# UAS Crew Resource Management and Communication

**Session Time:** Three, 50-minute sessions

## DESIRED RESULTS

### ESSENTIAL UNDERSTANDINGS

Effective communication before, during, and after a flight is essential to safe and efficient drone operations.

Even when operating as a single person crew, drone pilots should apply the principles of crew resource management (CRM) to ensure safe and efficient operations.

### ESSENTIAL QUESTIONS

1. What are the different roles on a UAS crew and how should they interact to ensure safe operations?
2. How can UAS crews manage their resources for safe and efficient operations?

### LEARNING GOALS

**Students Will Know**

- Common crew positions and their roles in a multi-person UAS crew.
- Basic principles of crew resource management.
- Key principles of effective communication.

**Students Will Be Able To**

- *Identify* the various members of a multi-person drone crew and explain their roles. [DOK-L1]
- *Determine* the crew and external resources to consult to ensure a safe and efficient operation. [DOK-L2]
- *Explain* the key elements of effective communication in a UAS operation. [DOK-L2]

## ASSESSMENT EVIDENCE

**Warm-up**
Students will identify and reflect on everyday risks and risk mitigation.

**Formative Assessment**
will task students with a mission exercise to contextualize the discussed concepts.

**Summative Assessment**
will provide students with questions to check retention of the discussed concepts.

## LESSON PREPARATION

## MATERIALS/RESOURCES

- UAS Crew Resource Management and Communication Presentation
- UAS Crew Resource Management and Communication Student Activity 1
- UAS Crew Resource Management and Communication Student Activity 2
- UAS Crew Resource Management and Communication Teacher Notes 1
- UAS Crew Resource Management and Communication Teacher Notes 2

## LESSON SUMMARY

Lesson 1: Preflight and Maintenance
**Lesson 2: UAS Crew Resource Management and Communication**
Lesson 3: Handling Emergencies
Lesson 4: Human Factors and ADM

The lesson will begin with a basic discussion of CRM and crew roles and will explain who is responsible for a flight when an operation consists of more than one crewmember.

Next, the lesson will examine auxiliary factors such as crew communication and phases of flight, as well as best practices for radio transmissions among crewmembers.

Finally, the lesson will discuss operational procedures and offsite resource management, in addition to the similarities and differences between manned and unmanned navigation.

## BACKGROUND

Crew resource management, or CRM, is an important factor in safe UAS operations. It applies regardless of whether the pilot-in-command (PIC) is operating alone or with supplemental crewmembers and encompasses personnel, data sources, and operational practice. Failure to manage personnel and resources properly could result in the loss of a UAS, injury to persons, damage to property, legal repercussions such as certificate forfeiture, or loss of potentially confidential data in the case of a flyaway. Because the PIC is ultimately responsible for the operation, it is imperative that in every phase of flight—from preflight to postflight debriefing—drone pilots adhere to effective CRM techniques.

## MISCONCEPTIONS

CRM is a means of managing and reducing the risks associated with flying. It applies to both manned and unmanned aircraft. The essence of crew resource management involves effectively using all the tools available, including crew members and outside resources, to improve decision making, reduce errors, alleviate stress, and promote safe operations. It is a common misconception that CRM applies only to multi-person crews. In fact, CRM also applies to single-person crews, in which case it is sometimes referred to as SRM, or single-pilot resource management.

Students may also think of communication as something that happens exclusively during the UAS operation (for example, when the visual observer and PIC exchange information during the flight). In reality, communication is a process that should begin long before the flight or operation, with appropriate planning discussions among crewmembers and, when necessary, with other authorities or stakeholders, such as air traffic controllers, venue operators, event planners, clients, or neighbors.

## DIFFERENTIATION

To prepare students for the EXPLORE and EVALUATE sections, give them an opportunity to practice preflight briefings, identify hazards, and make operational decisions using scenarios. Model how to do this for students and set up stations for them to practice in teams if time permits.

To aid student comprehension in the EVALUATE section, take a few minutes to present some scenarios related to operational decision making. If needed, use some of the scenarios described in the article "Confidential Drone Pilot Confessions" to present to students as you review slide 27.

## LEARNING PLAN

### ENGAGE

**Teacher Material:** UAS Crew Resource Management and Communication Presentation

**Session 1**

**Slides 1–3:** Introduce the topic and learning objectives of the lesson.

**Slide 4:** Conduct the **Warm-Up**.

**Warm-Up**

Ask students the following questions. Answers will vary widely.

