International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137

Volume – 09, Issue – 01, January 2024, PP – 72-87

Communication Competencies in the Age of Unmanned Aerial Vehicles (UAVs) Ecosystem

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Abstract: This study sought to identify critical communication competencies in the UAV ecosystem, exploring sectors, sustaining competencies, and essential communication skills**.** This research relied on the "14th Five-Year Plan for General Aviation Development" of China (Unmanned Airspace, 2022) for sector identification, employing textual analysis and validation through online literature searches. Using ChatGPT 3.5, competencies were extracted from original sectors, structured into a matrix, and examined for communication-specific attributes. Thematic analysis facilitated categorization under broader sectors. The study uniquely focused on competencies crucial for communication within the UAV ecosystem, addressing questions regarding sector constitution, competencies for sustainability, and vital communication skills. The comprehensive methodology involved multi-step validation, synthesis, and analysis, ensuring a robust exploration of communication requirements in the UAV ecosystem. Findings revealed six fields within the UAV ecosystem, four major competency categories, and three core communication competencies that can help sustain the UAV ecosystem.

Keywords: Unmanned Aerial Vehicles; UAV Ecosystem; Competencies; Communication Competencies

Introduction

Amid the COVID-19 pandemic, DJI employed Unmanned Aerial Vehicles (UAVs) for disinfectant spraying in Shenzhen, showcasing the versatile applications of drones (DJI Viewpoints Team, 2020). Surveillance drones were utilized by authorities for virus control, contributing to the increased demand for UAVs globally (Martin, 2020). This surge is projected to elevate the UAV market to $6.15 billion, surpassing the 2020 estimate of $3.64 billion (Greenwood, 2021). UAVs, known for their speed, cost-efficiency, and safety, have proven instrumental in diverse sectors. They monitor construction projects, reduce personnel exposure in hazardous environments, facilitate sustainable parcel delivery, aid agriculture with imaging data, and enhance safety in electrical engineering inspections (Rahbar, Selim, &Dweiri, 2023; Saadawi, 2020; Pugliese, Guerriero, &Marcina, 2020; Yui, 2023; Bitancor et al., 2023).

The researcher intends to contribute to UAV development and communication competence, addressing the rising demand for skilled workers in drone design, operation, and management (Changsha, 2023). This need is particularly prominent in China, the leading UAV manufacturer globally (Shih, 2016). The study aims to develop communication competency alongside drone training, aligning with China's estimated requirement for nearly 1 million drone pilots by 2025 (Zhipeng, 2023). The focus on communication skills reflects the evolving landscape of the UAV ecosystem, emphasizing the importance of effective communication in this rapidly growing industry.

History of UAVs

UAVs have a historical origin dating back to the First World War, with Britain's Aerial Target and the US Kettering Bug marking early developments (Imperial Ware Museums, 2023). In the inter-war period, British radio-controlled aircraft and the term 'drone' gained prominence, paralleled by US radio-controlled drones (Imperial Ware Museums, 2023). Significant UAV deployment occurred during the Vietnam War, showcasing varied roles (Imperial Ware Museums, 2023). China, led by DJI, dominates the global consumer market, with over 120,000 registered drones in 2017, surpassing the USA (Wang & Thomas, 2017). Military demand constitutes 70%, followed by the consumer sector (17%) and commercial sector (13%) (Castellano, 2023). The Top 25 global drone manufacturers include six from China, with DJI leading the list (DroneU, 2023). Shenzhen is a key hub, home to over 600 licensed drone manufacturers (Arc Group, 2021). Challenges include public safety concerns and regulatory issues (Arc Group, 2021). Balancing rapid expansion with safety considerations remains a global challenge, with new entrants potentially impacting prices and intensifying competition (Arc Group, 2021).

Types of UAVs

JOUAV (2023) categorizes UAVs into several typologies based on (1) wing types (multi-rotor, fixed wing, single-rotor helicopter, and fixed-wing hybrid VTOL), (2) sizes (nano, small, medium, and large), (3) payload capacity (featherweight, lightweight, middleweight, and heavy lift), (4) range (very close-range, close-range, short-range, mid-range, or long-range), (5) power source (battery-powered, gasoline-powered, hydrogen fuel cell-powered, and solar-powered), (6) abilities and equipment (toy, photography/videography, racing, RTF, GPS, professional, and military), and (7) motors (brushed and brushless). Each type and subtype has specific advantages and disadvantages (JOUAV, 2023).

UAV-related Competencies

Business developers in the UAV industry require competencies in aviation, privacy, security, and organizational culture (McNabb, 2016). UAV professionals are assessed based on technical proficiency, safety and compliance, business acumen, social impact, and professional development (LinkedIn, 2023). UAV engineers should possess a foundation in math, science, and technology-related courses, along with specialized knowledge in UAV technology and related fields (Vault). Pilot training demands cognitive abilities, theory knowledge, flight skills, personality, and interpersonal competencies (Schmidt et al., 2022). Licenses for UAV pilots have specific requirements related to flight experience, aviation knowledge, and theory tests (KaiRong Law Firm, 2020). Other professionals in the drone industry, such as photographers, roofers, and miners, require diverse skillsets (Indeed Editorial Team, 2023). The rise of artificial intelligence and swarm intelligence poses challenges to traditional roles in the industry, suggesting a shift towards autonomous and collective decision-making UAVs (Castellano, 2023; The Economist, in Castellano).

