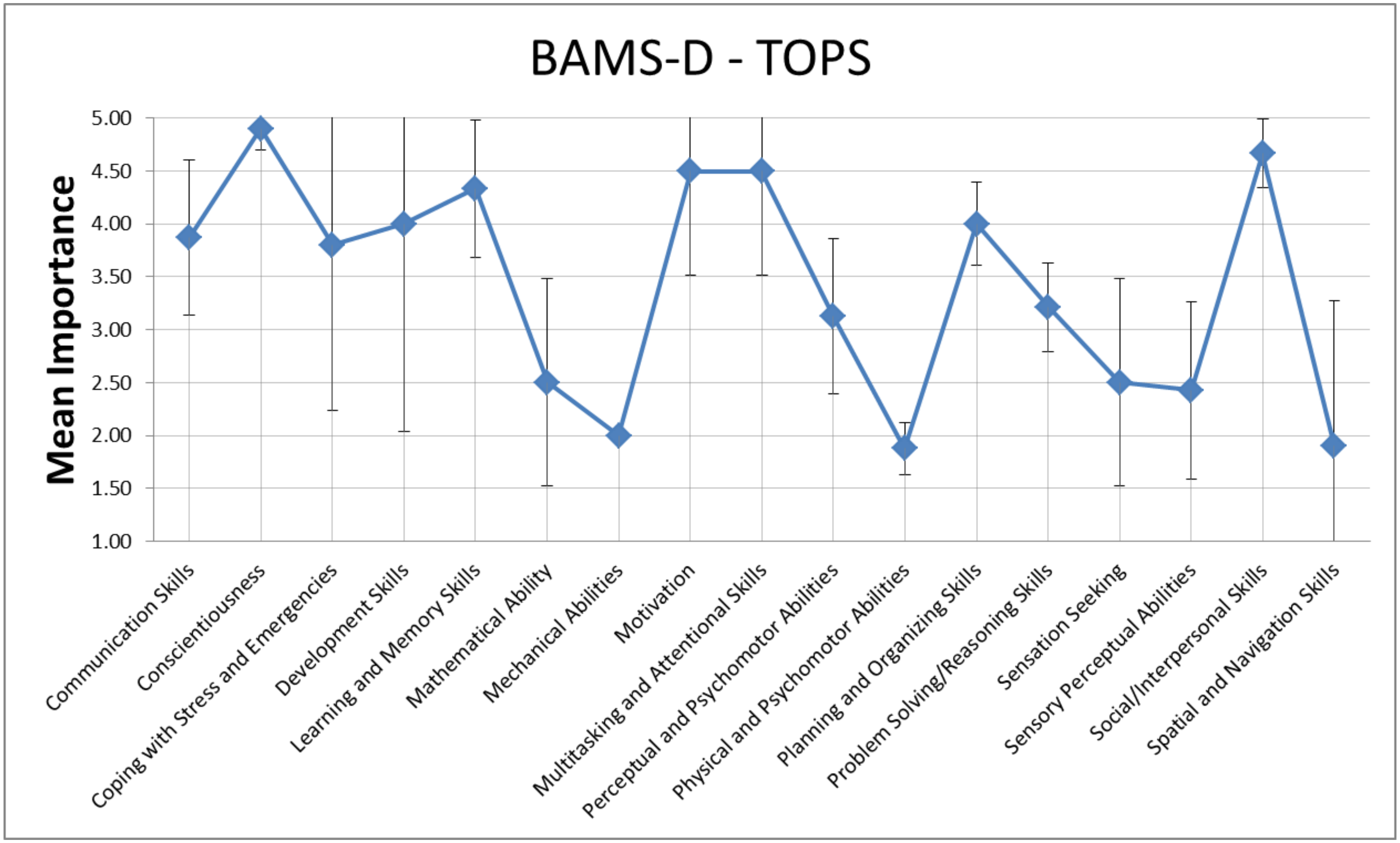


Figure 90: KSAO cluster profiles for BAMS-D – TOPS – Mean KSAO Importance



Position Clustering Results

To support future HSI efforts, including personnel selection and training interventions, we performed an additional set of analyses to develop a provisional job family structure of the Navy UAS domain. This two step process involved 1) estimation of Squared Euclidean Distance (SED) values between each possible pair of position-platform combinations, and 2) hierarchical cluster analysis of position-platform combinations to categorize them into families of functionally related "jobs" with similar task or KSAO profiles. The SED values reflect the distance between each position-platform combination in Euclidean space. Smaller values reflect relatively similar task profiles. The SED values are non-parametric and can be interpreted only in normative terms. Therefore, we calculated percentile values for the distribution of SEDs estimated for each possible pair of position-platform combinations. Values less than the 20th and 10th percentiles are highlighted in yellow and blue, respectively, within Table 2 below. For illustrative purposes, SED values were generated also based on KSAO values, and are shown in Table 3 below.

Additionally, we performed hierarchical cluster analysis to form families of related position-platform combinations. The clustering algorithm used Ward's method to cluster position-platform combinations based on their SED values, and produced a number of solutions ranging from 1 (all combinations in a single cluster) to $N - 1$, where N is the number of position-platform combinations. Results based on both task and KSAO profiles are shown in Figures 91 and 92, respectively. The task-based clustering results show an optimal solution of between three and four clusters. The four cluster solution groups the position-platform combinations as follows:

Cluster 1:

- MQ-8 Fire Scout -AVO/Pilot
- RQ-11 Raven -Sensor/Payload Operator
- MQ-4 BAMS -AVO/Pilot
- RQ-4A BAMS-D -AVO/Pilot

Cluster 2:

- RQ-11 Raven -AVO/Pilot
- RQ-7 Shadow -AVO/Pilot
- RQ-7 Shadow -Sensor/Payload Operator
- Other -AVO/Pilot (e.g., ACR SilverFox)

Cluster 3:

- ScanEagle -Mission Commander
- MQ-4 BAMS -Sensor/Payload Operator
- MQ-4 BAMS -Mission Commander
- RQ-4A BAMS-D -Sensor/Payload Operator
- RQ-4A BAMS-D -Mission Commander
- RQ-4A BAMS-D -TACCO

Cluster 4:

- MQ-4 BAMS -TACCO
- RQ-4A BAMS-D -TOPS
- RQ-4A BAMS-D –Other (e.g., Tactical Data Links Coordinator).
- Other -Sensor/Payload Operator

Figure 91: UAS Position Clusters – Clustering based on Mean Task Importance Ratings