- What kinds of risks do you face in your daily lives, when driving or riding in a car or bus?
  *Answers might include traffic accidents or car breakdowns.*
- How do you manage these risks?
  *Answers might include adopting safe driving practices such as following the speed limit and proper vehicle maintenance.*
- What kinds of resources do you have available to help manage these risks?
  *Answers might include mechanics, warning lights, and so on.*

When driving a car, there is always the risk that you could experience a mechanical failure, run out of gas, or be in an accident. Drivers manage those risks by doing things like performing regular maintenance on their vehicles to ensure they are operating correctly, keeping an eye on their gauges to make sure fuel levels and oil pressure are adequate, and following speed limits and traffic signs to reduce the risk of being in an accident.

Drivers may feel that they are performing all these risk-mitigation activities on their own. In fact, they are taking advantage of many different resources. These include a mechanic who performs maintenance, the equipment inside the car that signals when the tire pressure is low or the oil is too hot, rules of the road that set out correct procedures, traffic lights and speed limit signs, and even law enforcement officers. Resources like these help the driver and promote safety.

[DOK-L1; *identify*]

### EXPLORE

**Teacher Material:** UAS Crew Resource Management and Communication Presentation

**Slide 5:** Risk management is a key element of any flight operation and is the responsibility not only of the pilot-in-command (PIC) but also of the entire crew in a multi-person operation. The illustration on this slide is from the FAA and

shows the risk management decision-making process. A future lesson will discuss risk management in much greater detail.

For now, it is enough for students to understand that the FAA has created a framework for managing risks and that one element of managing risks is making the most of your team using Crew Resource Management, or CRM. Whether the UAS operation involves a crew of one (the PIC) or a much larger crew including visual observers and one or more people to manipulate the controls, you can use CRM to help ensure a safe operation.

**Slide 6:** Ask students the following question.

**Questions**

Why might it be useful to have a framework to manage risks?*Example responses:*

- *Provides structure to help ensure nothing is overlooked.*
- *Provides commonly accepted standards for what to do and how to do it.*
- *Helps simplify complex operations.*

## EXPLAIN

**Teacher Materials:** UAS Crew Resource Management and Communication Presentation, UAS Crew Resource Management and Communication Teacher Notes 1
**Student Material:** UAS Crew Resource Management and Communication Student Activity 1

**Slide 7:** CRM is a set of ideas that revolve around effectively using the crewmembers and all other resources available to them. Typically, these ideas and principles apply regardless of whether the crew is composed of one individual or multiple crewmembers.

In the case of a single-person crew, these principles may be referred to as SRM, or single-pilot resource management. These concepts were originally developed for manned operations but are equally valid for UAS applications. For brevity, this lesson will use the term CRM to refer to both single-person crews and crews with multiple members unless otherwise noted.

**Slide 8:** To understand CRM, it is important to recognize the roles of a UAS crew in a typical operation.

To check initial knowledge, ask the following question. Examples are given, but supply additional answers at your discretion. The subsequent slides will cover crewmember roles in more detail.

**Questions**

What roles might be included in a UAS crew?

*Pilot-in-command (PIC), visual observer (VO), supplemental pilot, mission commander, mission system operator*

**Slide 9:** Every UAS operation will have a pilot-in-command (PIC). In simple operations, the PIC may be the only member of the crew. PICs must meet FAA requirements because they are wholly responsible for the flight and maintain authority over the operation. Requirements include holding a Part 107 certificate if the operation is commercial.

**Slide 10:** Some operations, particularly more complex ones, may use a visual observer (VO) as a safety measure or as a requirement of flying under an FAA-issued waiver. In some cases, such as busy airspace (assuming authorization) or populous areas of operation, operations may require more than one VO. The VO is responsible for ensuring the UAS remains in visual line of sight (VLOS) at all times. When using multiple VOs, it is good practice to have one VO watching the aircraft while others scan the airspace for traffic or obstacles.

**Slide 11:** Under the Federal Aviation Regulations (FARs), Part 107.31 states that, "With vision that is unaided by any device other than corrective lenses, the remote pilot-in-command, the visual observer (if one is used), and the person manipulating the flight control of the small unmanned aircraft system must be able to see the unmanned aircraft throughout the entire flight."

