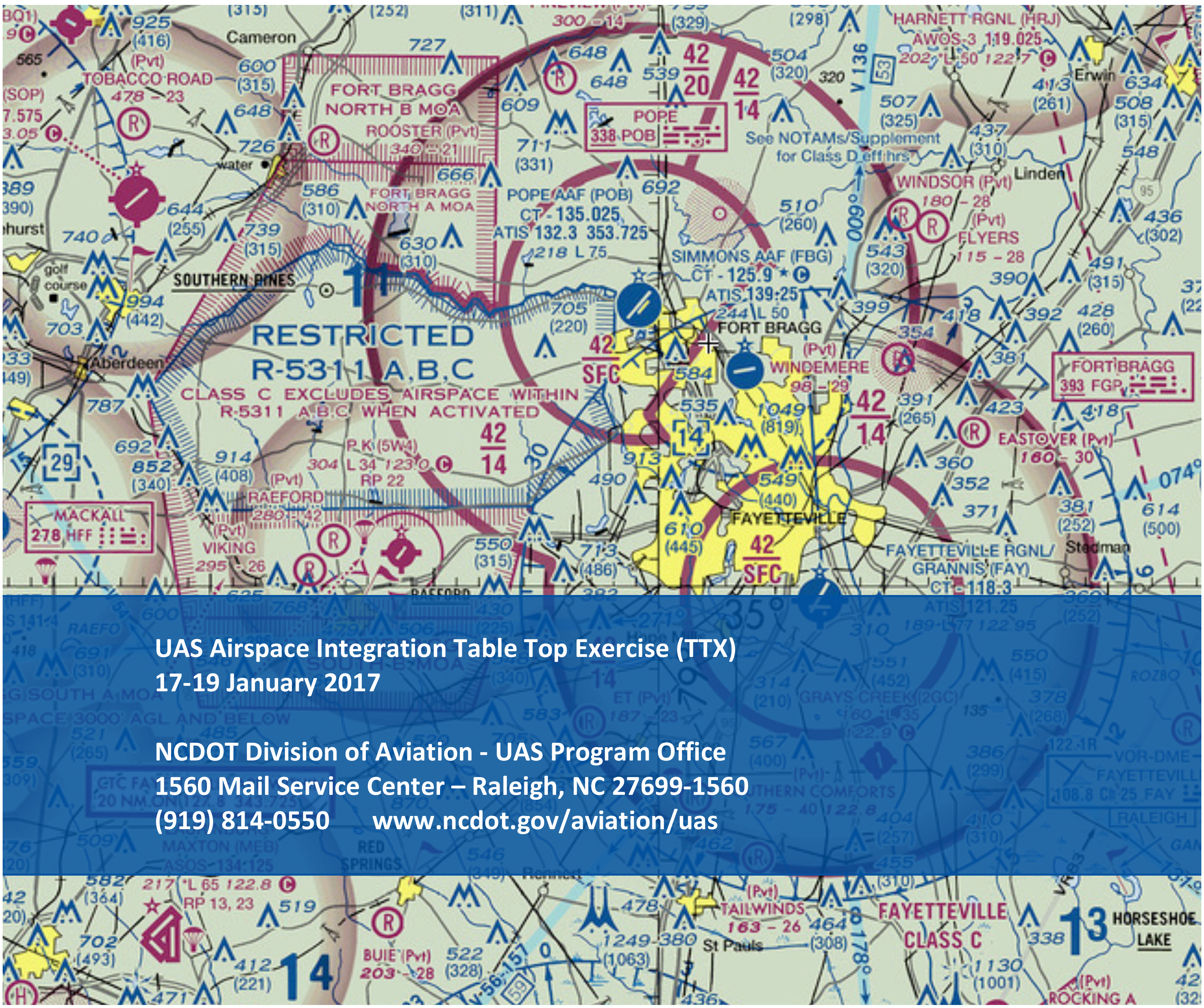
FINAL REPORT

NORTH CAROLINA

UAS AIRSPACE INTEGRATION EXERCISE



UAS Airspace Integration Table Top Exercise (TTX)
17-19 January 2017

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Executive Summary

The North Carolina Department of Transportation (NCDOT) sponsored the Airspace Integration Table Top Exercise (AI TTX) conducted from 17 – 19 January at the Raleigh Critical Public Safety Facility, Raleigh, NC. The TTX was planned and executed by the North Carolina State University's NextGen Air Transportation (NGAT) Consortium. This exercise was designed to support the transition of Unmanned Aircraft Systems (UAS) capabilities into disaster response preparedness planning, identify command and control requirements, provide potential users with situational experience with UAS, and provide test cases for evaluating policy and regulations related to UAS management at the state level.

While the TTX used emergency management scenarios to provide context and realism to the planning, policy and procedures development, the primary focus of the TTX was to identify and develop solutions for airspace integration challenges that can arise when a combination of manned and unmanned aviation assets or simply multiple unmanned aviation assets are to be used in a dynamic event such as an emergency response scenario. Manned and unmanned aircraft are both tools that have immense value in these types of operations, however making sure that the use of these tools is properly coordinated is of utmost importance to ensure that operations are conducted effectively and safely. The TTX focused on understanding the airspace integration challenges to enable UAS as a new capability to assist NCDOT, law enforcement, fire and rescue, and emergency managers in response operations during a major flood event, such as Hurricane Matthew. It served to support the safe and responsible integration of UAS into the National Airspace System for use by public agencies across North Carolina.

Exercise play concentrated on the potential use of UAS towards mitigating the damage, personal injuries, risk and vulnerability of two communities (Cumberland and Moore Counties) to large-scale flooding from Hurricane Matthew. The Raleigh Critical Public Safety Facility afforded an excellent locale for local, state and industry experts to gather and partner in an informal setting while providing an effective venue to assess the potential for select technologies to aid in disaster response. A demonstration of UAS technology applicable to the TTX scenarios was conducted at NC State's Lake Wheeler facility.

The AI TTX was designed around seven exercise play objectives as follows:

1. Examine airspace integration issues when UAS are operated in the National Airspace System (NAS) with manned aircraft and other unmanned aircraft.
2. Develop policies and procedures to ensure the safe use of airspace while responding to natural and man-made disasters.
3. Use actual flooding and disaster response experience collected during the aftermath of Hurricane Matthew as the ground scenario basis to examine UAS operations.
4. Examine how to best employ UAS to assist public safety officials during dynamic disaster events.
5. Examine the potential to integrate UAS into standard Search and Rescue (SAR) airspace management operations.
6. Develop guidelines for private and commercial UAS use in disaster response and recovery.
7. Examine and evaluate the draft UAS Best Practices.

Additional objectives for the TTX included:

1. Provide a stimulating environment for technical, organizational, and operational specialists to explore and discuss a wide range of issues regarding the employment of UAS in disaster and emergency response applications.
2. Develop insights and recommendations concerning the prospective operational utility, or drawback, of UAS technology in public safety applications.
3. Expand the understanding of how availability of UAS technologies may impact disaster preparation activities, such as crisis response planning and organizational coordination.
4. Identify the technical, regulatory, political, and organizational obstacles that currently constrain the use of UAS in public safety applications.

This TTX was the first of a series of exercises which is designed to assemble experts from multiple perspectives to evaluate UAS technologies, operational implications, and the general potential for unmanned systems to play expanded and beneficial roles in a broad range of domains. The AI-TTX provided each participant with an opportunity to contribute their expertise and experience and team with other experts to apply unmanned technologies in an integrated airspace operational context.

Participants received orientation and information briefings on commencement of the event and subsequently engaged in three successive exercise scenarios. In each scenario guidance was provided, responsive actions plans were planned, UAS operations were "played out," and observations were recorded. Scenario outcomes were debriefed by each group to explore observations, issues, and insights generated by the scenario. A final discussion session was held to promote participant open discussion and encourage participant feedback.
During the UAS Live Demonstration, the aircraft was effective at identifying a lost hiker, but the demonstration system was not designed to share the location coordinates between the search system and the surrogate rescue chopper. In an operational scenario, the rescue helicopter or ground search team would have used the target coordinates from the UAS search imagery to direct resources to missing person. The demonstration was successful at applying the policies and procedures defined in Scenario 1 for airspace coordination and operational communications to provide effective deconfliction and efficient operations. Lessons learned from the demo will help the production team to better design future TTX demos for airspace integration and focus on improving search and rescue efforts and effectiveness. The demo was also the first time many of the participants had seen UAS mission operations in action, not just a flight demonstration. This opportunity resulted in a much more tangible understanding of UAS capabilities, airspace integration complexity, and the role of UAS in the Incident Command data structure.