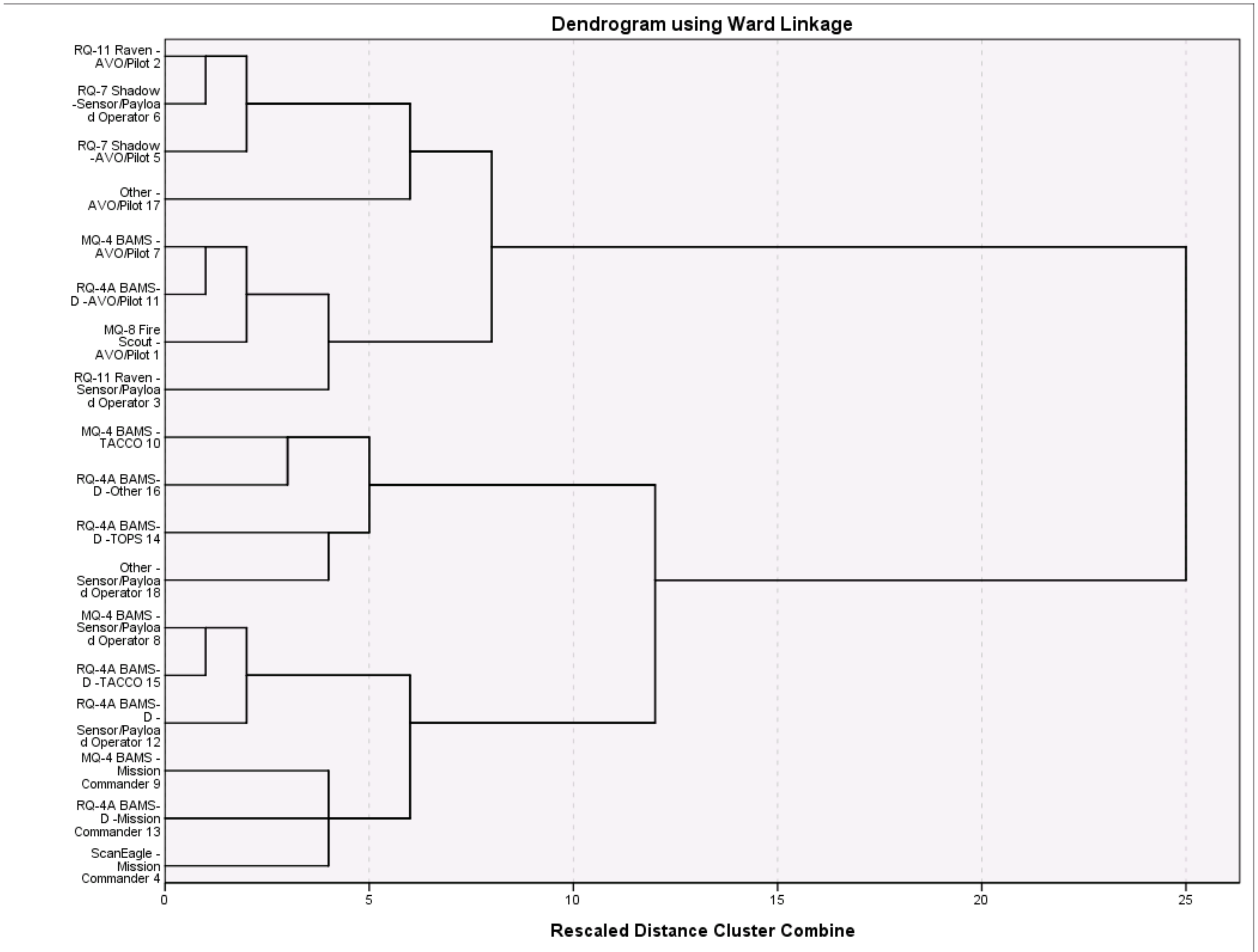


Figure 92: UAS Position Clusters – Clustering based on Mean KSA Ratings

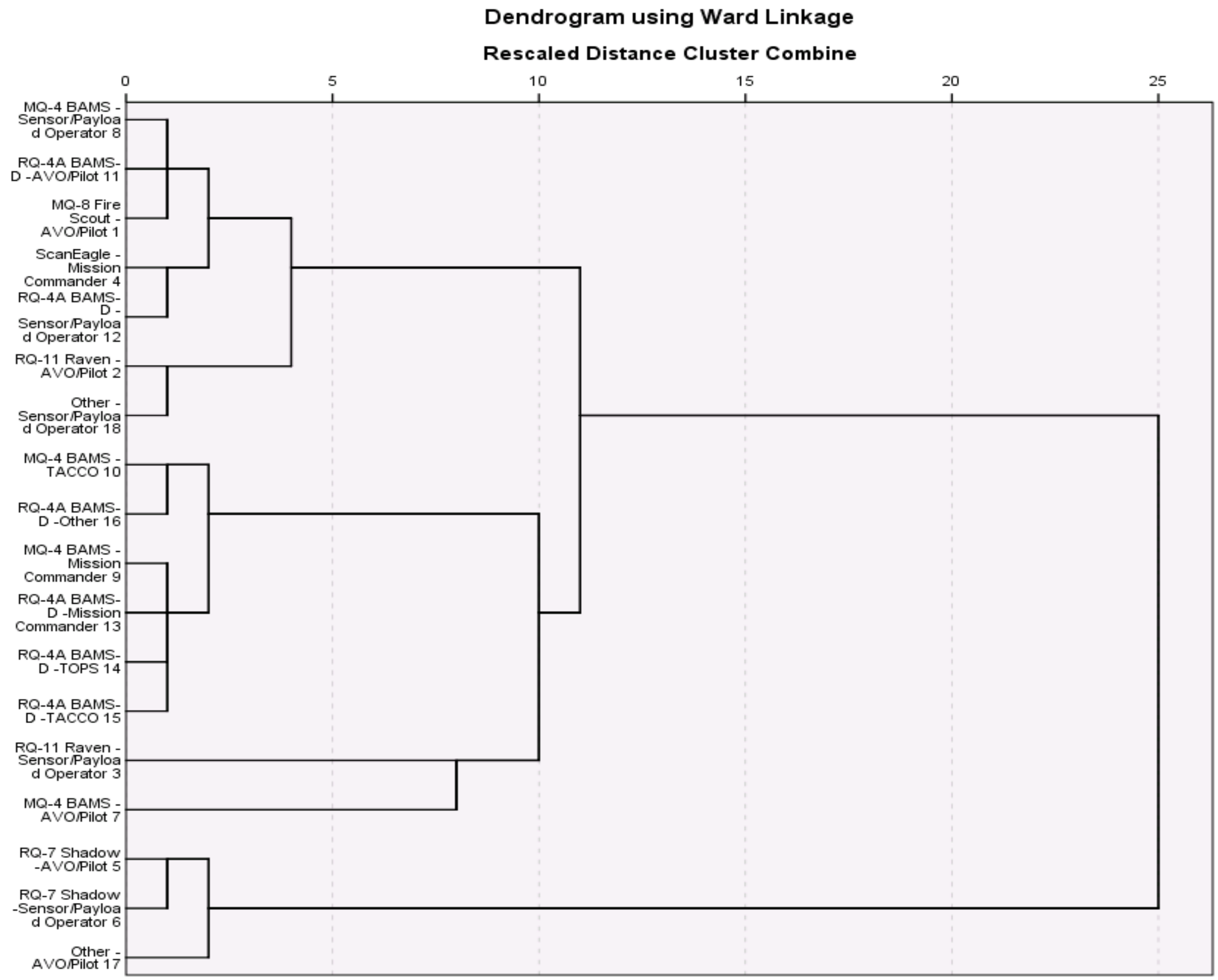


Table 3: Proximity Matrix – Squared Euclidean Distances for UAS Position Pairs Based on Mean Task Importance Ratings

Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. MQ-8 Fire Scout - AVO/Pilot	-																	
2. RQ-11 Raven -AVO/Pilot	64.87	-																
3. RQ-11 Raven - Sensor/Payload Operator	76.92	121.25	-															
4. ScanEagle -Mission Commander	96.03	85.20	151.11	-														
5. RQ-7 Shadow -AVO/Pilot	41.65	19.67	130.54	97.21	-													
6. RQ-7 Shadow - Sensor/Payload Operator	69.23	1.03	131.00	90.00	20.58	-												
7. MQ-4 BAMS -AVO/Pilot	38.93	42.05	71.61	53.73	51.43	47.66	-											
8. MQ-4 BAMS - Sensor/Payload Operator	114.71	89.47	146.69	91.19	100.62	97.21	81.66	-										
9. MQ-4 BAMS -Mission Commander	92.14	54.93	94.53	84.46	65.41	59.58	64.35	76.20	-									
10. MQ-4 BAMS -TACCO	166.50	161.63	139.83	131.19	163.85	170.21	121.50	59.40	70.74	-								
11. RQ-4A BAMS-D - AVO/Pilot	22.18	46.75	54.37	81.38	59.40	50.71	18.26	100.79	70.92	151.38	-							
12. RQ-4A BAMS-D - Sensor/Payload Operator	132.29	115.56	117.22	118.36	125.18	122.20	107.96	30.63	57.78	45.89	118.47	-						
13. RQ-4A BAMS-D -Mission Commander	131.34	88.79	160.61	89.74	100.96	94.15	87.66	45.71	77.89	98.52	113.25	78.62	-					
14. RQ-4A BAMS-D -TOPS	193.15	233.70	175.54	165.29	231.51	246.91	120.86	119.37	173.29	101.46	173.20	156.46	143.58	-				
15. RQ-4A BAMS-D -TACCO	109.37	92.57	138.64	96.51	104.14	100.79	84.70	4.68	74.85	67.77	95.27	26.36	58.33	145.64	-			
16. RQ-4A BAMS-D -Other	146.60	187.30	103.73	121.45	187.99	199.74	100.77	83.05	102.72	47.93	128.87	61.90	138.77	70.74	88.49	-		
17. Other -AVO/Pilot	69.83	94.56	167.70	148.11	61.98	93.97	92.01	142.48	141.92	222.88	88.99	172.10	196.98	264.32	139.31	208.75	-	
18. Other -Sensor/Payload Operator	166.52	193.96	217.62	163.27	157.14	203.86	145.28	87.38	146.30	67.08	191.03	123.91	100.73	86.82	116.69	99.71	209.27	-

Yellow shaded values are < 20^{th} percentile; Blue shaded values are < 10^{th} percentile; smaller values indicate greater similarity.

Table 4: Proximity Matrix – Squared Euclidean Distances for UAS Position Pairs Based on Mean KSA Ratings

Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. MQ-8 Fire Scout -AVO/Pilot	-																	
2. RQ-11 Raven -AVO/Pilot	7.18	-																
3. RQ-11 Raven -Sensor/Payload Operator	23.30	16.93	-															
4. ScanEagle -Mission Commander	5.12	5.10	21.73	-														
5. RQ-7 Shadow -AVO/Pilot	10.63	3.45	22.42	5.82	-													
6. RQ-7 Shadow -Sensor/Payload Operator	24.40	12.42	35.62	14.17	4.07	-												
7. MQ-4 BAMS -AVO/Pilot	19.89	31.01	27.61	30.96	38.10	62.85	-											
8. MQ-4 BAMS -Sensor/Payload Operator	2.35	6.29	17.17	5.33	9.51	23.98	16.60	-										
9. MQ-4 BAMS -Mission Commander	4.46	9.56	15.47	8.64	15.65	32.57	15.90	3.82	-									
10. MQ-4 BAMS -TACCO	7.57	14.77	27.76	7.92	20.22	36.35	19.51	7.19	5.07	-								
11. RQ-4A BAMS-D -AVO/Pilot	2.38	4.87	17.03	6.05	8.93	23.99	14.67	1.42	3.88	7.84	-							
12. RQ-4A BAMS-D -Sensor/Payload Operator	4.28	3.82	22.94	3.02	3.11	11.32	30.34	4.39	7.10	10.20	4.91	-						
13. RQ-4A BAMS-D -Mission Commander	2.22	9.13	19.12	6.29	14.69	30.09	18.07	3.20	1.74	3.77	3.20	6.05	-					
14. RQ-4A BAMS-D -TOPS	7.09	15.75	27.38	13.48	23.46	41.27	20.09	7.69	4.72	6.52	7.92	11.52	3.05	-				
15. RQ-4A BAMS-D -TACCO	5.08	16.58	28.91	13.14	23.64	42.94	15.15	7.37	4.66	5.89	5.74	12.64	3.02	4.20	-			
16. RQ-4A BAMS-D -Other	10.29	15.79	23.07	12.89	24.74	43.98	20.12	9.96	4.87	4.35	9.02	14.57	4.99	5.82	5.00	-		
17. Other -AVO/Pilot	23.85	11.06	42.28	13.72	6.75	5.07	68.62	26.71	33.69	37.02	24.97	12.84	30.98	41.90	42.97	42.60	-	
18. Other -Sensor/Payload Operator	11.26	2.72	17.40	9.97	5.43	15.81	26.50	7.43	11.84	18.51	5.41	7.20	13.12	18.24	19.48	19.56	17.50	-

Yellow shaded values are < 20th percentile; Blue shaded values are < 10th percentile; smaller values indicate greater similarity.

Conclusion

The purpose of the current study was to systematically and comprehensively assess the nature of taskwork and requisite competencies within the Navy UAS domain. Results showed clear patterns of consistently important tasks and KSAOs, both across and within platforms and positions. A number of key conclusions can be summarized as follows:

- When considered at the task cluster level, nearly all aspects of UAS taskwork examined in this study are important across most positions and platforms. Therefore, differences in the reported importance of overall task categories should be interpreted in a relative manner (i.e., virtually all categories are important, and some more so than others)
- Interrater agreement was generally good with some variation among tasks, and was dependent on the number of raters reporting on a common platform-position combination.
- There was some variability among specific platform-position combinations with respect to their task importance profiles
- There was greater variability among task frequency, difficulty to learn, and mastery profiles
- There is a slight tendency for tasks reported to be important to also be more difficult to learn and have more stringent mastery requirements
- Many task clusters and individual tasks were found to be universally important across positions and platforms. Among task clusters, those with the consistently highest importance ratings included:
    - Air vehicle launch and takeoff
    - Airspace area management
    - ISR
    - Shipboard tasks
    - Crew task management
- KSAO clusters that were rated as important consistently across positions and platforms include:
    - Conscientiousness
    - Communication Skills
    - Multitasking and Attentional Skills
    - Development Skills
    - Coping with Stress and Emergencies
    - Social/Interpersonal Skills
    - Learning and Memory Skills
    - Motivation
    - Problem Solving/Reasoning Skills
    - Planning and Organizing Skills

- Position clustering results were used as the basis for a position family structure consisting of three to four families. Platform-position combinations within each family were functionally similar in terms of their most important tasks, whereas those in different families were relatively different.

The results of this analysis are adequately representative of the Navy and Marine Corps UAS community to the extent to which the breadth and magnitude of the current sample size allow. These results can be used to inform a wide variety of HSI applications. Furthermore, the main deliverables of this analysis – searchable and sortable tables listing task and KSAO means for all positions, platforms, and position-platform combinations – can support ongoing analysis and comparisons. These data can inform future investigations of operator task and KSAO requirements, identification of elements common to all UAS platforms versus those unique to specific platforms, and those unique to each system-crew position combination. Furthermore, the use of a common data collection instrument with multiple, complementary rating scales provides a multidimensional investigation into representative UAS tasks and competencies. The resulting data can be used to develop integrated, streamlined HSI applications, for example, personnel selection, training, and performance measurement systems that incorporate the same minimum performance standards, which in turn are anchored to the current task analytic data (e.g., mastery requirements ratings).