Effective communication is paramount across various competencies in the UAV industry. Business developers must communicate visions, strategies, and values clearly to foster an organizational culture aligned with UAV operations. UAV professionals need strong communication skills to convey technical knowledge, engage with stakeholders, and support social causes, contributing positively to society. In engineering roles, clear communication is essential for collaboration, sharing information, and reporting. UAV pilots rely on communication for effective training, understanding aviation regulations, and ensuring safety and compliance. Furthermore, the advent of artificial intelligence and swarm intelligence underscores the importance of communication in navigating the evolving landscape of the drone industry, fostering collaboration, and adapting to technological advancements. Overall, communication skills enhance collaboration, safety, compliance, and the seamless integration of UAVs across diverse roles in the industry.

Communication in a Sustainable UAV Ecosystem

Building a sustainable UAV ecosystem requires the formation of communication competencies across various talent development sectors. Integrated talent development, as highlighted by Prathima (2022), necessitates collaboration between educational institutions, skills development councils, and the industry to address the skills gap in the UAV sector. Effective communication is crucial for promoting awareness among the youth, expanding UAV applications, and integrating foundational knowledge and skills through hands-on training.

In UAV pilot training, communication skills are vital for conveying theoretical knowledge and ensuring safety and compliance. As the industry evolves beyond piloting roles, higher education institutions must integrate UAV curriculum across disciplines, aligning with the projected growth in value-added services, maintenance, assembly, production, and design.

The UAV ecosystem involves a diverse range of industries, each requiring specific communication competencies. Aerospace, electronics, manufacturing, software development, telecommunications, and more contribute to the UAV ecosystem. Effective communication ensures seamless collaboration and integration across these sectors, fostering innovation, safety, and compliance. In custom drone parts manufacturing, talents with expertise in semiconductor manufacturing, sensors, aircraft hardware, autopilot, and computer processors must possess effective communication skills to drive progress.

Ultimately, the communication competencies developed in talent development programs contribute to the holistic growth of the UAV ecosystem, supporting research, innovation, environmental monitoring, logistics, maintenance, and more. This integrated approach ensures that the UAV industry thrives sustainably, meeting the demands of various sectors and shaping the future landscape of drone technology.

Study Framework

In the UAV ecosystem, Systems Theory elucidates the vital role of communication within the intricate web of interconnected components. This theoretical framework, widely employed in diverse disciplines, conceptualizes the UAV ecosystem as a complex system comprising various industries, sectors, and entities

collaborating for unmanned aerial vehicle development and deployment. "General Systems Theory: Foundations, Development, Applications" by Ludwig von Bertalanffy, published in 1968, is a seminal work in the development of systems theory. It offers a comprehensive overview, emphasizing the interconnectedness of diverse systems. Bertalanffy's groundbreaking concepts influenced the evolution of systems thinking across biology, sociology, and management. Despite being foundational, systems theory continues to evolve, with contemporary literature in specific fields contributing to its ongoing development.

Communication, serving as the linchpin in Systems Theory, is instrumental in fostering seamless collaboration among aerospace engineers, software developers, regulators, manufacturers, and end-users in the UAV ecosystem. Information exchange and feedback mechanisms ensure cohesive functionality and goal attainment. Systems Theory underscores the interdependence of UAV ecosystem components, emphasizing that effective communication facilitates the flow of information across domains like technology development, regulation, logistics, and environmental monitoring. This interconnected communication network enables adaptability to changes and promotes innovation in response to dynamic external influences, aligning with the UAV ecosystem's evolving needs.

Statement of the Problem

This study aims to surface communication competencies that are considered critical in the age of theUAV ecosystem. In particular, this study aimed to answer the following questions: (1) What sectors constitute the UAV ecosystem?; (2) What competencies are required to sustain a UAV ecosystem; and (3) What communication competencies are vital in the different sectors of the UAV ecosystem?

Methodology

First, this study involved the use of the *"14th Five-Year Plan for General Aviation Development"* of China(Unmanned Airspace, 2022) as the source of relevant sectors in the UAV ecosystem literature. This was done through textual analysis. Second, ChatGPT the results were validated by checking available online literature through a Google Search. This was followed by synthesizing the descriptions of the sectors constituting the ecosystem and, through thematic analysis, categorizing them under larger categories that may include more than one sector. Second, the required competencies were sought through ChatGPT per original sector identified. These competencies were organized using a matrix that puts together all the competencies belonging to the emergent composite sector and were synthesized under such. Third, competencies specifically categorized as "communication" were isolated and further analyzed by comparing and contrasting specific competency statements to arrive at an overall understanding of communication competencies required in the UAV ecosystem.