The exercise produced several key findings and recommendations that support the immediate, safe integration of UAS into the National Airspace System and will make our state public safety agencies more effective as UAS operations become more routine. Specific guidance regarding standard operating procedures and policies for UAS use during emergency response was established after reviewing a generic set of UAS best practices. Communications protocols and requirements were also identified. The need for standardized training and establishment of UAS qualifications for types of missions and agency expectations was a consistent theme during data analysis. The live demonstration also served to scope FTX (Field Training Exercise) recommendations for more extensive examination of UAS employment and integration. Ultimately the combination of the classroom discussions and the live operations provided the experience, data, and collective consensus that manned aircraft and unmanned aircraft can safely and responsibly share local airspace in emergency response scenarios with the proper procedures, communications, and staff. We believe the AI TTX objectives were met through the active efforts of the principal participants and our support team. The exercise participants, observers and facilitators gained valuable insights and an enhanced understanding of the potential positive impact and challenges of employing unmanned systems in public safety operations. All participants expressed appreciation and positive impressions of NCDOT for inclusion in this event and agreed we should continue doing this type of engagement.

1 Airspace Integration Table Top Exercise (AI TTX) Introduction and Background

The North Carolina Department of Transportation (NCDOT) sponsored the Airspace Integration Table Top Exercise (AI TTX) conducted from 17 – 19 January at the Raleigh Critical Public Safety Facility, Raleigh, NC. The TTX was planned and executed by the North Carolina State University's NextGen Air Transportation (NGAT) Consortium. This exercise was designed to support the transition of Unmanned Aircraft Systems (UAS) capabilities into disaster response preparedness planning, identify command and control requirements, provide potential users with situational experience with UAS, and provide test cases for evaluating policy and regulations related to UAS management at the state level.

The need for this type of exercise has never been stronger. In August of 2016 the FAA opened the skies to commercial and government operators under the Part 107 "Small UAS Rule" that defined the minimum operating requirements and constraints for broad UAS operations. Multiple UAS were operating during Hurricane Matthew recovery activities, including NC Emergency Management, at least one Part 107 commercial operator flying on request of a local county agency, and numerous reports of unauthorized, non-reporting small drones. On 27 January 2017 police in Pacifica, California arrested a 55-year old drone operator for impeding first responders at the scene of an emergency after the operator was identified flying a small drone near a Highway Patrol helicopter that was supporting the recovery of an injured person that had fallen off a steep cliff. Finally, on 9 February 2017 "Sheriff Neil Godfrey announced that the Moore County Sheriff's Office purchased an Unmanned Aircraft System (UAS) equipped with an eye-in-the-sky camera for surveillance in a variety of law enforcement operations. Three deputies have been trained and have received their FAA and North Carolina certifications which are required for the deputies to fly and operate these types of aircraft legally in North Carolina." These examples demonstrate that routine UAS operations are become more frequent and the need for policies, guidance, and education regarding safe integration is critical to the long term growth of the industry and to protecting the integrity of the national air transportation system.

1.1 Scope and Organization of the AI TTX Report

This report documents the highlights and major outcomes of the AI TTX and is intended to provide information which may advance the mainstream transition of UAS to civilian applications in general and bolster the value of integrating unmanned technology to emergency preparedness and response professions.

Section 1 of this report contains basic information on the TTX structure, assumptions, participants, overview of systems played, and a description of the scenarios and game steps. Section 2 is a summary of the TTX game steps and observations. Section 3 describes conclusions and key discussion points associated with the AI TTX, as well as offering recommendations for possible future TTX style events.

1.2 AI TTX Complete Project Schedule

The Airspace Integration TTX project followed the following schedule for organizing and producing the event in January 2017.

Month	Activity
October	Develop Project Plan
	Develop Baseline Exercise Material
November	Recruit Participants
	UAS Demo Flight Planning
	Planning Conference (production team only)
	Expand Exercise Material
December	Participant Confirmation
	Expand Exercise Material
January	Finalize Exercise Material
	Finalize UAS Flight Plan

	Pre-TTX Event Workshop
	Pre-TTX Reference Playbook Distribution
	UAS Flight Preparations
	TTX
February	TTX Analysis
	Prepare Draft Report
March	Publish & Distribute Final Report & Outbrief

1.3 AI TTX Location

The AI TTX was held at the Raleigh Critical Public Safety Facility in Raleigh, NC and was conducted from 17 – 19 January 2016. The setting and duration of the TTX afforded the broadest opportunity for participation among local, state and industry experts while providing a stimulating setting in which to tackle the TTX goals and objectives.

1.4 AI TTX Structure

The TTX focused on understanding airspace integration challenges to enable UAS as a capability to assist NCDOT, law enforcement, fire and rescue departments, and emergency managers in response operations during a major flood event, such as Hurricane Matthew. It served to support the safe and responsible integration of UAS into the National Airspace System for use by public agencies across North Carolina.

The AI TTX was designed around seven exercise play objectives as follows:

1. Examine airspace integration issues when UAS are operated in the National Airspace System (NAS) with manned aircraft and other unmanned aircraft.
2. Develop policies and procedures to ensure the safe use of airspace while responding to natural and man-made disasters.
3. Use actual flooding and disaster response experience collected during the aftermath of Hurricane Matthew as the ground scenario basis to examine UAS operations.

4. Examine how to best employ UAS to assist public safety officials during dynamic disaster events.
5. Examine the potential to integrate UAS into standard Search and Rescue (SAR) airspace management operations.
6. Develop guidelines for private and commercial UAS use in disaster response and recovery.
7. Examine and evaluate the draft UAS Best Practices.

Additional objectives for the TTX included:

1. Provide a stimulating environment for technical, organizational, and operational specialists to explore and discuss a wide range of issues regarding the employment of UAS in disaster and emergency response applications.
2. Develop insights and recommendations concerning the prospective operational utility, or drawback, of UAS technology in public safety applications.
3. Expand the understanding of how availability of UAS technologies may impact disaster preparation activities, such as crisis response planning and organizational coordination.
4. Identify the technical, regulatory, political, and organizational obstacles that currently constrain the use of UAS in public safety applications.

Participants received orientation and information briefings on commencement of the event and subsequently engaged in three successive exercise scenarios. In each scenario, guidance was provided, responsive actions plans were planned, UAS operations were “played out,” and observations were recorded. Scenario outcomes were debriefed by each group to explore observations, issues, and insights generated by the scenario. A final discussion session was held to promote participant open discussion and encourage participant feedback.

Participants were assigned to one of three functional “Player Cells” (Figure 1). Those with Airspace Management Expertise were assigned to the Blue Cell. Those representing State and County Agencies or with Emergency Response/Management expertise were assigned to the Green Cell. An Industry Support Team assisted the Blue and Green Cells by addressing questions and explaining the capabilities and utilization of the "Tool Kit" of unmanned systems "played" during the scenarios. This team of UAS experts was assigned to the Purple Cell and served as UAS Pilots-in-Command (PIC) throughout the TTX. The

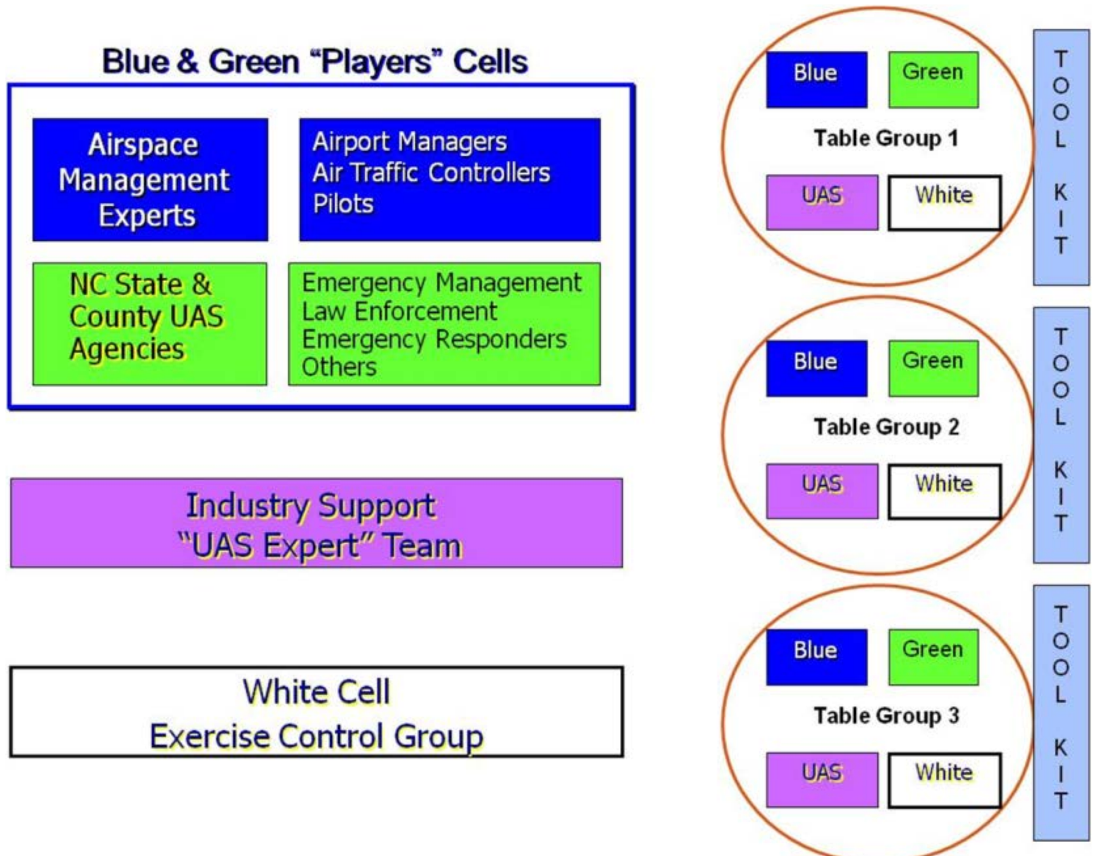


Figure 1: TTX Participant Structure

Purple Cell was staffed by individuals who are directly involved in unmanned system programs with current expertise in specific associated areas.