**Slide 12:**

Much like a copilot of a manned aircraft, a supplemental pilot may assist with secondary functions of the aircraft, such as telemetry monitoring, camera operation, and inflight route planning, or may operate the aircraft for the duration of the mission. Responsibilities will vary based on the needs of the PIC, the operational requirements, and the complexity of the UAS.

**Teaching Tips**

The PIC is responsible for the aircraft and operation in all cases and crew configurations, even if the PIC is not operating the UAS directly at any point.

In summary, the PIC, VO, and supplemental pilot are the most common roles. The next slides will discuss less common roles.

**Slide 13:** In complex operations, a crew may include a mission commander (MC). The MC is generally responsible for ensuring that the crew is adequately staffed, trained, and prepared, and that participants are briefed. The MC performs a key planning and oversight role and will typically work closely with the PIC to ensure all operational needs are met. This can include mapmaking, photo planning, scheduling, and more.

**Teaching Tips**

The MC may or may not be on site during the operation. Regardless of whether the MC is present, the PIC maintains full authority and responsibility for the flight.

**Slide 14:** If the UAS is carrying specialized equipment, a mission systems operator (MSO) may be part of the crew. This individual may be charged with operating that equipment or payload and processing the data or telemetry it gathers.

This could include stitching photos together in real time, performing photogrammetry (surveying), or operating a thermal imaging system. MSO is not a mandatory role, but this individual can help ensure the operation meets the required mission goals by assuming responsibility for specialized tasks, which enables the required crew members to focus on other factors of the operation.

**Slide 15:** It is possible to conduct operations with only a PIC, but most operations use a VO. This allows for a greater deployment range and reduces the workload of the PIC while maintaining VLOS requirements. When a crew includes a VO, the PIC can focus on operating the aircraft and the ground control station while the VO focuses on maintaining a visual line of sight.

**Session 2**

**Slide 16:** Communication is critical before, during, and after any operation. Throughout the operation, crew members must share information in a practiced, clear, and concise manner.

A good way for senders of information to ensure positive receipt is request participants to read back instructions; asking recipients to repeat transmissions they hear, whether they are direct verbal statements or transmitted via radio or other means.

Crewmembers should establish communication procedures to be used during an operation before a flight begins. When operations include a Mission Commander, this individual may be responsible for managing some transmissions or recording them for transcripts in the flight records.

**Slide 17:** Preflight briefings should contain information that could be relevant to the safety of the operation, such as the operating environment, weather, obstacles, airspace, and other factors that contribute to flight safety. It should also include an overview of the objective(s) of the operation.

Finally, the preflight briefing should lay out the roles and locations of all crewmembers, standard operating procedures, and any emergency procedures that might be required.

**Slide 18:** Before an operation, all crew members should be trained for their roles, such as airspace scanning and verbal obstacle redirection in the case of a VO or UAS operation in the case of a supplemental pilot. If the operation will use radios, it is important that crew members check radio frequencies for clear reception and clarity to mitigate the possibility of interference. They should also select emergency backup frequencies prior to the flight.

**Slide 19:** As in manned operations, using standard phraseology is key to successful communication and CRM. In most cases, crew members should be close enough to one another that everyone can speak freely and be heard, while allowing for enough space to effectively conduct their responsibilities under their given role.

In some cases, such as long-range operations or those in which the crew is positioned at different vantage points, radio communication may be necessary to maintain clear contact. Radio frequencies should be periodically checked for clear reception and clarity, and the emergency backup frequencies selected during preflight should also be readily available to the crew if a primary channel fails.

When using radios, remember that only one transmission can be heard at a time, and communications can quickly become garbled if radio operators are “stepping on” one another’s transmissions. Keep communications professional and “chatter” to a minimum to help ensure a safe operation.

**Slide 20:** In manned flight, the nose of the aircraft is used to determine reference direction. For example, “12 o’clock” means straight ahead of the aircraft, and “9 o’clock, high” means above and to the left of the aircraft. In UAS operations, the PIC is the reference point. Therefore, “12 o’clock” refers to the direction the PIC is currently facing.

In any case, crew members should agree on terminology during the preflight phase of the operation. The FAA’s Pilot Controller Glossary contains preferred language throughout aviation. This is updated often and can be found on the FAA’s website.