Results

Sectors constituting the UAV market ecosystem

The initial search for sectors in the *"14th Five-Year Plan for General Aviation Development" of China* (Unmanned Airspace, 2022) resulted in 22 initial categories (see Table 1) particularly drawn from specific paragraphs in the document.

Table 1

Sectors of the UAV Ecosystem identified in the "14th Five-Year Plan for General Aviation Development" of China (Unmanned Airspace, 2022)

Paragraph Number	Fields of Practice in the UAV Ecosystem
3	UAV Market-oriented System (A)
	UAV Socialized Service Guarantee System (B)
	UAV Low Altitude Economy (C)
	UAV Application Services (D)
	UAV Agricultural Services (E)
	UAV Industrial Applications (F)
4	UAV Logistics and Distribution (G)
5	Cross-border Integration (H)

6	UAV Certification (I)
7	UAV Legal System (J)
	UAV Promotion (K)
	UAV Safety Documentation (L)
	UAV Registration (M)
	UAV Airworthiness Management (N)
	UAV Personnel Qualifications (O)
	UAV Air Traffic Control Operations (P)
	UAV Market Operations (Q)
8	UAV Supervision (R)
9	UAV Operational Management (S)
10	UAV Airworthiness Management (M)
11	UAV Technology Application Policies (T)

UAV Market-oriented System (A). The concept of a market-oriented system revolves around prioritizing the identification of consumers' needs and desires, and subsequently developing products and services that cater to those needs (Kopp, 2021, para. 1). This system comprises several interdependent sub-sectors, including direct UAV market players (DUMP), suppliers of supporting goods and services (SSGS), and entities that exert influence on the business environment (EEBE) (Technoserve, n.d.). Direct market players, such as producers, buyers (or distributors), and consumers, are instrumental in driving economic activity within the market. SGSS, such as financial institutions, equipment providers, and business consultants, offer the necessary resources to facilitate smooth market operations. Furthermore, EEBE or entities such as regulatory agencies, infrastructure providers, and business associations also play a significant role in shaping the overall business environment.

UAV Low Altitude Economy (C). According to CGTN (2023), "The low-altitude economy covers a wide range of industries focused on both manned and unmanned civil aerial vehicles. The sector includes aircraft manufacturing, low-altitude flight operations, and a suite of related services" (para. 4). Hence, the low altitude economy is a specific market-oriented system defined by more specific players. Using the description of the market-oriented system above, the low altitude economy consists of DUMP composed of (1) producers, buyers, and consumers of low altitude products, particularly UAVs in this context; SGSS or (2) suppliers of goods and services supporting the UAV economy like financial institutions, equipment providers, and business consultants; and (3) EEBE or regulatory agencies, infrastructure providers, and business associations that shape the UAV market ecosystem.

DUMP (Q). Given the above, UAV Market Operations (Q) fall directly under DUMP, performed by producers, buyers, and users. A specific item, UAV Promotion (K), is considered a marketing activity, which is performed by producers (within business-to-business activities) and distributors (wholesalers and retailers) vis-a-vis redistributors and end-users. Market operations or marketing is defined as "the action or business of promoting and selling products or services, including market research and advertising" (Forsey, 2022, para. 1).

UAV Promotion (K). The Economic Times (2024), defines promotions as "the entire set of activities, which communicate the product, brand or service to the user. The idea is to make people aware, attract and induce to buy the product, in preference over others" (para. 1). In paragraph 7 of the *"14th Five-Year Plan for General Aviation Development",* promotion is contextualized as activities that "actively cooperate with and promote the introduction of UAVs". As such, UAV Promotion (K) does not simply involve producers and distributors of UAVs, but also educational institutions that provide the qualified personnel that sustain the low altitude economy. However, educational institutions do not fit well within DUMP, SSGS, or EEBE. Nevertheless, educational institutions that guarantee up-to-standard Personnel Qualifications, identified as 'O' in Table 1, render promotion as larger than what was initially defined by the Economic Times. In an environment where UAV producers are allowed to establish schools advancing the the number UAV professionals,

appreciation, and demand for UAVs, UAV producers can co-opt educational institutions to their agenda. This means that schools promoting UAV can fit within the producer sub-category of DUMP. Users, too, in a landscape of online user-generated content, help promote UAVs to the larger community.

UAV Personnel Qualifications (O). Paragraph 7 of *"14th Five-Year Plan for General Aviation Development"* mentions that "The Provisional Regulations on Aircraft Flight Management, formulate the Regulations on the Safe Operation of Civil Unmanned Aircraft (J) and supporting normative documents (L), and clarify the requirements for the registration (M), airworthiness management (N), personnel qualifications (O), air traffic control operations (P), and market operations (Q) of drones". This means that O falls under EEBE, as well, not just DUMP. Likewise, as schools enable equipment to be operated through its equipment training programs, O easily falls under B.