References

[* Reference used as a source material for the generation and/or categorization of task statements]

* Adams, J., Cooper, J., Goodrich, M., Humphrey, C., Quigley, M., Buss, B., & Morse, B. (2007). *Camera-equipped mini UAVs for wilderness search support: Task analysis and lessons from field trials* (BYUHCMI Technical Report No. 2007-1).

Biggerstaff, S., Blower, D.J., Portman, C.A. & Chapman, A.D. (1998). The development and initial validation of the unmanned aerial vehicle (UAV) external pilot selection system. Naval Aerospace Medical Research Laboratory, technical report NAMRL-1398.

* Bruskiewicz, K.T., Houston, J.S., Hezlett, S.A., & Ferstl, K.L. (2007). Development of a selection instrument of unmanned aerial system (UAS) operators. Technical report no. 580, Personnel Decisions Research Institutes, Minneapolis, MN

* Chairman of the Joint Chiefs of Staff Instruction. (2009). *Joint unmanned aircraft systems minimum training standards* (CJCSI 32.55.01).

* Department of the Army, Headquarters. (2006). *Small unmanned aircraft system aircrew training manual* (Training Circular No. 1-611).

* Department of the Army, Headquarters. (2007). *Unmanned aircraft system commander's guide and aircrew training manual* (Training Circular No. 1-600).

* Department of the Army, Headquarters. (2007). *Technical manual: Operator and field maintenance manual including repair parts and special tools list for small unmanned aircraft system (SUAS) RQ-11B* (Technical Manual 1-1550-695-13&P).

Dierdorff, E. C., & Wilson, M. A. (2003). A meta-analysis of job analysis reliability. *Journal of Applied Psychology, 88,* 635 – 646.

Dierdorff, E. C., & Rubin, R. S. (2007). Carelessness and discriminability in work role requirement judgments: Influences of role ambiguity and cognitive complexity. *Personnel Psychology, 60,* 597 – 625.

* Eaton, G., Geier, P., Kalita, S., Nagy, J., Palmer, B., Phillips, A., …Sanchez, C. (2006). *U.S. Air Force unmanned aircraft systems performance analyses: Predator front end analysis (FEA) report* (SURVIAC-TR-2006-XXX).

Equal Employment Opportunity Commission, Civil Service Commission, Department of Labor, & Department of Justice. (1978). Uniform guidelines on employee selection procedures. *Federal Register, 43,* 38294 – 38309.

* Hendrix, J., Schnell, W., Danehy, M., Mossey, T., Moser, J., Hanson, S., …Hylton. (2009). *Integration of small tactical unmanned aircraft systems (STUAS) with amphibious forces* (COMTHIRDFLT TACMEMO 3-02.1-09).

* Kalita, S., Duma, K., Eaton, G., & Christofferson, A. (2008). *U.S. Air Force unmanned aircraft systems performance analyses: Predator pilot multi-aircraft control front end analysis report* (SURVIAC-TR-08-686).

* Kalita, S., Duma, K., Nagy, J., & Christofferson, A. (2008). *U.S. Air Force unmanned aircraft systems performance analyses: Predator sensor operator multiple aircraft control (MAC) front end analysis (FEA) report* (SURVIAC-TR-2008-XXX).

* Kubisiak, C., & Katz, L. (2006). *U.S. Army aviator job analysis* (Technical Report No. 1189).

* Mangos, P.M., Arnold, R.D., Mead, A., Merket, D., Littrell, L., Credo, K., Young, R., Tolentino, A., & Kessler, S. (2005). Analysis of work of Naval Aviation training pipelines. Unpublished technical report. Naval Air Warfare Center, Training Systems Division. Orlando, FL.

Morgeson, F. P., Delaney-Klinger, K., Mayfield, M. S., Ferrara, P., & Campion, M. (2004). Self-presentation processes in job analysis: A field experiment investigating inflation in abilities, tasks, and competencies. *Journal of Applied Psychology, 89,* 674 – 686.

* Naval Air Training and Operating Procedures Standardization (NATOPS). (2002). *NATOPS flight manual Navy model RQ-2B pioneer unmanned aerial vehicle* (A1-RQ2BA-NFM-000).

* North Atlantic Treaty Organization (2006). Recommended guidance for the training of designated unmanned aerial vehicle operator (DUO). STANAG 4670, edition 1.

* North Atlantic Treaty Organization. (2006). *Standardization agreement (STANAG): Recommended guidance for the training of designated unmanned aerial vehicle operator (DUO)* (STANAG 4670, Edition 1).

* Program Executive Office for Unmanned Aviation Strike Weapons. (2009). Life cycle support plan for the MQ-8B Fire Scout vertical take-off and landing tactical unmanned aerial vehicle.

* Raymer, M. (2009). A comparative analysis of the Army MQ-8B Fire Scout vertical takeoff unmanned aerial vehicle (VTUAV) and Navy MQ-8B manpower & training requirements (Master's thesis, Naval Postgraduate School).

Triplett, J. (2008). The effects of commercial video game playing: A comparison of skills and abilities for the predator UAV. Thesis AFIT/GIR/ENV/08-M22, Air Force Institute of Technology, Wright-Patterson Air Force Base, OH.

Tvaryanas, A.P. (2006). The development of empirically-based medical standards for large and weaponized unmanned aircraft system pilots. USAF 311th Human Performance Wing, report HSW-PE-BR-TR-2006-0004

* U.S. Marine Corps Headquarters (1999). *Aviation training and readiness manual, volume 6, unmanned aerial vehicle* (Marine Corps Order P3500.21A).

* U.S. Naval Air Systems Command. (2009). *Navy training systems plan for the small tactical unmanned aircraft system (STUAS)/Tier II (STUAS/TIER II)* (N86-NTSP-A-50-0905/D).

* U.S. Naval Air Systems Command. (2010). *Manpower analysis report for the small tactical unmanned aircraft system (STUAS)* (STUAS MAR, February 2010-004).

Weeks, J.L. (2000). Unmanned aerial vehicle operator qualifications. Air Force Research Laboratory, report AFRL-HE-AZ-TR-2000-0002, Mesa, AZ

Appendix A – Task List

Task Category 1: Preflight Tasks

1	1.01	Set, prepare, and check the operation of communication and navigation equipment.
2	1.02	Perform preflight inspection of UAS to check for apparent aircraft discrepancies (for example, fluid leaks, missing nuts or rivets, frayed wires).
3	1.03	Complete planning specific to flight (for example, plan en route points, obtain weather, determine alternate routes).
4	1.04	Conduct crew mission briefing to identify specific mission goals during the preflight brief.
5	1.05	Perform sensor calibration.
6	1.06	Compute basic flight information, including estimated time en route, altitude, and heading for each section of the course.
7	1.07	Perform general safety precautions to protect oneself and others from harm.
8	1.08	Complete planning specific to operational and emergency missions.
9	1.09	Complete and file flight plan, including takeoff, climb, en route, descent, approach, and landing information.
10	1.10	Complete preflight brief, following guidelines regarding crew coordination, weather, emergency plans, operational risk management, and mission goals.
11	1.11	Assemble peripheral equipment to support aircraft takeoff procedures (for example, Ground Control Station, Remote Video Terminal).
12	1.12	Complete the appropriate preflight checklists (for example, AVO checklist).
13	1.13	Prepare, validate, and update Ground Control Station configuration.
14	1.14	Complete preflight Operational Risk Management assessment and brief.
15	1.15	Prepare or assemble payload.
16	1.16	Verify system align and degradations to determine impact to mission.
17	1.17	Ensure clearance of line personnel, ground equipment, and other aircraft.
18	1.18	Prepare specialized launch equipment (for example, catapult system) and complete associated checklists.
19	1.19	Perform aircraft taxi preparation activities.