In order to stimulate interaction among all participants in responding to the simulation game conditions, members from each of the cells were placed at one of three table groups. In addition to the "Players," White Cell facilitators and recorders were assigned to each table. There were also a number of individuals who participated in the TTX as general observers. These "Observers" were free to roam among the table groups to monitor actions and develop independent observations and conclusions.

1.5 AI TTX General Process

Exercise play concentrated on the potential use of UAS to mitigate the damage, personal injuries, risk and vulnerability of two communities (Cumberland and Moore Counties) to large-scale flooding from Hurricane Matthew. The Raleigh Critical Public Safety Facility afforded an excellent locale for local, state and industry experts to gather and partner in an informal setting while providing an effective venue to assess the potential for select technologies to aid in disaster response. A demonstration of UAS technology applicable to the TTX scenarios was conducted at NC State's Lake Wheeler facility.

Cell definitions and organizations:

- <u>Blue Cell: Airspace Management Experts</u>. This group of individuals provided each table group with the necessary expertise to effectively manage the airspace during the scenarios. The most experienced Blue Cell representative at each table functioned as the "***Air Boss***" and made final decisions on airspace allocation and direct aircraft in the area through the EOC (Green Cell) or directly to the UAS PIC (Purple Cell). Other Blue Cell representatives at the table assisted in Airspace De-confliction and SAR aircraft planning.
- <u>Green Cell</u>: State and County Agency representatives with (or anticipating to have) UAS programs that filled the role of the EOC. The Green Cell representative at each table with the most emergency response experience functioned as the ***Incident Commander***. The Incident Commander planned and executed the operations for each game step and assigned available UAS to the PICs at the table. The other Green Cell representatives at the table assisted with UAS/manned SAR aviation management and communications.
- <u>Purple Cell</u>: UAS Industry Experts. These individuals played the role of UAS Aircrew PIC and assisted in the planning and execution of assigned UAS flight operations using the UAS in the TTX Toolkit.
- <u>Observers</u>: Those individuals invited to the TTX to observe and assess the actions and decisions of the cells working in each of the three table groups. Observers were not assigned to any table and could roam around to gather information to answer the questions provided.

- White Cell: TTX planners and managers who controlled and moderated the actions and discussions at each table. They also recorded and evaluated the actions and discussions of the Blue, Green and Purple cell participants as they responded to the scenarios.

Once the players were assigned their roles and tables, they were introduced to the "toolbox" of UAS products that were identified for game play. The complete Toolbox is included in Appendix F. The Toolbox includes aircraft images, capability descriptions, and potential missions. An example from the Toolbox is the Indago 2 (Figure 2):

Figure 2: Indago 2 Quad Chart from Toolbox

1.6 AI-TTX Event Schedule of Events

The TTX was managed to a preliminary schedule of events and though deviations were made to allow the exercise to flow, the schedule was effectively maintained as detailed in the figures below.

Day One – 17 Jan	Day Two 18 Jan	Day Three – 19 Jan	Day Four– 20 Jan
Presentations and Scenario #1 Brief 7:00 am – 5:30 pm	Demo Day and TTX Scenario 08:00 am – 5:00 pm	Backup Demo Day and Scenario 08:00 am – 5:00 pm	White Cell Post TTX Analysis
➢ 0700 - Check In & Breakfast ➢ 0800 - Welcome/Opening Remarks › *Chris Gibson* (NC DOT) › Kyle Snyder (NGAT) ➢ 0815 - Introductions ➢ 0830 - Technology Briefs › NGAT UAS Portfolio – Kyle Snyder (NGAT) ➢ 0900 – Air Traffic Control Basics – *Tom Waterman (FAA FSDO)* ➢ 1000 - Break ➢ 1030 - Discussion Sessions › Coordinating UAS and Manned A/C – *Tom Zajkowski (NGAT)* › Use of Aircraft during Floods – *Curt Johnson (NC EM)* ➢ 1100 – COA Status & Part 107 – Kyle Snyder (NGAT) ➢ 1130 - UAS Best Practices – Kyle Snyder (NGAT) ➢ 1200 - Lunch ➢ 1300 – Scenario 1 Brief –Tom Zajkowski ➢ 1330 – Scenario 1 Exercise Play ➢ 1530 – Scenario 1 Debrief & Discussion ➢ 1630 – Scenario 2 Brief – John Lambert ➢ 1645 – Networking at Static Displays ➢ 1730 – Adjourn	➢ 0800 – Reconvene & Review ➢ 0815 – Scenario 2 Exercise Play ➢ 1045 – Scenario 2 Slide Preparations ➢ 1145 - TTX Scenario 3 Brief ➢ 1200 - Lunch ➢ 1230 - Depart for UAS Demos ➢ 1230 – Operations & Safety Briefings – Tom Zajkowski (NGAT) ➢ 1315 – UAS Demos ➢ 1700 – Adjourn	➢ 0800 – Reconvene & Review ➢ 0815 – Scenario 3 Exercise Play ➢ 1100 – Scenario 3 Slide Preparations ➢ 1200 - Lunch ➢ 1300 – Scenario 2 Table Group Presentations ➢ 1400 – Scenario 3 Table Group Presentations ➢ 1500 – Discussions & Lessons Learned ➢ 1630 - Wrap Up ➢ 1700 - Adjourn	➢ 0800 – White Cell Debrief & Quick Look Plan ➢ 0900 – Scenario Debriefs ➢ 1100- After Action Analysis & Draft Quick Look Report ➢ 1200 - TTX Final Report Planning ➢ 1230 – TTX Adjourn & Depart

Figure 3: Master Schedule of Events

Table 1: Scenario 2 Schedule of Events- Wednesday, 18 January

Time	Step	Action
0815		Exercise Play Begins
0815	1 – Planning During Storm	Step 1 Begins
0855	1	Wrap up Step 1 Discussion and Identify Key Points for Debrief
0900	1	Step 1 Ends
0900	2 – SAR Operations	Step 2 Begins
0940	2	Wrap up Step 2 Discussion and Identify Key Points for Debrief
0945	2	Step 2 Ends
0945	3 – Extended SAR Ops	Step 3 Begins
1020	3	Step 3 Inserts (See Table Inserts Below)
1040	3	Wrap up Step 3 Discussion and Identify Key Points for Debrief
1045	3	Step 3 and Exercise Play End
1045		Begin Drafting Debrief Slides
1145		End Scenario 2

Table 2: Scenario 3 Schedule of Events – Thursday, 19 January

Time	Step	Action
0815		Exercise Play Begins
0815	1 – Planning During Storm	Step 1 Begins
0855	1	Wrap up Step 1 Discussion and Identify Key Points for Debrief
0900	1	Step 1 Ends
0900	2 – Data Collection & Planning for Potential Dam Breach	Step 2 Begins
0955	2	Wrap up Step 2 Discussion and Identify Key Points for Debrief
1000	2	Step 2 Ends
1000	3 – Response to Dam Breach	Step 3 Begins
1040	3	Step 3 Inserts (See Table Inserts Below)
1055	3	Wrap up Step 3 Discussion and Identify Key Points for Debrief
1100	3	Step 3 and Exercise Play End
1100		Begin Drafting Debrief Slides
1200		End Scenario 3

1.7 AI TTX Participants

Over 50 individuals attended the TTX over the three day period. A complete listing of participants is provided in Appendix B. The participants supplied a mix of industry, state government, local government, and university backgrounds. Some of the participants had prior experience with TTX-style events, some did not.

1.8 Overview of Scenarios and Air Assets Assigned

Three TTX scenarios were structured to incrementally examine UAS employment and develop policies, procedures and operations. Scenario 1 focused on developing the policies, procedures and checklists required to safely operate UAS supporting emergency response to flooding in Moore County in the vicinity of Woodlake Dam. These items were developed from existing Search and Rescue (SAR) manuals and were used during the two operational scenarios. These items will be updated based on the results of the operational scenarios and TTX discussions and evaluations.

Scenarios 2 and 3 were operational scenarios based on historical actions and flood levels in Cumberland and Moore Counties respectively. Each scenario included three game steps. In general, Step 1 was an air operations planning step, Step 2 included initial flight operations once the storm cleared and Step 3 included operations in response maximum flooding levels. In Scenario 3, Step 3 we simulated the breach of the Woodlake Dam and resultant response in neighborhoods downstream.