SSGS (B). A service guarantee is "a marketing tool used to reduce consumer risk perceptions, signal quality, and differentiate a service offering" (Success Tax Professionals, 2024). Additionally, "by delivering service guarantees companies entitle customers to an easy-to-claim replacement, refund or credit, when service delivery fails. Interdependent sectors that ensure that service guarantee is ensured constitute a service guarantee system" (para. 1). A socialized service guarantee system, meanwhile, from a socialized healthcare system perspective (healthinsurance.org, 2024) is a "system in which the government owns and operates… (the service guarantee) facilities and employs… (their) professionals, thus also paying for all… (their) services" (para. 1). Financial institutions were not specifically mentioned in China's *14th Five-Year Plan for General Aviation Development.*

UAV (Application) Services (D) and Logistics and Distribution (G). UAV application include more generally the category UAV Industrial Applications (F), and its sub-category UAV Agricultural Applications (E). Both make use of UAVs for different and specific purposes. Hence, UAV application services (D) refer to activities that ensure E and F in the larger UAV market ecosystem. According to Bernstein (2024) UAV application services aresometimes called 'Drones as a Service', to help sectors such as E and F with tasks such as collecting imagery and measurements and managing or broadcasting events. This renders Logistics and Distribution (G) as an integral part of the UAV (application) services system. Robert (2020) defined logistics and distribution in this manner: "logistics focuses on creating a strategic plan for moving goods, while distribution executes the transportation of such goods using thoughtful strategies" (para. 1).

UAV Industrial Applications (E) and AUV Agricultural Applications (F). Ten areas of application were identified as constituting E, and they are as follows: (1) utilities and power, (2) construction, (3) infrastructure, (4) mining and aggregates, (5) oil and gas, (6) public safety, (7) firefighting, (8) agriculture (F), (9) Military, and (10) Research (Vision Aerial, 2024). It must be noted again that agricultural applications fall under this category.

UAV Supervision (R). Chen, Barnes, and Harper-Sciarini (2010) explained supervision of UAV using the concept of 'supervisory control of technology'. They defined it in the words of Sheridan (2002) "in terms of human information processing and the operator's role in a given task, or from the perspective of the level of automation employed and the types of operator interactions with the automated technology. Humans play a variety of roles in supervisory tasks, including planning, teaching, monitoring, intervening, and learning (p.1). This necessarily involves the use of information technology, both hard ware and software to facilitate better service guarantee.

EEBE (J). Composed of regulatory agencies, infrastructure providers, and business associations (Technoserve, n.d.), EEBE was elaborated more in terms of UAV Certification (I), UAV Legal System (J), UAV Safety Documentation (L), UAV Registration (M), UAV Airworthiness Management (N), UAV Personnel Qualifications (O), UAV Air Traffic Control Operations (P), and UAV Operational Management (S). The EEBE is considered here as J.

Regulatory Agencies. UAV Certification (I), may, at times, go together with testing (UL Solutions, 2024) and other services to facilitate "market access readiness to help with successful access to (manufacturers') desired markets, as well as compiling technical files and other compliance documentation (para. 16). Hence, testing and certification fall under the function of regulatory agents under EEBE. Specifically, this covers product certification, global market access, component certification, EMC (Technologies), functional safety, CRS Labs, 'interoperability, cybersecurity, and performance', hazardous locations, and regulatory assessment.

Meanwhile, UAV Registration (M) includes the passing a UAV flying theoretical test and/or registering as an operator of an UAV (Civil Aviation Authority, 2024). This required before the use of any UAV.

Safety documentation (L) is defined as "not only the results but also the whole UAS safety risk assessment process… to ensure a continuous safety assurance" (Aerotract Geospatial, 2022, p. 2). For manned aircrafts, airworthiness management (N) involved a maintenance program that seeks to ensure that all aircrafts are deemed safe for flights, otherwise called 'preventive maintenance' (Mrusek, Kiernan, & Clark, 2018).

However, this requirement does not yet apply to AUVs. They wrote, "current regulations and requirements… refer only to maintaining airworthiness, with no specific scheduled or unscheduled maintenance practices required" (p.1). However with the rise in safety threats, more stringent requirements based on component reliability are expected to emerge.

UAV Air Traffic Control Operations (or management) (P) is defined as "the dynamic, integrated management of air traffic and airspace (including air traffic services, airspace management and air traffic flow management) – safely, economically and efficiently – through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions" (ICAO, n.d., p. 2). UAV Operational Management (S), meanwhile, refers to "automating and centralizing flight, operations, and compliance" (Drone Deploy, 2024, para. 8). This means that P is a sub-category of S.

Infrastructure Providers. Examples of UAV infrastructure, most important for N or determining airworthiness are airfields of for safe flight testing; hangars or bases with fuel dispensers, meteorology station, radio service, offices and workshops; onsite services such as test pilots, engineers, flight communication officers, flight dispatchers, logistics support, drone video footage and public relations; flight conditions favorable for drone flights; and living amenities (EU Drone Port, 2022). UAV training centers that ensure high quality personnel qualifications (O) are available, make these infrastructure viable and competitive.

The provision of services and facilities favorable to UAVs across all areas make way for Cross-border Integration (H). H focuses on said provisions that decrease integration gaps between bordered areas. "Cross-border integration is seen as a consequence of the emerging opportunities induced by the opening of state borders to free movement of goods, services, capital, and people" (Sohn & Durand, 2020, para. 1) facilitated by cross-state infrastructure providers. Associations that make infrastructures available for N across borders are key.