Task Category 2: Mission Planning

20	2.01	Obtain and organize mission information to be referenced during flight (e.g., publications, payload plan, contingency route plans).
21	2.02	Determine the mission goals, flight plan, and data collection requirements.
22	2.03	Plan mission tasks in accordance with mission requirements, procedures, and regulations.
23	2.04	Prepare or review appropriate references (for example, charts, forms, notices, manuals) to plan mission requirements.
24	2.05	Obtain and Review Mission Planning data, information, and necessary documents (for example, weather information, maps, flight data, and potential emergencies, etc.) from the appropriate sources.
25	2.06	Use electronic charts, mapping software, or mission planning software to determine and plot course information (for example, route, distance, altitude, landing location, course distance, landmark positions, magnetic course).
26	2.07	Use paper charts to determine and plot course information (for example, route, distance, altitude, landing location, course distance, landmark positions, magnetic course).
27	2.08	Plan communication requirements and procedures for missions.
28	2.09	Conduct a thorough Operational Risk Management (ORM) assessment prior to launch.
29	2.10	Perform weapon launch checklist (e.g. recognize error codes, and payload start up

		procedures).
30	2.11	Develop, review, and brief loss-of-link plan.
31	2.12	Revise flight plan, waypoints, or route to redirect air vehicle for unplanned missions.
32	2.13	Plan maintenance activities that must be addressed during the mission (for example, battery change requirements).
33	2.14	Plan for potential emergencies.
34	2.15	Plan safe flight parameters considering factors such as terrain, obstacles, and line-of-sight boundaries.
35	2.16	Determine Optimized Sensor Mix for Target of Interest.
36	2.17	Prepare special route requirements (for example, develop deconfliction plan, effect of thermal crossover).
37	2.18	Identify devices that could create interference with air vehicle.

Task Category 3: System Configuration/Start-up

39	3.01	Test, troubleshoot, and correct air vehicle system problems or failures.
40	3.02	Check main and alternate fuel or battery reserves to ensure adequate energy to conduct the mission.
41	3.03	Check peripheral aircraft navigation and communication systems (for example, IFF, transponder).
42	3.04	Load and operate system instruments, displays, indicators, and controls .
43	3.05	Perform instrument/indicator check to ensure readings are within normal operating parameters.
44	3.06	Crosscheck flight parameter data (e.g., compare GPS location and navigation positions).
45	3.07	Perform system configuration tasks (single/dual controller or laptop).
46	3.08	Perform comprehensive aircraft configuration checks.
47	3.09	Test AV systems, controls, and communications and navigation system equipment for correct operation.
48	3.10	Perform Control Station preflight procedures.
49	3.11	Prepare and start auxiliary power systems.

Task Category 4: Air Vehicle Launch and Takeoff

50	4.01	Start engine and perform associated systems check while attending to appropriate cues to assess engine operation.
51	4.02	Maintain taxi boundaries and yield to other aircraft when appropriate.
52	4.03	Taxi aircraft at the appropriate speed considering traffic and surface conditions.
53	4.04	Perform preflight/take-off checks and complete checklists.
54	4.05	Perform instrument cross-check.
55	4.06	Perform aircraft take-off under normal environmental conditions.
56	4.07	Perform take-off during special or adverse conditions (for example, night operations, adverse weather, near obstructions) and perform necessary corrections.
57	4.08	Make necessary adjustments after take-off (for example, adjust power).
58	4.09	Monitor instruments/indicators to check flight parameters (for example, engine, airspace, altitude) during take-off.
59	4.10	Select or adjust flight mode based on altitude and wind conditions.
60	4.11	Establish and maintain desired flightpath, altitude, airspeed, and heading.
61	4.12	Perform Post-Launch Procedures.
62	4.13	Abort take-off when an emergency situation warrants (for example, engine, hydraulic, or

		electrical problems).
63	4.14	Launch Group-1 UAS from a mobile vehicle.
64	4.15	Complete after take-off checks and checklists.

Task Category 5: In-flight Operations - General

65	5.01	Control, change, or adjust air vehicle flight mode parameters.
66	5.02	Perform basic aircraft operations under instrument flight rules.
67	5.03	Use instruments or displays during instrument flight.
68	5.04	Monitor aircraft performance and flight path and make necessary adjustments.
69	5.05	Perform basic adjustments to air vehicle configuration during cruise.
70	5.06	Calculate new estimated times of arrival (ETAs).
71	5.07	Troubleshoot problems in-flight.
72	5.08	Update in-flight log.
73	5.09	Interpret instruments, displays, and outside visual references during flight.
74	5.10	Perform maneuvers to avoid or recover from adverse conditions (for example, physical obstructions, stalls, or power loss).
75	5.11	Adjust aircraft control to perform in diverse terrain (e.g. Mountain Operations and Urban).
76	5.12	Adjust heading, speed, or estimated time en route to compensate for computed wind effects.
77	5.13	Avoid in-flight wake turbulence.
78	5.14	Execute before-descent-checklist.
79	5.15	Adjust flight parameters to avoid or correct for turbulent conditions.

Task Category 6: In-flight Operations - Safety and Checks

80	6.01	Perform all applicable in-flight checks.
81	6.02	Identify alternatives and develop alternate flight plan if the flight cannot be completed as planned.
82	6.03	Identify and avoid hazardous in-flight weather.
83	6.04	Manage flight automation mode and override when necessary.
84	6.05	Monitor Traffic Collision Avoidance System.
85	6.06	Monitor, control, and manage electronic log of operator specified events.
86	6.07	Monitor Air vehicle health and status (for example, monitor MOS health and status displays).
87	6.08	Activate and verify Flight Essential Avionics (for example, communication systems, IFF, Radios, Navigational Systems).

Task Category 7: Communications

88	7.01	Use proper terminology and formats when communicating with crewmembers or other personnel.
89	7.02	Ensure effective radio communication (for example, listening before transmitting, planning what to say, being alert to sounds, and using proper terminology).
90	7.03	Communicate with Air Traffic Control at required and appropriate times.
91	7.04	Set-up, check, and start radio and related communication systems (for example, C2DL).
92	7.05	Select, adjust, or use different communication modalities (for example, intercom voice versus data mode).
93	7.06	Coordinate, communicate, and execute changes or deviations to planned mission or flight profiles.

94	7.07	Comply with Air Traffic Control communication requirements.
95	7.08	Perform communications during ground operations (for example, obtain clearance from ground control, obtain weather information).
96	7.09	Perform non-voice communications (for example, chat messaging, e-mail) during mission.
97	7.10	Address special Air Traffic Control instructions (for example, special clearance requirements).
98	7.11	Assist and communicate with flight operator as needed during phases of flight.
99	7.12	Manage data security and data links during communications.
100	7.13	Obtain IFR clearance over radio.
101	7.14	Perform cryptographic communications.
102	7.15	Communicate engagement information (for example, visual landmarks, target features).
103	7.16	Use control beacons to support navigation.
104	7.17	Manage LOL settings.
105	7.18	Perform C2 Radio procedures.
106	7.19	Communicate with observer, ground force commander, or other mission-essential personnel at required and appropriate times.