In each of the scenarios, each Table Group was assigned responsibility for a geographic area and allocated specific UAS to deploy. In addition, each table was allocated one National Guard Lakota and one US Coast Guard UH-60 to examine manned/unmanned airspace integration. Geographic areas and the UAS allocated to each Table Group for Scenarios 2 and 3 are listed in the figures and tables below.

Cameron Road – Table 1

Morrozoff Drive – Table 2

Pennystone Drive – Table 3

Figure 4: Scenario 2 Geographic Area Assignments

Table 3: Scenario 2 UAS Allocations

Cameron Road Table Group 1	Morrozoff Drive Table Group 2	Pennystone Drive Table Group 3
• Inspire • UX-5 • Airprobe Besra	• Inspire • ZX-5 • Indago • Airprobe Besra	• Inspire • Penguin • Tethered aerostat • Airprobe Wraith

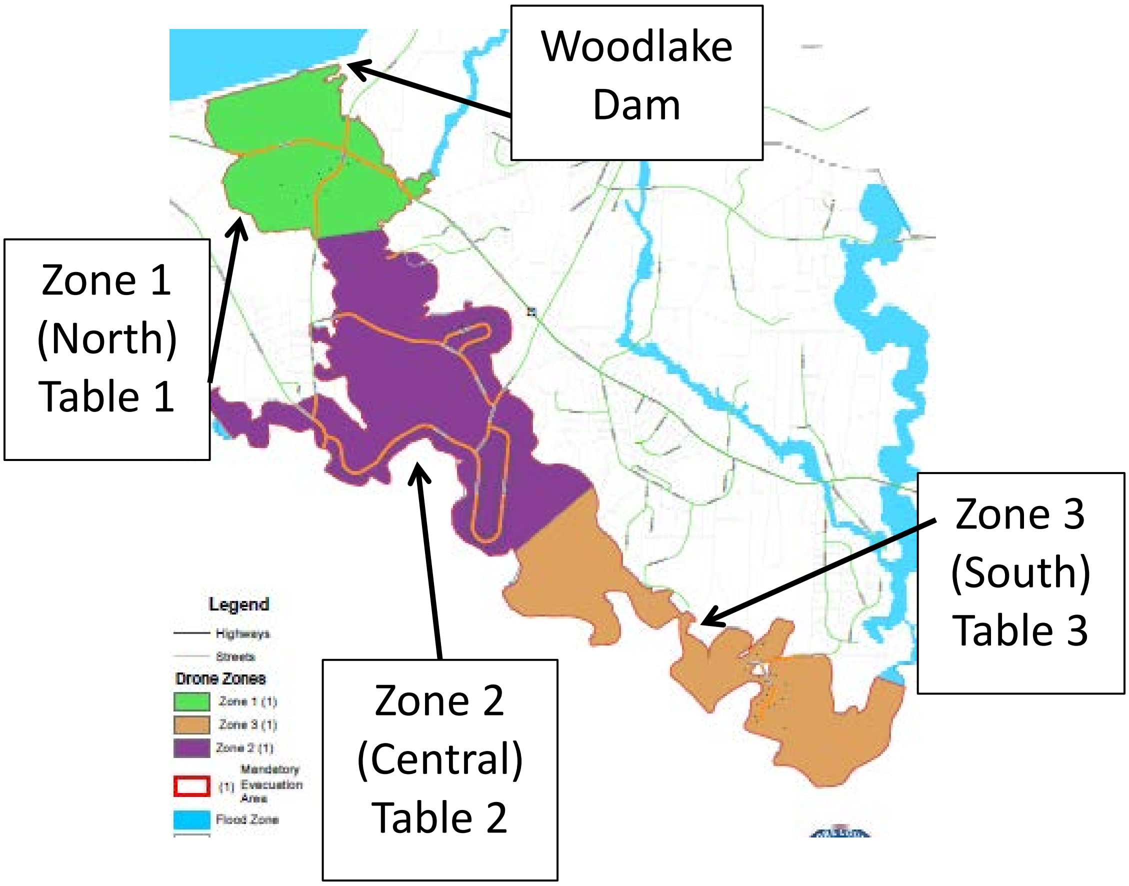


Figure 5: Scenario 3 Moore County Geographic Area Assignments

Table 4: Scenario 3 UAS Allocations

Zone #1 (North) Table Group 1	**Zone #2 (Central) Table Group 2**	**Zone #3 (South) Table Group 3**
• Inspire • ZX-5 • Airprobe Wraith • Tethered aerostat	• Inspire • Penguin • Tethered aerostat	• Inspire • UX-5 • Airprobe Besra • Indago

1.9 Airspace Policy and Procedures (Scenario 1)

Scenario 1 was used to develop the airspace integration management policy, procedure, and planning documents that were used throughout the remainder of the table top scenarios 2 and 3.

1.10 Operational Exercises (Scenarios 2 & 3)

Two operational scenarios were introduced to the participants and each Table Group proceeded independently to work the exercise with the objectives and the game steps listed below:

- Scenario 2 and 3 Objectives
  - Examine airspace issues by simulating the real world event
  - Discuss and work the airspace integration exercise with the Guidance, Actions and Questions assigned to each cell (see Appendix A)
  - Record your actions & thoughts; answer questions; prepare Table Debriefs using the briefing template provided
- Scenario 2 (Cumberland County) Game Steps
  - Planning (Step 1)
  - Initial SAR (Step 2)
  - Extended SAR (Step 3)
- Scenario 3 (Moore County) Game Steps
  - Planning (Step 1)
  - Data Collection and Planning for Potential Dam Breach (Step 2)
  - Response to Dam Breach (Step 3)

1.11 Review Material (SAR, Best Practices)

In order to understand how UAS would be integrated into disaster response operations and examine how the various public agencies would structure their UAS programs, the TTX Reference Library provided some background material for the participants to review and provide comments for future revisions. These materials included the Search and Rescue Manual and the draft NGAT UAS Best Practices. These materials are referenced in Appendix F.

2 AI TTX Scenarios and Observations

2.1 Scenario 1: Policy and Procedures Development for TTX

Participants were asked to review documents that are currently used for manned aviation to conduct public safety missions. These documents included checklists, manuals, regulations, and project aviation safety plans (Appendix E). Once the participants reviewed the document, the facilitators used the document to develop a pre-mission checklist, and the following policies that were used to guide game play in scenarios 2 and 3. Table groups were free to modify the procedures if they found the policies too restrictive, as long as they documented the changes. The following guidelines were established to scope the roles, responsibilities, and operations during the TTX game play in Scenarios 2 and 3. These are not intended to be guidance results from the exercise, but were used to evaluate potential recommendations or frame boundaries for exercise play.

Personnel Guidance

- UAS Crews shall include a minimum of three personnel- Pilot-in-Command, Visual Observer, and Mission Commander.
    - Pilot-in-Command- The Pilot in Command (PIC) is in charge of the flight operation and is the responsible party with respect to FAA and State regulations. This person may act as both PIC and UAS Operator, however if a separate person acts as the UAS Operator, the UAS Operator acts under the command of the PIC and must follow PIC instructions at all times.
    - Observer- The role of the Visual Observer is to keep watch on both the UAS being operated as well as the surrounding airspace to maintain the safety/integrity of the airspace and meet "See and Avoid" requirements as outlined in FAR Part 91.113.
    - Mission Commander- The Mission Commander is the primary authority responsible for interfacing the UAS Flight Crew with the Incident Command System. The Mission Commander does not have to maintain a UAS Operator License, but may fill the role of incident Air Boss, Pilot-in-Command, or possibly Incident Commander for a small operation.

- Any incident requiring more than one aircraft (manned or unmanned) requires the local incident commander to identify an Air Boss or equivalent (i.e. Type III Air Support Group Supervisor) to manage mission assignments and airspace control.
- A standard ICS Unmanned Aircraft position should be created with a standardized task book (see detailed comment below).

Communications Guidance

- All Ground to Ground communications shall be conducted via the 800 MHz VIPER Networks (talk group to be designated by the local Incident Commander).
- All Air to Air, Ground to Air, or Air to Ground communications shall be conducted via the Aircraft band (frequencies determined per FAA regulation).
- Communications between Incident Command and the flight crews should be limited to the Air Boss or a single individual if an Air Boss is not required/identified.
- All operational aircraft shall be grounded if there is an aircraft (manned or unmanned) in the airspace with which communications cannot be established.
- Radio frequencies should be assigned and documented during preflight planning.
- All aircraft will broadcast launch intent in-the-blind on the Air Boss-assigned communications frequency before they begin operations, every 15 minutes during operations, and at the end of operations.
- Cell Phones can be used as backup for Ground to Ground communications. A phone list should be developed and maintained.

Airspace Control Guidance

- Positive control of all aircraft must be established prior to any air operations.
- Any incident requiring more than one aircraft (manned or unmanned) requires the local incident commander to identify an Air Boss or equivalent (i.e. Type III Air Support Group Supervisor).
- Aircraft shall be separated both laterally and vertically and/or by time of entry and departure, as assigned by the Air Boss
- The Visual Observer is responsible to confirm visual separation of the aircraft from other

air traffic per the pre-flight plans.