Table 2
Distribution of low altitude market sectors (based on the "14th Five-Year Plan for General Aviation Development" of China (Unmanned Airspace, 2022) across the UAV low altitude market ecosystem categories

UAV Low Altitude Market System (A and C)

DUMP (Q)			**SSGS (B)**			**EEBE (J)**		
Producers	Buyers	Consumers	Financial Institutions	Equipment providers	Business consultants	Regulatory agencies	Infrastructure providers	Business associations
K	K	K		D	D	I	H	N
P	P	P		E	E	L	N	
O				F	F	M	O	
Legend:				G	G	N		
UAV Application Services (D)	Cross-border Integration (H)	UAV Safety Documentation (L)	UAV Air Traffic Control Operations (P)	R	R	O		
UAV Agricultural Services (E)	UAV Certification (I)	UAV Registration (M)	UAV Market Operations (Q)	O	O	P		
UAV Industrial Applications (F)	UAV Legal System (J)	UAV Airworthiness Management (N)	UAV Supervision (R)			S		
UAV Logistics and	UAV Promotio	UAV Personnel	UAV Operational					

Distribution (G)	n (K)	Qualifications (O)	Management (S)

Competencies required to sustain a UAV ecosystem

Previously, the UAV market was discussed as having three sectors, namely, DUMP, SSGS, and EEBE. Within the UAV ecosystem, the UAV market is just one field among many (UAV Market Field or UMF). Together with the UMF are the UAV Operation Field (UOF), the UAV Regulation Field (URF), the UAV Promotion Field (UPF), the UAV Technology Field (UTF), and the UAV Service Guarantee Field (UGF). Each field is constituted by more particular and interdependent sub-fields.

UMF is a field that brings together four sub-fields (Raw Materials, Manufacturing, Support Services, and Knowledge), with each sub-field requiring relevant competencies. The UOF competencies were established through four sub-fields (Air Traffic Control, Supervision and Service, Operational Management, and Technology Application Policies). The URF competencies were surfaced from six sub-fields (Certification, Registration, Safety Documentation, Airworthiness Management, and Personnel Qualifications. The UPF competencies were mined from four sub-fields (New Aircraft Development, Urban Air Traffic Development, Promotion, and Market Operations). The UTF competencies were built from four sub-fields (Aircraft Manufacturing, Flight Operations, Application Industries, and UAV Support Services). Finally, the UGF competencies were constituted by competencies from four sub-fields (Help Desk and Technical Support Services, Real-Time Online Support, Automated Customer Service Lines, and Automated Support Resources).

ChatGPT3.5 was used to surface the competencies needed per sub-field. The name of the competencies used in this study came directly from the label given by GPT based on specific contexts of practice (sub-fields). Common, similar, and related competencies were clustered under one competency group across the fields and sub-fields. The competencies that appeared most frequently after clustering were considered the most important and baseline competencies that must be developed in students in a UAV school that aims to sustain the UAV ecosystem. Table 3 below lists the competencies per cluster.

Data reveal that there are four major competency clusters. Following the order of decreasing importance, the first cluster named ‘Communication and Transaction Management Competencies’ relates to marketing, stakeholder relations, multi- and interculturality, collaboration and networking, and content production. The most prominent competencies in this sub-cluster were “Communication Skills” and “Teamwork and Collaboration/ Cross-Functional Collaboration/ Collaboration Skills”. The second, coded as ‘Ethics and Quality Management Competencies’ deals mostly with quality control, policy compliance, ethical response to problematic scenarios, and safety assurance which revealed “Ethical/ Legal and/ Regulatory Compliance/ Advocacy/ Awareness/ Ethical and Legal Understanding” as the most dominant competency sub-cluster. The third, ‘Technical, Scientific, and Technological Adaptability and Innovation Competencies’ highlights knowledge of specific content and disciplines, use of technology, adaptability, problem-solving and innovation. It underscored the prominence of the “Continuous Learning/ Training and Education/ Development” competency sub-cluster. Finally, ‘Resource Management Competencies’underscore material, human, and other assets like leadership that help organizations remain viable and effective.This highlighted the “Project Management/ Event Planning and Management” competency sub-cluster.

The data suggest that preparing students for the UAV ecosystem requires more than just knowledge of new technology, how to operate it, and apply it to different fields that are deemed to benefit from it. The prominence of communication indicates that the foundation of education towards better integration within the UAV ecosystem must be firmly grounded on knowledge of the social sciences and humanities since communication draws much of its knowledge from both fields. Ethics and quality management competencies, emerging second, points to the importance of building in students a commitment to follow what is right and good – areas learned mostly in philosophy and religious studies and guiding people beyond industry practice.