Task Category 8: Navigation

107	8.01	Use onboard navigation equipment to maintain aircraft position.
108	8.02	Navigate a specific operational area using select fly-to-point parameters.
109	8.03	Perform each maneuver within assigned airspace.
110	8.04	Perform Fix-to-fix (waypoint) navigation.
111	8.05	Perform in-flight navigation planning.
112	8.06	Determine the aircraft's position and course by interpreting topographical charts and referencing visual landmarks during flight.
113	8.07	Use a navigation computer and appropriate charts to determine critical data (for example, wind or ground speed, drift, time-to-ground reference point).
114	8.08	Switch to a Contingency Mission Plan/Route and make changes in Navigation as necessary.
115	8.09	Make recommended corrections (for example, heading or airspeed) to return aircraft to intended course.
116	8.10	Perform navigation under instrument flight rules (IFR).
117	8.11	Perform navigational communications to obtain or share position, mission, or tactical information.
118	8.12	Plan route to destination/alternates (such as safe passage assessment and detection reduction profile).

Task Category 9: Airspace and Operating Area Management

119	9.01	Perform Air Vehicle operations within restricted operating areas.
120	9.02	Maintain awareness of other air traffic and deconflict as necessary.
121	9.03	Perform airspace coordination with Air Traffic Control.
122	9.04	Perform airspace coordination during tandem operations with other air vehicles (for example, vertical, lateral, and timed separation procedures).
123	9.05	Maintain airspace clearances while performing mission-specific tasks.

Task Category 10: Crew Task Management

124	10.01	Manage crew task loading to ensure compliance with all restrictions and limitations (for

		example, crew rest).
125	10.02	Perform crew resource management (AVO to MPO).
126	10.03	Perform crew resource management (AVO or MPO to UAC).
127	10.04	Complete changeover procedures between launch, mission control, and recovery phases.
128	10.05	Perform air vehicle handoff procedures for receiving controller.
129	10.06	Perform air vehicle handoff procedures for releasing controller.
130	10.07	Troubleshoot unsuccessful air vehicle handoffs.
131	10.08	Perform centralized operations.
132	10.09	Perform split-site operations.

Task Category 11: Fuel and Power Management

133	11.01	Plan fuel or battery power requirements for the flight considering course, mission, and aircraft requirements (for example, weight computations).
134	11.02	Monitor, calculate, and update fuel/battery state and requirements at specified intervals (for example, at navigational checkpoints).
135	11.03	Calculate actual fuel or battery power consumption and compare to planned rate of consumption.
136	11.04	Monitor fuel/battery status closely during high consumption or other special situations (for example, during climb, acceleration, etc.).
137	11.05	Execute appropriate course or destination deviations if estimated fuel or battery power levels are insufficient.
138	11.06	Optimize fuel or battery power consumption for maximum endurance.
139	11.07	Contact the operating unit for new tasking orders and flight route in case of inadequate fuel or battery power levels.
140	11.08	Check for possible fuel system anomalies affecting fuel use and transfer.

Task Category 12: Payload Operations

141	12.01	Set up, adjust, or optimize information displays under various conditions (for example, day versus night, limited symbology).
142	12.02	Develop, execute, or modify station sensor data collection plan.
143	12.03	Manage information sources (for example, video imagery, sensor data, IFF data) during payload operations.
144	12.04	Perform calculations to support mission objectives (for example, range and bearing between two points).
145	12.05	Perform payload operations under different control modes.
146	12.06	Identify, classify, and manage actual or potential targets during payload operations.
147	12.07	Properly employ payload sensor, including coordination and deconfliction tasks.
148	12.08	Coordinate with crew members regarding aircraft or mission payload control.
149	12.09	Perform sensor cross cueing with other collection platforms.
150	12.10	Perform tests on payload operations peripherals and equipment (for example, IR sensors, lasers).
151	12.11	Use, control, or adjust EO/IR system.
152	12.12	Manage payload data displays, preferences, and filters.
153	12.13	Manage, control, or use Electronic Support Measures (ESM) system and status.
154	12.14	Manage/Control AIS.
155	12.15	Monitor GIG / SIPER.
156	12.16	Monitor/Update the Common Tactical Picture (CTP).

Task Category 13: Intelligence, Surveillance, and Reconnaissance

157	13.01	Perform intelligence, surveillance, and reconnaissance tasks, including collecting, reporting, and disseminating intelligence information.
158	13.02	Establish and maintain air vehicle position to conduct surveillance.
159	13.03	Position, optimize, and employ sensor system to support surveillance tasks.
160	13.04	Perform aerial observations.
161	13.05	Perform area reconnaissance tasks.
162	13.06	Incorporate environment, masking requirements, and terrain to facilitate collection plan.
163	13.07	Gather EEI during the course of a mission.

Task Category 14: Flight Maneuvers

164	14.01	Perform advanced flight techniques under adverse weather conditions.
165	14.02	Perform advanced flight techniques during night operations.
166	14.03	Perform advanced flight techniques (e.g. covert approach, high altitude approach, low level flying). .
167	14.04	Perform same channel AV maneuvers through a relay AV.

Task Category 15: Mission Execution

168	15.01	Review and evaluate mission outcomes (for example, BDA, tactical operations).
169	15.02	Communicate and coordinate with ground forces and AV operations.
170	15.03	Manage mission data (for example, data recordings, streaming to customer).
171	15.04	Determine weather conditions (for example expected wind levels and effect of humidity) and effects on AV during flight operations.
172	15.05	Review and brief crew swap contingency plans.
173	15.06	Perform mission egress and ingress checks.
174	15.07	Perform air vehicle operator tasks using the appropriate tools and resources (for example, Falconview).
175	15.08	Plan, execute, and modify calls for direct or indirect fire during missions.
176	15.09	Ensure Completion of AVO Preset Checklist.
177	15.10	Execute Loss-of-link procedures coordinated through ATC and Range Control agencies.
178	15.11	Mitigate collateral damage and risk of fratricide.
179	15.12	Prioritize and optimize scheme of maneuvers, considering safety, endurance, and flexibility.

Task Category 16: Missions – Target management

180	16.01	Perform planning tasks (for example, collateral damage estimation) in preparation for weapons engagement.
181	16.02	Select weapon type, features, or parameters depending on target or environmental factors.
182	16.03	Plan and execute weapons engagement tasks to maximize probability of destruction.
183	16.04	Identify, track, manage, and engage targets using the appropriate procedures and resources (for example, laser, target discrimination, tracker).
184	16.05	Conduct target acquisition and tracking.
185	16.06	Determine distance from friendly or enemy forces to position of the aircraft.

186	16.07	Perform target acquisition on static targets.
187	16.08	Perform Fire Support coordination procedures.
188	16.09	Perform threat assessment during the course of a mission.
189	16.10	Perform tasks to assess and minimize collateral damage during weapons engagement.
190	16.11	Perform post-mission damage assessment (for example, battle and collateral damage).
191	16.12	Provide sensor support during talk-ons.