- For large incidents, the Incident Commander shall request a Temporary Flight Restriction (TFR) through the FAA. In North Carolina, the local Emergency Management Agency can request the TFR on behalf of the Incident Commander.

Planning Guidance

- Current FAA Sectionals and USGS Topo Maps shall be used to conduct preflight planning with Google Earth used as an additional reference.
- Preflight planning shall be conducted using the 7.5 Minute Quads from the Civil Air Patrol Grid System, which equates to the 1:24,000 USGS Quads. The 7.5 minute quad can be identified and retrieved from the U.S. Geological Survey, USGS US Topo Map Collection KML file[1]. USGS also provides a map viewer to display images[2].
- All flights must complete the Preflight Mission Planning and Safety Checklist.
- The Air Boss or ASGS shall complete an ICS 220 (Air Operations Summary) for any incident/operations with more than one aircraft.

Training

- All UAS Pilots in Command should maintain a Part 107 Remote Pilot Certificate from the FAA and the NCDOT UAS Permit (Commercial or Government depending on representation).
- In lieu of a NCDOT UAS Permit, Visual Observers can be provided just-in-time training by the Mission Commander or Air Boss to support airspace deconfliction.
- Pilots will be trained on specific North Carolina Agency-related UAS Policies and Procedures.
    - Pre-Flight Mission Checklist
    - Communication procedures
    - Air Boss training should include:
        - At minimum Part 107 Remote Pilot Certificate

[1] https://catalog.data.gov/dataset/usgs-us-topo-map-collection/resource/1c39eb7a-09c7-4520-a051-a61d77d47b41
[2] https://ngmdb.usgs.gov/maps/topoview/viewer/

- ■ NCDOT UAS Permit
- ■ E0986: NIMS ICS All-Hazards Air Support Group Supervisor[3]
- ■ Specific North Carolina Agency-related UAS Policies and Procedures.

Volunteer Aircraft Guidance

- Use of volunteer aircraft is at the discretion of the Incident Commander. Local liability policies and procedures apply.
- All authorized volunteer aircraft can fly under the Part 107 Remote Pilot Certificate of the Air Boss, Mission Commander, or Air Support Group Supervisor.
- All volunteer aircraft pilots are required to show proof of the applicable NCDOT UAS Permit.
- If a TFR is established, all authorized volunteer aircraft pilots shall have both a Part 107 Remote Pilot Certificate and a NCDOT UAS Permit.

Continuing Education Guidance

- Jurisdictions shall convene the public safety UAS and manned aircraft operators and stakeholders (Incident Management Teams, Local Law Enforcement, etc.) to discuss policies, procedures, and relevant updates at least annually.
- Jurisdictions shall conduct Airspace Integration Exercises (Tabletop, Functional, Training, or Full Scale) at least annually.
- NextGen Air Transportation (NGAT) Program will maintain a statewide list of recommended UAS resources for public safety.

One of the Table Groups organized and prioritized a procedural plan of actions to assist in the UAS Integration Decision-Making Process (Figure 6).

[3] https://www.firstrespondertraining.gov/frt/npccatalog?courseId=2226#anc-search-results

UAS Integration Decision-Making Process
INITIAL STEPS 1. What is/are the mission(s)? a. Identify Initial objective(s) (i.e. recon/search/survey). b. What is Command Signal (Authority Chains of Command & Tasking)? 2. What airspace impacts & usage? a. Who are the cognizant airspace managers? b. How do we coordinate? 3. What are resource(s) availability & capabilities? a. What are weather forecasts for scheduling? b. Manned & Unmanned Deconfliction (geo boundaries, altitudes, time)? 4. When & how do we establish TFR/Airspace Management/NOTAMs? What size? 5. Mensuration/Apportionment/Allocation. a. Priority of mission(s) b. Establish Launch/Recover points c. Establish Air Tasking Order & Crew selection(s) 6. Risk Management Assessment: a. Go-No Go Criteria (A/C vs Weax vs other issues/priorities) 7. Command, Control, Communication, Information (C3I): a. Centralized Planning / De-centralized Execution b. Information Sharing/Collaboration Plan 8. Manned & Unmanned Deconfliction PROCEDURES (Rules of the Road/Airspace)

Figure 6: UAS Decision Making Process Tree

2.2 Scenario 2: Cumberland County Exercise Play

Each of the three Table Groups organized their Blue, Green and Purple Cell members to execute the scenario objectives in their assigned areas with the allocated aircraft. Significant Exercise Play actions are provided below.

Table Group 1 (Cameron Road) began by identifying and assessing the likelihood of probable flooding areas. The Incident Commander (IC) requested manned and UAS aerial support from the Air Boss to support EOC SAR and Evacuation operations. The team worked to develop a coordinated SAR plan using the assigned UAS and the manned UH60 within search area boundaries. Typical landmarks would not support this effort due to the flooding levels. The team set the boundaries with the unflooded section of Route 301, Elk Road, South View High School, Legion Road, First Baptist Church, and the southern water line.

The UAS Search and Manned Rescue (USMR) operations plan outlined the purpose, mission, and operating parameters for the assets. UX5 was employed for hydrological survey and scouting since it does not have streaming video capabilities and is limited to 30 minute operating sessions. Also, the UX5 must be pre-programmed, traversing in blocked patterns at 350 ft and cannot be re-tasked remotely. The Besra would operate at 400ft with streaming video to identify and locate targets and their position relative to the boundary landmarks. The Inspire would be hovering at 150ft to search for people by providing spot and zoom details. It was initially fixed hovering over houses, but was eventually re-tasked to cover a flooding SUV in support of rescue operations.

The Air Boss coordinated a request with ATC for a TFR with a 3 mile radius that intersected the 5 mile ring around the airport on the 260 radial. The TFR enabled control of UAS/manned airspace integration based on time, altitude and geographic reference. The Incident Commander conducted an EOC briefing with the pilots and crews on the planned operations including:

- Launch sites on South View High School roof for fixed wing. Observe from roof or baseball field. Land and recover on South View High School Baseball Field;
- Manned AC land and depart from South View High School Football field;
- Entry into the search areas from Hwy 301 West, exit path will cross Legion Road to return to South View High School Football field, takeoffs and landings to the South due to cross winds and no current flooding;
- Logistics of all batteries and communications available (Coast Guard and NG using UHF/VHF, Viper for ground team monitoring and Fayetteville ATC);
- At sightings, Inspire will hover and maintain position; Incident Commander will report bearing and distance;

- For Rescue, the Air Boss will alert Coast Guard and ATC to ensure UAV flights do not negatively impact neighboring teams or events;
- Incident Commander or Air Boss will prioritize requested SORTIES (ad hoc requests, etc.) as they come in.

During the exercise, a Good Samaritan offered use of his Tethered aerostat that was confirmed compliant with FAA requirements, registered and outfitted with the necessary communications relay system. The aerostat was tethered at 400ft at the South View Town Homes entrance, which was not flooded. The UX5 needs 200-300 meters for turnaround lines so the location of the tethered aerostat at this time, with winds out of SSW, is not a concern.

At any time, a loss in communications between aircraft and ground control station or between ground assets mandates the aircraft return to landing site. To further de-conflict assets during manned rescue, the operating plan is to ground UAVs to allow full access for manned rescue flights. The Air Boss also assessed and dictated communication and data reporting procedures with the UAS flight crews.

The limited assets (small UAS less than 55 lbs) and corresponding capabilities (small sensors, short endurance except for the Penguin C), did not allow additional tasking such as persistent real-time streaming of evacuation routes. However, the Inspire could periodically be directed to the desired areas of interest since there were no viable evacuation routes to the south.

The Incident Commander was notified of an incoming, unauthorized helicopter that was planning a rooftop rescue. The ATC was immediately contacted to direct the unauthorized aircraft to return to the airport. The rescue requirement was added to the SORTIE queue as a high priority but was listed after the current/immediate rescue already in progress for an SUV extraction.

As flood waters rose, USMR operational adjustments and considerations were minimal. The UX5 was monitoring for flood waters. The Inspire Team was already mobile to support emergent relocation requirements and the remaining teams were still far enough away in the safe zone to avoid rising waters.

Table Group 2 (Morrozoff Drive) focused on organization, procedures, training and communications. Standard Operating Procedures (SOP) need to be established for UAS interactions with manned aircraft and ground rescue teams. There should be a standard form that can be used throughout the ICS structure similar to the FEMA Incident Command System Form: Air Operations Summary (ICS 220). Frequency spectrum and communications coordination and briefings should be held, as well as procedures on how UAS enter and exit the airspace.

Table Group 3 (Pennystone Drive) began by assessing the overall objective for the scenario, including possible need for UAS operations to assist flood mapping and search and rescue within the neighborhood. The Incident Commander requested Air Boss permission for UAS operations near Pennystone Drive for surface to 1000 feet. Air Boss determined that a TFR would be necessary for UAS operation and requested a TFR for Cumberland County.