Table 3
Competencies across different fields in the UAV ecosystem

Communication and Transaction Management Competencies	Ethics and Quality Management Competencies	Technical, Scientific, and Technological Adaptability and Innovation Competencies	Resource Management Competencies
Sales and Marketing Skills	Quality Control/ Management/ Focus/ Assurance	Technical/Tool/ Knowledge/ Skills/ Proficiency/ Adaptability	Time Management
Supply Chain Management/ Vendor and Supplier Management	Testing and Evaluation/ Validation	Technical Documentation/ and Reporting/ Documentation Management and Records Keeping	Cost/ Financial/ Crew Resource Management
Negotiation Skills/ Sales and			

Negotiation

Market Analysis/ Research/ Awareness/ Knowledge/ Strategy

Communication Skills*

Live Chat Expertise

Remote Support/ Assistance Tools

Customer Service Skills/ Centric Approach/ Focus and Empathy/ User Empathy

Feedback Management/ Customer/ User Feedback Analysis

Customer Retention

Customer Education/ End-User Training/ Training and Support

Community Engagement

Interpersonal Skills

Public/ Government Relations/ Advocacy Skills

Conflict Resolution

Global/ Cultural/ Multicultural/ International Awareness/ Business

Language and Cultural Sensitivity

Multilingual Support

Active Listening

Teamwork and Collaboration/ Cross-Functional Collaboration/ Collaboration Skills*

Networking

Content Development

Visual Design

Attention to Detail

Environmental and Safety Regulations/ Sustainability Practices/ Impact/ Awareness
Safety Knowledge/ Management/ Health and Safety Compliance

Ethical Decision-making

Ethical and Professional Conduct

Risk Assessment/ Management

Emergency Response

Ethical/ Legal and/ Regulatory Compliance/ Advocacy/ Awareness/ Ethical and Legal Understanding*

Policy Development

Research and Development

Product Knowledge

Mechanical Aptitude

Lean Manufacturing Knowledge

Industry Knowledge

Computer/ Digital Literacy

IT/ Security Awareness
Scripting and Programming/ and Coding

Voice User Interface Design/ User Experience Design

CAD and CAM Proficiency

Remote Sensing and Imaging

Integration Skills

Continuous Improvement

Efficiency Optimization

Innovation/ and Technology Adoption

Problem Solving/ and Decision Making/ Skills

Crisis Management/ Emergency Response Planning

Creativity and Innovation and Efficiency/ Adaptability and Innovation

Technical/ Adaptability/ to user Skills/ Technology Changes

Multi-Tasking

Continuous Learning/ Training and Education/ Development*

Mathematical and Statistical Skills
Measurement and Analytics/ Data Analytics

Strategic Thinking/ Operational Planning

Analytical Thinking
Data Analysis/ and Interpretation/ Management

Weather Assessment/ Awareness

Situational Awareness

Pilot Proficiency/ Flight Training

Aircraft Handling/ Remote Sensing ad Imaging Simulation and Training Technology

Navigational Skills/ System Operation/ Traffic Management/ Mapping
Aircraft Systems Knowledge/ Technology Familiarity/ Aerospace Engineering/ Avionics and Systems Integration

Airworthiness Certification

Flight/Mission Planning

Project Management/ Event Planning and Management*

Human Factors Integration

Inventory Management

Leadership Skills

	Mechanical Engineering
	Systems Engineering
	Materials Science and Structural Design
	Aircraft Manufacturing/ Manufacturing Process/ Prototyping and Testing
	UAV Operation and Maintenance
	Urban Planning and Infrastructure Development

Legend: * prominent competencies across the UAV ecosystem fields

Communication competencies vital in the age of the UAV ecosystem

Competencies that were clearly identified by ChatGPT 3.5 as 'Communication Skills' were drawn from all its results and understood in relation to one another.

Communication competencies in the UMF. In the UMF, communication skills were given as: (1) Clear communication with team members, suppliers, and clients; (2) Effective reporting and documentation; (3) Effective communication with team members and management; (4) Reporting on production progress and challenges; (5) Clear and concise verbal communication; (6) Professional written communication in emails, reports, etc.; (7) Ability to convey information effectively; (8) Effective written and verbal communication; (9) Ability to convey complex information clearly.

The highlighted competencies center on effective communication, playing vital roles in professional interactions. Foundational to this is clear communication with team members, suppliers, and clients, ensuring accurate information exchange. The ability to convey complex information aligns with this, representing a more advanced form of communication requiring precision. Reporting and documentation contribute to systematic information recording, crucial for project updates and decision-making. Clear and concise verbal communication, valuable in meetings, complements professional written communication in emails and reports. The combined competency of effective written and verbal communication emphasizes a holistic approach, ensuring comprehensive information conveyance. These competencies are interconnected—clear communication enhances reporting, concise verbal communication complements written communication, and conveying complex information aligns with the overarching theme of effective communication. Altogether, they foster a communicative environment supporting collaboration, informed decision-making, and efficient workflow, highlighting the importance of clarity, conciseness, and precision in professional communication.

Communication competencies in the UGF. In the UGF, the communication skills identified were: (1) Clear and effective communication with end-users; (2) Ability to convey technical information in non-technical term; (3) Clear and concise communication in real-time; (4) Adapting communication style to the user's level of technical understanding; (5) Clear and concise communication through automated prompts; (6) Ensuring that voice prompts are easily understood by users; (7) Clear and effective communication to convey complex technical information to non-technical stakeholders; (8) Developing user guides and documentation for automated resources.