**Teaching Tips**

FAA’s Pilot Controller Glossary (Current as of 1/26/2020)
https://www.faa.gov/air_traffic/publications/media/pcg_8-15-19.pdf

Example UAS terminology between PIC and VO
Examples of phrases from https://www.dronepilotgroundschool.com/visual-observer/ for a VO and PIC are shown below:

VO Phrases

- "Approaching distance limit"—To be used when the VO is in danger of losing their line of sight with the drone.
- "Distance is a go"—To be used when the PIC has moved the drone back into a range where the VO can comfortably observe it.
- "Cannot locate"—To be used when the VO loses sight / cannot locate the drone (the latter in response to the PIC's command "Locate drone").
- "Bring it down!"—To be used when the VO determines there is imminent danger and the drone needs to be grounded immediately.
- "Climb, climb, climb!"—To be used when the PIC needs to climb immediately to avoid an imminent collision.

PIC Phrases

- "Preparing to launch"—To be used when the PIC is preparing to launch.
- "Launching"—To be used when the PIC is launching.
- "Descending"—To be used when the PIC is descending for a landing.
- "Landing at new position"—To be used when the PIC is manually flying to a position that is not the original home position.
- "Locate drone"—To be used when PIC loses visual contact with the drone.
- If either the VO or the PIC cannot locate the drone visually for a period longer than approximately 15 seconds, the PIC should initiate the Failsafe Return to Home function of the drone and alert all observers that they have done so.

**Slide 21:** Postflight briefings can prove valuable and are an important factor of CRM. Discussing what went well and what did not during an operation can help optimize mission flow in the future, mitigate risk, and contribute to overall team cohesion.

**Slide 22:** Crew members should assume that there is always something that could have been done better, and it is important to remember that room for improvement and mission success are not mutually exclusive. Self-assessment is key to ensuring a high degree of professionalism in missions.

Even the Blue Angels, the U.S. Navy's demonstration team, engage in thorough debriefings following each performance. During these debriefings, they both admit the things that went wrong (or could have gone better), as well as the elements of the performance that went well.

"Blue Angels Debriefing" (Length 4:13)
https://video.link/w/PB11

For teachers unable to access Safe YouTube links, the video is also available here: https://youtu.be/bFGL04LiMgc

**Slide 23:** Most UAS require radio communication between the ground control station and the UAS. Typically, the bands UAS use are 2.4 and 5.8 GHz, which are the same frequencies most wireless networks use. In areas with a high density of these signals, such as heavily populated areas like office buildings, apartments, and various metropolitan areas, this can create an interference hazard.

Some UAS split image and flight transmission between the two bands or use automatic switching to minimize this risk. A frequency spectrum analyzer can scan the airwaves and enable UAS operators to make an informed decision

regarding the least crowded frequency in those bands. Some UAS have this scanning feature built into the software of the ground control station (GCS).

**Teaching Tips**

Some frequencies require an FCC license to use. More information on licensing can be found here: www.fcc.gov/licensing-databases/licensing

**Slide 24:** Flyaways and lost links are relatively common problems with UAS. High-end UAS have programming that will trigger one of several different failsafe methods—which the operator can select—if the link is lost. More inexpensive models may simply land in place, hover, return to the takeoff point, or begin some other procedure.

Regardless of the model, it is important that operators know how the UAS being operated will behave in such a situation and to familiarize themselves with any related failsafe settings available.

**Slide 25:**

Complete the **Formative Assessment**.

**Formative Assessment**

Provide students with **UAS Crew Resource Management and Communication Student Activity 1**. Have students work in teams of three or more to propose a UAS mission. In Section 1, students will sketch a flight plan and the mission area. In Section 2, students will lay out the roles and responsibilities of each crew member. In Section 3, students will list at least two hazards they may face on the proposed mission and their location on the sketch. In Section 4, students will compose a short preflight briefing for the mission. Sample answers are provided on **UAS Crew Resource Management and Communication Teacher Notes 1**.

[DOK-L2; *determine*]

## EXTEND

**Teacher Material:** UAS Crew Resource Management and Communication Presentation

**Session 3**

**Slide 26:** CRM involves more than just crewmembers; it includes the resources available to the crew as a whole. Before flight, the crew should determine how to conduct the operation safely and legally. Resources may include weather forecasts and current conditions, navigational charts, air traffic control, local law enforcement, local ordinances in the operational area, regulatory sources such as the FAA, and information on the UAS from the manufacturer.

These resources enable the PIC to ensure that issues such as visibility, obstacles, operational limits of the UAS, and applicable laws are taken into account before commencing an operation.

**Slide 27:** During a flight, ambient conditions such as the weather may change, or the operation can encounter moving hazards, such as people walking below, air traffic, other UAS, or birds.