Task Category 17: Emergency Tasks

192	17.01	Read, understand, and analyze warning or emergency messages.
193	17.02	Reference information and prioritize mission objectives during emergencies.
194	17.03	Identify and respond to alerts and warning displays (for example, Tactical Control System monitors).
195	17.04	Perform destructive emergency landings.
196	17.05	Communicate emergency information and plans-of-action to crew members, ATC, or key personnel.
197	17.06	Perform emergency tasks related to adverse weather conditions (for example, emergency low visibility approach).
198	17.07	Deconflict and coordinate with controlling agency during emergencies.
199	17.08	Perform in-flight navigation changes/planning in response to emergencies.
200	17.09	Maintain the appropriate flight profile during an emergency considering critical flight parameters (for example, altitude, rate of descent).
201	17.10	Plan or coordinate emergency procedures around physical obstructions in the environment.
202	17.11	Use specialized equipment in response to emergencies (for example, barricade).
203	17.12	Respond to emergencies related to propulsion.
204	17.13	Respond to emergencies related to communication systems (for example, voice, GPS, uplink failure, etc.).
205	17.14	Respond to emergencies related to Ground Control Station failures.
206	17.15	Respond to in-flight emergencies related to engine, systems, or sensor failures.
207	17.16	Respond to emergencies related to unexpected vehicle equipment or mechanical failures (for example, stuck throttle, high engine temperature).
208	17.17	Respond to in-flight electrical emergencies (for example, power or fuse failures, low battery).
209	17.18	Respond to emergencies related to systems failures (for example, electrical).
210	17.19	Respond to emergencies related to airframe failures (for example, flight surfaces).
211	17.20	Respond to emergencies related to environmental conditions (for example, icing, extreme temperatures).
212	17.21	Respond to emergencies related to sensor failures (for example, camera).
213	17.22	Perform automated emergency recovery procedures.
214	17.23	Execute contingency or override plans in the case of an emergency (for example, change speed, direction, or altitude of the air vehicle).
215	17.24	Execute emergency shutdown procedures.
216	17.25	Maintain air vehicle control during unexplained or unexpected aircraft behavior.
217	17.26	Abort launch in the case of an emergency.
218	17.27	Recognize when the air vehicle is exceeding normal flight parameters and recover to normal flight (for example, unusual attitude recovery).
219	17.28	Respond to laser malfunctions for both on- and off-board weapons
220	17.29	Respond to ground emergencies.
221	17.30	Perform automated flight termination or self-destruct procedures.

222	17.31	Transfer Air Vehicle control in case of an emergency, when appropriate.

Task Category 18: Air Vehicle Approach and Landing

223	18.01	Configure AV for landing while maintaining the appropriate rate of descent, angle of attack, and airspeed.
224	18.02	Maintain aircraft control during landing (for example, correct for variations in rate of descent and airspeed, maintain proper aircraft attitude).
225	18.03	Compute landing data and comply with ATC clearance prior to landing.
226	18.04	Perform pre-approach checklist to validate AV has completed approach procedures prior to landing (e.g., landing gear, radar altimeter functioning, .
227	18.05	Maintain course and glide slope control while reacting to meterological conditions (for example, turbulence, IMC) during flight.
228	18.06	Use special instruments, techniques, or procedures (for example, precision approach radar) to guide final approach.
229	18.07	Perform manual landing.
230	18.08	Perform automated landing.
231	18.09	Perform flight and landing utilizing automated flight modes.
232	18.10	Perform and maintain holding pattern and pattern maneuvers.
233	18.11	Perform go-around or missed approach procedures.
234	18.12	Perform heads down landing procedure with and without assistance.
235	18.13	Command or perform waveoff landings.
236	18.14	Prepare site and land AV in variety of conditions (e.g., night, adverse weather, physical obstructions).
237	18.15	Identify recovery site and perform recovery, including mobile recovery, in various conditions (for example, cold weather, nighttime, hot weather).
238	18.16	Perform FTS (Flight Termination System) site selection.

Task Category 19: Postflight Tasks

239	19.01	Supervise and review post-flight checks, procedures and logs.
240	19.02	Command/monitor AV during auto approach and command AV to land when appropriate.
241	19.03	Complete post-flight checks, logs and reports (for example, maintenance logs, operator flight logs).
242	19.04	Shutdown systems properly by powering down, switching to safe mode or standby mode (for example, Payload Platform, Master Power).
243	19.05	Shut down and secure air vehicle following recovery.
244	19.06	Visually inspect AV, perform maintenance, and repair or requisition damaged parts.
245	19.07	Complete debrief procedures (e.g., crew debrief, AVS log, debrief sheet).
246	19.08	Prepare and distribute postflight reports (e.g., mission reports).
247	19.09	Report incidents according to regulations and current procedures (e.g., deviations from flight rule, loss-of-link).
248	19.10	Retrieve, process, analyze, and archive images and data from AV system.
249	19.11	Check Flight/Mission documentation for completion and accuracy and close flight plan.
250	19.12	Provide mission review and notify external agencies, as applicable.

Task Category 20: Shipboard Tasks

251	20.01	Perform shipboard takeoff or landing.
252	20.02	Enable/Disable the Harpoon.
253	20.03	Communicate with ship Command and Control or other relevant agencies during takeoff/landing.
254	20.04	Divert to shore-based landing as necessary.
255	20.05	Perform Air Vehicle shipboard shutdown.
256	20.06	Evaluate shipboard environmental conditions (for example, ship pitch and roll, surface or deck winds) for launch and recovery.

Appendix B – Rating Scales

Dimension	Definition	Rating scale response options
Importance	The degree to which incorrect performance of the task would result in negative consequences (for example, potential injury to self or others, damage to aircraft or equipment, increased time to complete a mission task).	1= Not important 2 = Slightly important 3 = Moderately important 4 = Highly important 5 = Extremely important
Difficulty to Learn	The degree of difficulty in learning to perform the task successfully and independently, relative to all other tasks performed in training. Difficulty to learn reflects the total amount of time and effort required to learn a task relative to all other training.	1 = One of the easiest tasks to learn 2 = Easier to learn than most other tasks 3 = Approximately half of the tasks are easier to learn and half are more difficult to learn 4 = Harder to learn than most other tasks 5 = One of the most difficult to learn of all tasks
Frequency	How frequently a task is performed over the course of an event with a relatively fixed time period, such as a mission. Frequency reflects the total number of times a task is performed, on average, within a given time period.	1 = Less than once per mission 2 = At least once per mission 3 = 2 – 5 times per mission 4 = 6 – 10 times per mission 5 = More than 10 times per mission C = Almost continuously

Level of Mastery - Qualified Operator	For a **QUALIFIED OPERATOR**, the percentage of time a task must be performed at a high level of mastery, without errors or excessive delays, and without assistance or coaching from others.	Mastery-level performance must be demonstrated: 1 = 0 – 20% of the time 2 = 21 – 40% of the time 3 = 41 – 60% of the time 4 = 61 – 80% of the time 5 = 81 – 100% of the time

Appendix C – KSAO List

KSAO Category 1: Communication Skills

1	**Oral Comprehension**	To understand spoken English words and sentences (for example, information, ideas, or instructions).
2	**Written Comprehension**	To read and understand written English words and sentences.
3	**Oral Expression**	To speak English words or sentences so others will understand; to express information or ideas clearly.
4	**Written Expression**	To write English words or sentences so others will understand; to spell correctly; to write clearly and use language appropriate for the audience.

KSAO Category 2: Conscientiousness

5	**Dependability**	To be responsible, reliable, and punctual; to follow through on commitments.
6	**Rule Abiding**	To respect authority; to follow instructions and orders; to adhere to military rules, standards, and procedures.
7	**Self-Discipline**	To perform difficult, repetitive, or boring tasks while avoiding distractions or alternate activities.
8	**Accountability**	To consider oneself responsible for one's actions; to take corrective actions after making a mistake.
9	**Deliberation**	To be careful, thoughtful, and calculating when planning actions; to avoid impulsive actions; to imagine the possible outcomes of one's actions before acting.

KSAO Category 3: Coping with Stress and Emergencies

10	**Adaptability**	To adjust easily to changing situations or unexpected events; to flexibly change one's actions in response to changing task priorities.
11	**Emotional Control/Stability**	To control one's emotions in stressful situations; to avoid feelings of anxiety, insecurity, depression, or worry.
12	**Stress Tolerance**	To perform effectively under high workload, time pressure, or other stressful situations; to effectively handle stress under demanding situations.
13	**Handling Crisis/Emergency Situations**	To remain calm, analyze the situation, act appropriately, and make quick, accurate decisions in emergency situations.
14	**Disengagement**	To avoid disruptive thoughts after making an error; to quickly refocus attention on a task after a disturbing situation.