The highlighted competencies revolve around effective communication, especially in technical contexts and end-user interactions. They collectively aim to create a seamless and user-friendly experience, ensuring the clear and comprehensible conveyance of complex technical information. Fundamentally, clear and effective communication with end-users is crucial for a positive user experience, not just transmitting information but ensuring user understanding and ease in navigating technical processes.

Adapting communication style to the user's technical understanding enhances accessibility and avoids confusion, while conveying technical information in non-technical terms makes complex concepts understandable to a broader audience. Clear and concise real-time communication and automated prompts emphasize efficiency without sacrificing clarity in dynamic situations, crucial in automated systems like customer service lines.

The competency of conveying complex technical information to non-technical stakeholders bridges the gap between experts and decision-makers, enabling informed decisions. Developing user guides and documentation for automated resources extends beyond real-time interactions, contributing to long-term user satisfaction and reducing the need for continuous support. Together, these competencies create a cohesive skill set vital for effective communication in technical contexts, emphasizing adaptability, real-time clarity, automation utilization, and accessibility of technical information to diverse audiences.

Communication Competencies in the UTF. In the UTF, ChatGPT enumerated the following communication skills: (1) Effective communication with team members, stakeholders, and regulatory bodies; (2) Documenting design specifications, manufacturing processes, and test results; (3) Effective communication with air traffic control and other aircraft in the vicinity; (4) Clear and concise radio communication to relay important information; (5) Effective communication with team members and clients; (6) Clear reporting of mission results and findings; (7) Clear and effective communication with clients and internal teams; (8) Providing technical guidance in a user-friendly manner.

The competencies detailed here form a comprehensive framework for effective communication across diverse operational facets. At its core, effective communication with team members, stakeholders, and regulatory bodies establishes a vital link for collaboration, understanding, and adherence to standards. This foundational competency is complemented by the structured documentation of design specifications, manufacturing processes, and test results, serving as a lasting reference for internal teams and external entities.

Real-time communication skills, crucial for interactions with air traffic control and other aircraft, emphasize the need for clear and timely exchanges during aerial operations. Clear and concise radio communication, tied to specific nuances, mitigates the risk of misinterpretation during critical missions. This proficiency is intertwined with effective communication with team members and clients, ensuring clarity on project objectives, updates, and expectations. Clear reporting of mission results and findings facilitates the dissemination of key outcomes to internal teams and clients. The competencies collectively contribute to a cohesive communication ecosystem, enhancing operational efficiency and supporting overarching organizational objectives.

Communication Competencies in the UPF. In the UPF, the communication competencies deemed important were the following: (1) Clear and effective communication with internal teams, stakeholders, and regulatory authorities; (2) Presentation skills for reporting on project progress and findings; (3) Clear and effective communication with internal teams, stakeholders, and the public; (4) Engagement with local communities to address concerns and foster acceptance; (5) Clear and effective communication to convey the benefits of UAVs to different audiences; (6) Writing skills for creating compelling promotional materials; (7) Clear and effective communication with internal teams, clients, and industry stakeholders; (8) Presentation skills for conveying complex technical information to non-experts.

The interconnected proficiencies emphasized within the UAV ecosystem highlight the diverse aspects of communication. The fundamental competence of transparent and efficient communication with internal teams, stakeholders, and regulatory authorities forms a collaborative foundation, guaranteeing adherence and comprehension across the different facets of UAV operations. In addition, the ability to present project progress and findings is crucial for conveying intricate technical details in a cohesive manner, providing advantages to internal teams, stakeholders, and regulatory authorities. This expertise also broadens its reach to include the public, promoting transparency, managing expectations, and cultivating positive community relations through engagement with local communities.

Furthermore, the competency of conveying UAV benefits to diverse audiences reflects the importance of tailored messaging, closely tied to writing skills for creating compelling promotional materials. The comprehensive competency of clear and effective communication with internal teams, clients, and industry stakeholders ensures organizational alignment, positive client relationships, and collaboration within the industry. Presentation skills for conveying complex technical information to non-experts contribute to this competency, bridging the gap between technical intricacies and diverse audiences. In summary, these interrelated competencies form a holistic communication framework, showcasing the integrative nature of communication in advancing UAV initiatives across internal collaboration, regulatory compliance, public engagement, and industry partnerships.

Communication Competencies in the URF. In the URF, communication competencies deemed critical were: (1) Clear communication with regulatory authorities, engineering teams, and other stakeholders; (2) Presentation skills for conveying technical information to non-experts; (3) Clear and effective communication with legal stakeholders, clients, and regulatory authorities; (4) Drafting legal documents, reports, and agreements; (5) Clear and effective communication to convey safety procedures and protocols; (6) Writing skills for creating comprehensive safety documentation; (7) Clear and effective communication with UAV owners and operators; (8) Writing skills for preparing communication materials and documentation; (9) Clear and effective communication with regulatory authorities, engineering teams, and stakeholders; (10) Documentation of airworthiness assessments and compliance; (11) Clear and effective communication within the UAV team and with external stakeholders; (12) Use of communication tools and protocols during UAV operations.