The Incident Commander and Air Boss determined that for any UAS operations in the area, communication should occur every 15 minutes and for every take off/landing. Primary communications should be with Viper radios between UAS PIC and Air Boss, with cell phones as a secondary option.

When flight operations commenced, the Incident Commander requested a DJI Inspire to support search and rescue operations in the Pennystone Drive Neighborhood. He communicated with the Air Boss and the Inspire PIC to determine optimum launch and recovery location for Inspire Operations. Operations were conducted as follows:

- Inspire launched from Tom Starling Road, assumed launch point is easily accessible.
- Intersection of Tom Starling Road and Pennystone Drive was chosen as optimal launch and recovery location for the Inspire.
- Inspire was operated at 300 feet AGL to maintain surveillance of the Pennystone Development.
- Inspire was providing location specific surveillance and continuous in air video surveillance to aid in any needed SAR objectives.

Shortly after Inspire was launched, the Incident Commander requested a Wraith for flood mapping operational support.

- Wraith was launched from a small field half a mile from Pennystone Drive.
- Assumed land owner permission was granted to launch and recover from field.
- Wraith operations were conducted at 400 feet AGL to ensure vertical separation of Wraith and Inspire.
- The Wraith was used to map the entire Pennystone Development for rising flood waters.

During UAS operations, the PIC found a family in need of immediate rescue. The PIC relayed their position to the Air Boss and then lost all communication with Air Boss. The Air Boss realized that primary communication was inoperable and tried to contact the PIC using the secondary communication method (cell phone). Additionally, a delegate was sent to ensure communication with the PIC was regained.

Due to the 15 minute reporting schedule established by PIC and Air Boss, the PIC would not have resumed flying upon realizing communications were down.

With the short flight time of the Inspire, the Inspire would have been on the ground within 15 minutes. The PIC of the Wraith grounded the Wraith as soon as communications with the Air Boss failed, despite maintaining control link with the aircraft. Therefore the airspace was de-conflicted when the manned asset arrived on scene. UAS operations resumed as soon as communication was reestablished and the manned asset was clear of the area.

During the third game step, the flood waters were simulated to have reached the maximum level experienced during the storm. Due to pre-flight planning, the rising flood waters did not affect UAS operations. Additionally, the arrival of a 15 knot wind did not compromise UAS operations. Both UAS crews (Inspire and Wraith) continued operations until the Incident Commander no longer needed UAS support.

2.3 Scenario 3: Moore County Exercise Play

Table Group 1 (North Zone closest to Woodlake Dam) began by making some assumptions that they felt should be factored into Public Agency and Law Enforcement Plans supporting various Mission Operations parameters like those in this workshop. Specifically, the Incident Commander was assumed to have been granted:

- A blanket public COA – permits flights in Class G airspace at or below 400 feet, self-certification of the UAS pilot, and the option to obtain emergency COAs (e-COAs) under special circumstances;
- An ATC Waiver letter in hand to fly within 5 miles of the local airports;
- All Part 107 waivers (good for 4 years):
    - Operation from a moving vehicle or aircraft (§ 107.25)*
    - Daylight operation (§ 107.29)
    - Visual line of sight aircraft operation (§ 107.31)*
    - Visual observer (§ 107.33)
    - Operation of multiple small unmanned aircraft systems (§ 107.35)
    - Yielding the right of way (§ 107.37(a))
    - Operation over people (§ 107.39)
    - Operation in certain airspace (§ 107.41)
    - Operating limitations for small unmanned aircraft (§ 107.51)

Planning considerations included Safety, Logistics, Operations, Teams, Communications, Assets, Staging (UH60 - Moore Co Airport; VOR – Sand Hills; Hospital – Southern Pines). The Air Boss established flight parameters for manned and unmanned vehicles and teams with methodology similar to that used in Scenario 2.

The Air Boss requested, and was granted, a TFR around Woodlake Dam (center point) via Fayetteville ATC for 2 nm around Moore Co Airport. The Incident Commander identified civilian personnel and assets at risk for potential rescue and evacuation plans. Staging considerations kept the team upstream, identified Launch and Recovery sites, accounted for Media locations (above the dam and on a Private Golf Course and Housing with permission), and communications (NG and CG air crews use UHF, Ground crews use Viper, Video streamed live from UASs via Mission Caster). Specific "teams" (operators and assets) for emergency response were vetted for valid certifications and training and were assigned operational parameters and tasking, according to capabilities and payload.

If and when a situation/rescue like Scenario 2's SUV of civilians washing away, the following adjustments would be made when the Incident Commander calls in the SITREP: (1) If the INPIRE locates the distressed individuals, the Wraith overflies to capture location and begins monitoring/live streaming; or (2) if the Wraith locates them, operations continue until UH60s are airborne and close, then the WRATH would offset South East to provide direction and guidance to the UH60 rescue crew.

In support of manned rescue operations, the Air Boss will call ATC to Spin up UH60's, which can be airborne in 6 minutes. The Inspire on-scene will be relocated for stationary loitering/view of the rescue site. The Wraith will be made ready for launch (based on power/battery/etc.) for live feed from southeast of the rescue site. The UH60s will be approaching from the northwest (Moore Co Airport). Coordinates and status of the distressed individuals will be provided based on positioning relative to the determined landmark boundaries. Unmanned assets not involved in the rescue will be offset to the southeast to make way for manned assets.

Recognizing the limitations of flying UAS within the line of sight (LOS) restrictions of Section 107 and under many COAs, one participant took action to contact the FAA via email. The email inquired about the possibility of obtaining an emergency COA (eCOA) for a Public Safety COA holder to get a Beyond Visual Line of Sight (BVLOS) waiver for operations. The response was received in about 3.5 hours: "*I have seen an approval for Beyond Visual Line of Sight (BVLOS) for a UAS operation that took place in a TFR. The accountable executive who was controlling the airspace took on the responsibility for deconfliction but since the airspace was sterilized that was not a problem. Obviously, you have to explain how you are going to provide an equivalent level of safety to that of see and avoid to accomplish the operation.*"

Table Group 2 (Central Zone) took an innovative "out of the box" (and outside the TTX) approach to working this scenario. They were very knowledgeable of the Moore County location and airspace. One participant decided to call a friend who managed airspace at

Fort Bragg and the associated US Army Airfields. This yielded some recommendations regarding the restricted airspace management and transition to TFRs under situations such as Hurricane Matthew. They established a notional Memorandum of Agreement (MOA) and an open dialogue with military airspace managers with a recommendation to have MOAs already in place for later activation when necessary.

This group examined the issues of commercial and unauthorized private UAS flights in the area, discussed how to establish approval processes for commercial operators, and addressed educational outreach for the general public on the preferred use of drones during public safety operations.

They also advocated for the development of a UAS Incident Response Pocket Guide, patterned after the National Wildfire Coordinating Group's Incident Response Pocket Guide. A draft of the UAS pocket guide was developed and is provided in Appendix F.

Table Group 3 (South Zone) began scenario 3 by evaluating the airspace above the given location of interest with the assumption that UAS would be needed to operationally support search and rescue as well as flood water mapping. The Air Boss immediately determined the location bordered Restricted Airspace 5311A which was under the jurisdiction of the Washington DC Center. The Air Boss assumed DC would hand communication/permission back either Pope or Simmons Army Airfields. The Air Boss was prepared to be in contact with the Restricted Area 5311A authority if the need arose.

During pre-flight planning and during/before the storm, the Incident Commander determined that an emissary would be sent to houses within the area of interest to evacuate the population. This allowed someone to evaluate potential locations for UAS operations as well as provide location profile for areas of responsibility. Additionally, the emissary was assumed to have an idea of who refused to evacuate the area.

The Incident Commander referred to the SAR Manual Appendix F to facilitate UAS operations above the area of responsibility. In coordination with the Air Boss, the Incident Commander determined that VTOL UAS would be the best operational platform for use in the area of responsibility. He choose to operate using a blanket COA instead of Part 107. Primary communication was Viper radio, secondary was cell phone, and tertiary was sending a runner to relay face to face with the UAS PIC. PIC was to report every 15 minutes or on launch and recovery.

Incident Commander Requested an Indago to launch when the weather cleared. The Indago would map roads, flood waters, and areas where people may not have evacuated. The Air Boss assumed that a TFR was in effect for the area.

When flight operations commenced in Game Step 2, the Indago was launched when the weather cleared to gather initial mapping and an overall area survey. A UAS was launched from a turnabout intersection east of the central area of responsibility.

Information from a Woodlake Dam observation team reported that there may be a breach of the Woodlake Dam in the future and could result in night UAS operations. The Incident Commander and Air Boss determined that the Indago should be used with the Air Boss submitting an emergency night operations waiver request.

- Map area for obstructions and to determine an operate area of operations for safe night flights.
- Determine latitude and longitude of area of operation with an assumed one mile radius indication of UAS night operations.

Within the operation area, the PIC noticed a party occurring just south of the main road. Additionally, a hobby drone was seen operating in the airspace. In response to this observation:

- The PIC grounded the Indago and informed the Air Boss of the situation. The Air Boss informed the Incident Commander.
- The Incident Commander dispatched a ground unit in an attempt to make contact.
- UAS operations were grounded until the hobby flights ceased.
- UAS PIC marked the location of the party in event of a dam breach and the possibility of necessary evacuation.