To address emerging issues, crew members need to use all available resources. For example, they can use air traffic control to communicate with manned aircraft; UAS equipment, such as an onboard cameras, to assist in visual assessment; and automated systems on the UAS, such as autopilot, obstacle avoidance, hover, or return-to-home, to allow the crew to shift their attention to an emerging hazard.

## EVALUATE

**Teacher Materials:** UAS Crew Resource Management and Communication Presentation, UAS Crew Resource Management and Communication Teacher Notes 2
**Student Material:** UAS Crew Resource Management and Communication Student Activity 2

**Slides 28–41:** The questions on these slides resemble actual questions on the FAA exam. Review the questions and answers with students.

**Slide 42:** Conduct the **Summative Assessment**.

**Summative Assessment**

Provide students with **UAS Crew Resource Management and Communication Student Activity 2**. This scenario-based individual assessment will ask students to make operational decisions and determine whether the given situations constitute no-fly conditions, and if so, what could be used to make the operation safe. Sample answers are provided on **UAS Crew Resource Management and Communication Teacher Notes 2**.

[DOK-L2; *explain*]

**Summative Assessment Scoring Rubric**

- Follows assignment instructions
- Postings show evidence of one or more of the following:
    - Demonstrates knowledge of phases of flight planning
    - Provides details about crew member roles and responsibilities in different phases of flight
    - Provides explanation of best practices for communication and planning.
- Contributions show understanding of the concepts covered in the lesson
- Contributions show in-depth thinking including analysis or synthesis of lesson objectives

| Points | Performance Levels |
|---|---|
| 9–10 | Thoroughly assess each scenario to determine whether or not the given operation can be executed safely conducted as-is. Correctly uses the CRM techniques to make the operation safe as needed. |
| 7–8 | Sufficiently assesses each scenario to determine whether or not the given operation can be executed safely conducted as-is. Uses the CRM techniques to make the operation safe as needed. Some gaps in understanding is evident. |
| 5–6 | Assess each scenario partially or incorrectly. Uses the CRM techniques incorrectly. |
| 0–4 | The student does not appear to understand the lesson objectives. |

## GOING FURTHER

**Slide 43:** Have students research United Flight 232, a flight that resulted in the widespread adoption of CRM by airlines. As a class, discuss the following questions. Particular answers are not necessary, but examples are given to guide the discussion.

- What lessons did airlines learn as a result of this accident, and how might those lessons apply to UAS operations?
  *This event is widely considered to reflect good CRM because the captain fielded the concerns of the crew. Before the*
  *1970s, the captain of the aircraft was considered the expert and not to be questioned.*

- How could this approach to crew cooperation become even more important in the future, as the number, type, and variety of drone operations increases?
  *As UAS platforms develop new capabilities and flight characteristics, more specialized skills may be required.*
  *In addition, flight data and expertise will grow as UAS systems become more widespread, enhancing CRM abilities.*

- What could be added to the current approach to CRM in regard to UAS?
  *Students could suggest additions such as recording preflight briefings or keeping specialized logs of every operation.*

Consider also sharing with students this article about team building, from AOPA's website: https://www.aopa.org/news-and-media/all-news/2019/february/pilot/turbine-pilot-team-building-in-the-cockpit

## STANDARDS ALIGNMENT

### COMMON CORE STATE STANDARDS

- **RST.11-12.2** - Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- **RST.11-12.4** - Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11–12 texts and topics*.
- **WHST.11-12.6** - Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.
- **WHST.11-12.8** - Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
- **WHST.11-12.9** - Draw evidence from informational texts to support analysis, reflection, and research

## REFERENCES


FAA's Pilot Controller Glossary (Current as of 1/26/2020)
https://www.faa.gov/air_traffic/publications/media/pcg_8-15-19.pdf
Example UAS terminology between PIC and VO
https://www.dronepilotgroundschool.com/visual-observer/
FCC Licensing
www.fcc.gov/licensing-databases/licensing
Team Building
https://www.aopa.org/news-and-media/all-news/2019/february/pilot/turbine-pilot-team-building-in-the-cockpit
ASA 2019 Remote Pilot Test Prep
https://www.dronepilotgroundschool.com/visual-observer/
https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/media/remote_pilot_study_guide.pdf

https://www.cfinotebook.net/notebook/aeromedical-and-human-factors/crew-resource-management
"Blue Angels Debriefing" (Length: 4:13): https://video.link/w/PB11