The interconnections among specified competencies highlight communication's pivotal role in fostering seamless collaboration, compliance, and safety within the UAV ecosystem. At its core is the foundational

competence of clear communication with regulatory authorities, engineering teams, and stakeholders, forming a transparent and efficient channel for information exchange. This proficiency is essential for effective collaboration and regulatory adherence, bridging the gap between technical intricacies and a broader audience, ensuring internal team alignment and engaging stakeholders with varying technical knowledge.

Clear and effective communication extends to legal stakeholders, clients, and regulatory authorities, encompassing the drafting of legal documents, reports, and agreements. This competency ensures that legal requirements, client expectations, and regulatory compliance are documented, contributing to the overall success of UAV initiatives. Additionally, conveying safety procedures and protocols emphasizes safety's paramount importance, with writing skills for creating comprehensive safety documentation complementing this competency for risk mitigation and regulatory adherence. Communication with UAV owners and operators highlights the need for tailored messaging, with writing skills playing a crucial role in conveying accessible and relevant information. The repetition of clear communication with regulatory authorities, engineering teams, and stakeholders underscores its overarching significance, emphasizing seamless communication processes and the use of communication tools for real-time exchange, coordination, and responsiveness. In summary, these competencies underscore the holistic nature of communication within the UAV ecosystem, forming the foundation for successful initiatives by integrating various skills and ensuring accurate conveyance and understanding across diverse stakeholders, ultimately contributing to the safe, compliant, and efficient operation of UAVs.

Communication competencies in the UOF. In the UOF, the competencies that are considered are as follows: (1) Clear and effective communication with UAV operators and other air traffic control personnel; (2) Coordination with pilots and ground personnel to ensure safe operations; (3) Clear and concise communication with UAV operators, clients, and team members; (4) Ability to convey technical information to non-technical stakeholders; (5) Clear and effective communication with team members, stakeholders, and clients; (6); Provide mission briefings and updates to ensure everyone is informed; (7) Clear and effective communication of technical concepts to non-technical stakeholders; (8) Creation of accessible materials for policymakers and the general public.

The interrelated skills within the UOF underscore the essential function of communication in promoting collaboration, safety, and understanding. The key proficiency of communicating clearly and effectively with UAV operators and air traffic control personnel lays the foundation for well-coordinated and secure UAV operations within airspace. This foundational skill is intricately connected to coordinating with pilots and ground personnel, highlighting the necessity of smooth communication among all participants. This connection emphasizes the importance of preventing conflicts, adhering to safety protocols, and ensuring the overall safety of UAV operations.

Another versatile competency is clear and concise communication with UAV operators, clients, and team members, accentuating the importance of tailored messaging for diverse stakeholders. The ability to convey technical information to non-technical stakeholders is intricately connected, emphasizing the necessity of translating complex concepts into accessible language. Expanding the communication spectrum, the competency of clear and effective communication with team members, stakeholders, and clients underscores the significance of transparent and collaborative interactions. Providing mission briefings and updates reinforces the need for timely and informative communication to keep everyone well-informed and aligned with mission objectives. Moreover, the competency of clear and effective communication of technical concepts to non-technical stakeholders highlights the importance of bridging the knowledge gap, with a specific focus on creating accessible materials for policymakers and the general public. In summary, these interrelated competencies collectively depict the multifaceted nature of communication within the UAV operational context, addressing safety, collaboration, and understanding across technical and non-technical audiences for the successful integration of UAVs into airspace activities.

Figure 1
Word cloud representation (from www.jasondavies.com/) based on competency statements classified by ChatGPT3.5 as "Communication Skills"

Core Communication Competencies. The core communication competencies distilled from the cumulative list encompasses several crucial aspects.

Transmission of information and cultivation of a transparent and comprehensible communication environment. Firstly, there is a proficiency in clear and effective communication, ensuring a shared understanding among UAV operators, team members, stakeholders, and clients. This involves not only the transmission of information but also the cultivation of a transparent and comprehensible communication environment. Additionally, the competencies extend to coordination and collaboration, emphasizing the facilitation of seamless communication and teamwork among UAV operators, air traffic control personnel, pilots, and ground teams to ensure the safety and efficiency of operations.

Message customization according to specific target audiences. Furthermore, the ability to tailor messaging emerges as a significant competency, demonstrating the aptitude to communicate clearly and concisely while adapting styles to suit the diverse needs of both technical and non-technical audiences. The competency set also includes providing timely updates and mission briefings, ensuring that all relevant parties remain well-informed and aligned with mission objectives.

Making complex technical information more accessible. Lastly, there is a crucial competency related to the translation of technical concepts. This involves the skillful communication of complex technical information to non-technical stakeholders through accessible materials, fostering understanding and garnering support. Together, these core competencies form a robust foundation for successful communication within the UAV operational context, prioritizing safety, collaboration, and mutual understanding across various stakeholders.

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