KSAO Category 4: Development Skills

15	**Confidence**	To believe that one is capable of performing tasks in a wide variety of situations; to have confidence in one's skills and abilities.

KSAO Category 5: Learning and Memory Skills

16	**Learning Ability**	To be willing and able to acquire new skills quickly and easily; to quickly understand new concepts, ideas, or facts.
17	**Working Memory**	To hold information in memory while processing other information
18	**Long-term Memory**	To retain and recall information (for example, words, numbers, pictures, and procedures) after long time periods.

KSAO Category 6: Mathematical Ability

19	**Mathematical Ability**	To add, subtract, multiply, and divide accurately.
20	**Mental Math**	To perform mathematical operations in one's head quickly and accurately.
21	**Numerical Reasoning**	To reason through math problems to determine the operations that can be performed and possible solutions; to apply mathematical formulas to problems.

KSAO Category 7: Mechanical Abilities

22	**Mechanical Comprehension**	To understand how machines, tools, and mechanical equipment work; to understand how physical forces affect mechanical components.

KSAO Category 8: Motivation

23	**Work Motivation**	To take a genuine interest in work tasks; to be willing to go above and beyond normal role duties; to be hard-working and ambitious.
24	**Initiative**	To initiate difficult tasks without excessive procrastination; to work independently and accomplish tasks without constant supervision; to take personal responsibility for completing work tasks.

KSAO Category 9: Multitasking and Attentional Skills

25	**Concentration/Selective Attention**	To maintain high levels of performance on a task in distracting or repetitive conditions; to maintain focus despite interruptions.
26	**Attention Allocation and Control**	To flexibly switch attention across different tasks; to attend to multiple, potentially conflicting sources of information.
27	**Task Prioritization**	To perform multiple tasks in order of their importance; to direct attention to tasks when they change priorities (e.g., emergencies).

KSAO Category 10: Perceptual and Psychomotor Abilities

28	**Pattern**	To identify or detect a known pattern (for example, a numerical code); to

	Recognition	combine and organize different pieces of information into a meaningful pattern quickly.
29	**Perceptual Speed and Accuracy**	To perceive or compare information (for example, letters, numbers, symbols, or patterns) quickly and accurately; to notice or compare details about things quickly and accurately.
30	**Response Selection**	To choose between two or more possible responses quickly and accurately when two or more different signals are given.
31	**Control Precision**	To control the motion of a machine, vehicle, or piece of equipment (for example, joystick or yoke) quickly and accurately; to make fine, precise movements or adjustments.

KSAO Category 11: Physical and Psychomotor Abilities

32	Manual Dexterity	To make skillful, coordinated movements of the hands; to grasp, place, move, or assemble objects using hand movements.
33	Multilimb Coordination	To coordinate the movements of the body or limbs.
34	Hand-eye coordination	To make precise, coordinated movements based on visual information.
35	Reaction Time	To respond quickly and accurately to one signal with a manual (hand or foot) or verbal response.

KSAO Category 12: Planning and Organizing Skills

36	**Organization Skills**	To schedule and organize one's work activities, materials, tools, and equipment in order to complete tasks efficiently; to keep one's work space neat and tidy.
37	**Time Management Skills**	To manage one's own time and the time of others to accomplish work goals.
38	**Planning Skills**	To carefully plan out the sequence of actions needed to meet short- and long-term work goals.
39	**Attention to Detail**	To pay close attention to the details of one's work; to ensure work is accurate and complete; to carefully review and scrutinize one's work.
40	**Safety Consciousness**	To be aware of safety hazards; to take steps to protect oneself and others from harm; to avoid risky behavior that could lead to accidents.

KSAO Category 13: Problem Solving/Reasoning Skills

41	**Information Management Skills**	To perform research and gather information necessary to solve specific problems; to identify and locate important sources of information (for example, technical manuals).
42	**Systems Comprehension**	To understand a system as a whole and the relationships among its components; to anticipate how changes in one component will affect the system as a whole.
43	**Technical**	To use technical information to identify the source of a problem and

	Troubleshooting	potential solutions.
44	**Critical Thinking Skills**	To analyze the strengths and weaknesses of specific actions or decisions.
45	**Reasoning Skills**	To apply rules to come up with logical answers to problems; to combine separate pieces of information to form general rules or conclusions; to recognize patterns or trends and anticipate outcomes.
46	**Problem Solving Skills**	To recognize problems, their potential causes and solutions, and when they are likely to occur; to create effective and innovative solutions to problems.
47	**Decision Making Skills**	To make effective, confident decisions in a timely manner; to use sound, informed reasoning and avoid bias when making decisions.

KSAO Category 14: Sensation Seeking

48	**Energy**	To feel excitable and energetic; to show enthusiasm when performing work activities.
49	**Adventure Seeking**	To prefer tasks that may involve danger or risks (for example, high speeds); to avoid boring or routine activities.

KSAO Category 15: Sensory Perceptual Abilities

50	**Visual Acuity**	To accurately discriminate details of near or distant objects or objects near the edge of the visual field; to see under low light conditions.
51	**Hearing**	To detect and discriminate among sounds that vary in pitch or loudness.
52	**Smell**	To identify odors and their possible sources.
53	**Touch**	To feel heat, vibration, or textures; to feel differences or changes in heat, vibration, or textures.
54	**Color Discrimination**	To discriminate between different colors and levels of brightness or shades of the same color.
55	**Auditory Attention/Localization**	To focus on a sound in the presence of other distracting and irrelevant auditory stimuli; to tell the direction from which a sound came.
56	**Depth Perception**	To judge the distance of an object from an observer; to judge the relative distance of multiple objects from an observer.

KSAO Category 16: Social/Interpersonal Skills

57	**Interpersonal Skills**	To get along and interact effectively with a variety of people; to be tactful and diplomatic; to build and maintain effective working relationships with others.
58	**Cooperation (formerly Agreeableness)**	To avoid interpersonal conflicts; to reach solutions to problems in a cooperative manner; to avoid upsetting others.
59	**Listening Skills**	To actively listen to and understand others; to attend to verbal and nonverbal cues (for example, body language, eye contact)
60	**Teamwork Skills**	To coordinate with others in a team setting to accomplish group goals; to assist team members who are overwhelmed; to offer and receive

		feedback.
61	**Leadership Skills**	To persuade and influence others to do perform specific actions; to act as a role model for others; to offer instruction and feedback to others as part of a team.
62	**Assertiveness**	To take charge and make decisions; to be persuasive, influential, and direct when dealing with others

KSAO Category 17: Spatial and Navigation Skills

63	**Navigation Skills**	To effectively navigate through an unfamiliar area to a desired location
64	**Spatial Orientation**	To know one's location in relation to the environment; to maintain directional orientation when navigating an unfamiliar area; to accurately estimate direction or location after traveling for a certain amount of time.
65	**Spatial Visualization**	To form a mental image of a pattern or figure; to visualize how an object would look after certain changes are made (for example, when it is moved around or when its parts are rearranged).
66	**Mental Rotation**	To accurately rotate an object (for example, a map) in one's imagination while maintaining an accurate sense of direction.
67	**Map Reading**	To understand a visual representation of an area; to use information from a map to aid in navigation.