Images from UAS team monitoring the Woodlake Dam indicated the dam was breaching and flood waters were rising. It was assumed that the Air Boss had contacted the FAA and a night waiver was in place for UAS operations. The Incident Commander pulled the PIC and UAS team out of possible flood areas and reevaluated their location as flooding increased.

In Game Step 3, the dam breached with floodwaters rising dangerously.
The Incident Commander evacuated the UAS flight team and UAS operations were suspended.
The Incident Commander and Air Boss reevaluated aircraft capabilities and determined a new launch and recovery area for UAS operations.

- Besra was launched from a field ¾ of a mile north of the operating area.
- Assumed permission from field owner was granted.
- Used both commercial and public agency Besra aircraft that were available.
  - Applied one-in one-out procedure.
  - Used two different locations for Launch and Recovery to ensure lateral separation.
  - Applied both lateral and vertical separation during launch and recovery as defined by the Air Boss.
  - Applied a secondary loiter as one aircraft was launching and the other recovering.

A PIC was operating when he realized that flood waters were rapidly advancing to the point of impeding UAS operations and evacuation was necessary.

- The PIC considered whether (1) to land the aircraft and then evacuate, or (2) to land aircraft in an alternative location before evacuating, or (3) to operate from a moving vehicle.
- In this scenario a waiver to operate from a moving vehicle would have been necessary. As a result, emergency situations should define specifications for aircraft performance. Develop the technological standards for emergency management UAS.

2.4 Scenario 2 and 3 Observations

Discussion points and observations were recorded by the White Cell and the Observers. A listing of the significant items, comments and questions to be resolved are provided below as written by TTX participants:

1) It appeared all groups came up with plans and concepts to manage airspace safely. It helps having the experience of law enforcement, industry partners, emergency managers, and flight operations in each group. All groups appeared to use the best practices that were developed or presented on the first day, and it is believed that each used the UAS Decision Making Addendum (Figure 9) in their planning. Each group seemed to have a similar approach to the planning but varied slightly from other groups.
2) All groups seemed to manage the airspace safely and effectively in slightly different ways. Airspace was managed by each group through coordination with the Air Boss and Incident Commander. Appropriate communication was provided from the PIC to both. Groups seemed to come up with a streamlined process for this so the information would get back to the Air Boss and I.C. If groups knew they would lose communication with PIC, they had contingency plans. If complete communication was lost, most groups mentioned stopping all unmanned operations and having them land until communications were operational again. All groups appeared to have the PIC and VO in appropriate positions.
3) The airspace was managed safely and effectively for public evacuation and unmanned systems were used to look for those in distress and monitor land and flooding. Additional training beyond Part 107 and NC UAS Permit minimums, as well as supplemental flight training and certification for mission specific operations was also discussed. These additional requirements could be agency specific or align with standards recognized by professional organizations representing a specific community (e.g. fire, search and rescue, law enforcement professionals). It was also suggested that only vetted/approved UAS operators and companies would be allowed into the briefing and operations. The operators would also have to sign waivers that they would not share any images, data, etc. from the mission outside of the operation. UAS should be pre-registered and pilots have proof of flight qualifications, and they would have to be credentialed within the EM jurisdiction. This would help make operations safer and communications more efficient, and hopefully build a better working relationship with all parties involved in the

operation.

4) To ensure a qualified cadre of UAS operators are available for disaster response, UAS operations contracts for each county jurisdiction could be put in place on a calendar basis. This will enable on-call services that have been properly checked to assist throughout the county. Their contract should show proper flight training and certifications along with copies of any waivers, COA, and Part 107 licenses.
5) UAS flights were executed in accordance with assigned flight plans. They did a good job coordinating manned and unmanned assets to maximize safety and SAR efficiency. No discernible difference was found in operations between commercial UAS and public UAS and the group seemed to utilize UAS very effectively. They first used UAS to monitor communities that bordered the bodies of water prior to the flooding. Target lists for problem areas were established. If the selected UAS detected something with its sensors/cameras, the National Guard would be triggered to send manned aircraft to rescue those in distress.
6) The groups did a good job gathering available information about the breached dam. They asked for available down link information from the tethered aerostat feed that was monitoring the dam. This information was then used to help with coordinating manned and unmanned assets for rescue of those in the flood area, along with coordinating a swift water rescue team. The discussion included the need to encrypt any important data that should not be available to the public or accessed by media in any way that could hinder the operation. Airspace was managed safely for all SAR operations.
7) SAR operations could be improved with Part 107 waiver conditions that would allow for night operations without having to fill out additional paperwork during emergency situations. For the safety of night operations, it would be helpful to be able to map land and all obstacles in the daylight.
8) It is important to have back-up launch and recovery points in case the main point becomes flooded or another access issue arises. This should be addressed in an initial briefing and the PIC should make the call, in the field, if the situation worsens and commands recovery at alternatives site is necessary. The UAS improved the

overall SAR operation and made it more efficient and effective to complete missions, monitor flood conditions, and rescue people in need of assistance. It is also important and should be emphasized that any UAS operator involved in a scenario like this should have a 72 hour back up plan (i.e. generators, batteries, etc.).

9) There were several questions about the legality and process for approving night operations during emergency search and rescue operations. It was decided that through a TFR, COA, etc., and the Air Boss communicating with the Incident Commander and the FAA official, night operations would probably be accepted in emergency life and death situations with approved licensed unmanned operators. Does it need to be included in an authorized long term waiver prior to the emergency operation? Appears the FAA needs to come up with specific regulations for approving night UAS operations during emergency operations. This does not seem that clear.

10) The groups did a good job of using unmanned assets to monitor for downed trees, flooding, and other obstructions that were introduced in the inject step.

11) I am not sure how many more percent of rescues could be conducted by utilizing unmanned assets, but it would definitely help. They can be up in the air quicker than most, if not all manned assets, to provide initial assessment and mitigation of the situations.

12) One thing I learned was how important it is to have an experienced GIS person in the EOC that can help overlay maps, flood areas, topography maps, etc. This was probably one of the biggest items I picked up from this scenario. I was able to see how valuable an efficient GIS technician is to a SAR operation. I think without the GIS technician it would have delayed the operation significantly in this scenario.

13) Not having any experience in search and rescue operations or unmanned systems operations, besides writing papers, it has been helpful to learn about more of the behind the scene items. I have been familiar with incident management concepts and set ups but have not had much live experience, so this was very helpful.

14) I know these exercises were focused on unmanned aerial assets and that is the

focus of this group, but in certain situations where a SAR operation was being conducted on harsh terrain could Unmanned Ground Vehicles (UGV) that are capable of crossing the terrain assist too? I believe so but that would require more operators, observers, and coordinators. It could be another helpful asset as an unmanned ground vehicle may be able to sense something the aerial vehicles may not pick up. Granted the UGV would only be helpful in these situations if a manned ground vehicle could not reach a victim, and the ground vehicle was capable of doing so.

15) Public Agencies and Law Enforcement can get “jurisdictional” or county COAs after proving the capabilities via test/demo.

16) Groups discussed the need for advance decisions on whether to fly under a COA vs Part 107 and Part 107 waivers.

17) Access to hobbyist and other databases to determine private assets within operational areas would be beneficial to reduce hobby flights during a disaster response. Reverse 911 or social media public service announcements could remind the public of the rules and prohibitions to flying. Public policy should

    - Allow the States to have their own permit laws to handle issues vs elevating to Federal level
    - Require real-time aircraft registration at point of sale.
    - Allow LE to actively enforce Permit laws.
    - Provide guidance to law enforcement on how to interact with hobbyists and unauthorized operators.

18) We should employ FirstNet NC. It is available in all 50 states, DC, 5 Territories with bandwidth used for Public Safety

19) We should establish common altitude reference (Barometric or GPS)

20) Can a landowner really say “no” in a life threatening emergency scenario? Should they be?

21) Incident Commander and Air Boss should have access to detailed description of

both Blanket COA and FAA Part 107 Operational Restrictions/Regulations.

22) Consider requiring the UAS industry to design some UAS to an emergency management standard.
    - Need to develop set standards for UAS performance.

23) UAS operations during emergency situations should be planned assuming worst case scenarios and that the worst that could happen.
    - Should have a plan for rising flood waters requiring an immediate evacuation.

24) Communication standards need to be set for UAS operations. In all cases, PIC to Air Boss and Incident Commander communication procedures should be established. The communication standards should include procedures for lost communications.
    - Freeform conversations detracted from the Incident Commander's ability to make decisions. Without clear roles for others in the group (other than the Air Boss and Incident Commander), there was lots of pontificating.
    - Tethered aerostats were used to assist in manned/unmanned coordination. They were stationed at locations that marked safe helicopter operation boundaries while maintaining UAS operating at locations outside those boundaries.
    - Public agencies can use whatever they need to use and do whatever they need to do without credentials – Is this true? What is the actual rule in emergencies?

2.5 AI-TTX Open Discussion

Upon completion of exercise play, each table was tasked to summarize their results and findings to the entire TTX group. Those briefing slides are provided in Appendix C. Some of the more notable discussion points are provided below.

- Efficient use of UAS provides cost effective, economical augmentation to aviation assets for many missions. Some offer live streaming video necessary for real time decision-making in areas where manned assets may not be able to operate safely. Their versatile capabilities offer different mission-equipped systems for broad surveying, precision, pinpointing, and low altitude search.

- The UX-5 was not a valuable system in Scenario 2 for the search and rescue op due to still imagery limitations and processing time. The Inspire (VTOL) was extremely valuable for on-station close up surveillance with immediate action and follow up surveillance after rescue. VTOL enables ingress/egress to station and operations areas.
- One Table Group included actual footage from a private drone used during Hurricane Matthew in their Scenario 3 debrief. The video was examined and used as an example to consider and examine different procedures and/or policies for managing ad hoc private drone operations that can be expected during significant public safety events.

Blanket or Real-Time Waivers:

- Under the current incident, the agency (Fayetteville PD and Cumberland County EOC) would most likely be given the Waivers for IR use and night flights. If using a private/commercial organization that has the authorizations to use the systems, they would fall under the umbrella of the SAR event and potentially could be used for emergency circumstances.
- From the observer locations, the fixed wing UAS could be monitored and not lose LOS. The Inspire may require some LOS loss due to the close proximity to the location. COAs and/or part 107 waivers would allow for limits to be unrestricted.

Recommended Changes to Processes & Procedures include:

- Under search and rescue operations, immediate waivers for night ops, FLIR, LOS, Moving Vehicle, altitude restriction release should previously be approved.
- There should be a skills minimum performance qualification for PICs to operate during emergency SAR ops.
- Establish and enforce training-hours requirements per air platform per agency.

UAS Operator Position Comment:

- A standard ICS “UAS Operator (UASO)” position should be established for all hazard use. However, it may make more sense for the position to be housed in the Situation Unit of the Planning Section and be thoroughly integrated with the Air Ops Branch in the

Operations Section. This is a dynamically changing technological industry and similar technical positions are already housed in the SIT Unit (e.g., GISS, IRIN, LTAN, FBAN, FOBS, etc.). These existing positions already have workflows and processes for integrating data into the Incident Action Plan and providing data to Ops for operational decisions. Much of the operator's responsibility will be highly technical and often times the need will be to process and integrate the data into a geographic information system for additional analysis or for incident mapping. A UASO would likely need to work closely with a FOBS and GISS, and similar to how FOBS personnel interact closely with Division Supervisors, Crew Bosses, and Strike Team Leaders now, UASO would stay tied in to both field operations and data collection responsibilities within the SIT Unit. It may make the most sense for the Air Tactical Group Supervisor (ATGS) position to be expanded to include coordination of UAS operations with the SIT Unit. Similar to the Situation Unit Leader (SITL) on smaller incidents where the SITL may be charged with making maps (GISS) and other SIT tasks, the ATGS would perform their traditional duties and collaborate with the SITL on UAS Operator activities. On larger incidents, it may make sense if an additional ICS position existed under the Air Ops Branch to report directly to the ATGS and act as a "UAS Tactical Operations Liaison (UTOL)." This position would be filled by knowledgeable aviation personnel who are well-versed in manned and unmanned operations. The UTOL would liaise outgoing operational objectives to the SITL (similar to how operational objectives are communicated now for field observations, mapping, etc.) and the SITL/SIT Unit would be responsible for communicating intelligence data/information collected by the UASO back to the ATGS/UTOL for operational decision making. Remote sensing data currently acquired in wildland fire and other incident situations through NIROPS and other sources are the responsibility of the SIT Unit, and when fire intelligence data is produced, this information already passes to Ops through standard processes. UAS operations and the associated data would seem to align more seamlessly with the SIT Unit than with Air Ops; given how frequently data will need to be managed, analyzed, and integrated into other similar data services under the SIT Unit in an ICS structure.

2.6 UAS Demonstration

The flight demonstrations for the Public Safety Table Top Exercise were designed to show participants how small UAS performed in realistic mission conditions. Two missions were simulated; Search and Rescue and Mapping Coordination. Policy and procedures developed in Scenario 1 were used in the demonstrations to ensure they can support safe and successful missions. The two missions demonstrated three platforms that were part of the TTX toolkit: a Lockheed Martin (Sentera) Indago, a DJI Inspire, and a tethered aerostat (BlimpWorks) with an Inspire as the sensor payload.

- Lockheed Martin (Sentera) Indago: 2 flights, 0.7 hours
- DJI Inspire 1: 4 flights 1.1 hours
- Tethered aerostat: 1 flights 2.5 hours

<u>Search and Rescue Mission Summary</u>– During Hurricane Matthew, hundreds of search and rescue missions took place. The table top scenarios examined how UAS could be used to extend the capabilities of manned rescue aircraft by searching for individuals requiring assistance and directing the manned aircraft to their location. For the demonstration, we used an Indago to find a missing a hiker and the Inspire as a surrogate helicopter. The aerostat with its DJI Inspire derived payload was used for synoptic surveillance. The mission was successful. However, it did highlight the need for training and practice for the mission data capture to go smoothly.

The original plan was to use a manned helicopter for the search and rescue exercise. When the helicopter that was identified for the exercise was no longer available, we used the Inspire to simulate the helicopter. The Inspire is limited in its ability to simulate a manned helicopter; for instance, the Inspire does not display a heading, which is the standard method used by search and rescue personnel for directing manned aircraft to a location. The Indago UAS used as the search asset was able to provide both GPS coordinates as well as heading and distance to the missing person once detected, however this information must be consumable by the rescue asset to effect the rescue. In the case of a manned rescue helicopter or ground based search teams (if equipped with a compass or GPS), both of these pieces of information would be used to move the rescue asset to the missing person for rescue. It is recommended that agencies practice search and rescue missions with UAS before attempting actual operations.

Comments and Recommendations:

- Difficult to see individuals with existing technology (visual and thermal sensors), even flying at low altitudes. Experienced operators are a significant asset in these scenarios. Persons who are experienced performing search operations with UAS are much more likely to identify the often small and perhaps fleeting thermal or visual signature of a missing person in a real time search than those who have little experience operating these types of systems in high-stress dynamic mission scenarios.
- All parties need to be using the same maps for communication consistency and coordination.
- Having someone in direct contact with UAS PICs and manned aircraft pilots to coordinate the search and rescue efforts is essential. This can be the same person as the person acting as the on-site Air Boss. It can be quite difficult for a UAS PIC and a manned aircraft pilot to do all the coordination themselves without the assistance of an Air Boss or Search Coordinator due to the concentration each person has to have on their specific part of the mission. Coordination by someone who can concentrate on the big picture, rather than on the details of monitoring sensors for a missing individual, is extremely beneficial and highly recommended.
- Primary and backup radio communications systems are required.
- UAS used for SAR should have the aircraft heading (magnetic or true) displayed on their GCS. This is how ground crew directs aircraft to a location. In addition, it is preferable that UAS used for SAR should be able to provide GPS coordinates in real time for where the camera is looking. GPS coordinates can be communicated to rescue teams (airborne or ground based) relatively easily and nearly all rescue teams are equipped with GPS devices so this becomes a simple way to provide rescue location information to rescue teams.
- Agencies should train with air, ground, and water teams before responding to an incident.

- When coordinating manned aircraft and unmanned aircraft coordination, pilots need to keep in mind that manned aircraft typically report altitude in Mean Sea Level and unmanned aircraft use Above Ground Level altitude.

Mapping Coordination Mission – The mapping coordination mission examined a condition that actually occurred at Woodlake Dam. One aircraft was tasked by an agency to image the dam at close range (low level) to assess the current structural state of the dam and another was tasked to map the dam and surrounding area. Two aircraft were used: LM Indago mapping at 300 ft., Inspire at 50 ft. for situational awareness. Before the operation, the participants discussed the reasons to operate two aircraft near the small location to perform different missions (situational awareness, mapping). Both aircraft operated from the same take-off and landing location, but they were always separated vertically and horizontally. The site manager briefed both pilots on the operational parameters, including lost link and communications procedures, before flight operation began. This mission was possible because both pilots where well trained and have extensive experience operating UAS. Although mapping performance was not a focus of the Airspace Integration Exercise, participants discussed mapping requirements for various missions, chain of custody (LEI missions), and privacy issues. These should be a topic for another exercise.

Comments and Recommendations:

- Assign an Air Boss if two or more aircraft will be in the same airspace.
- Mission requirements including launch locations, endurance, flight altitudes (account for image resolution) should be addressed and briefed before mission is launched.
- A specific chain of command, radio frequencies, lost link procedures, lost communications, etc. should be coordinated preflight.
- Pilot qualifications need to be addressed to meet agency expectations, not just FAA.
- Define mission objectives and plan in advance of every operation.
- Define desired products that are expected data, type, accuracy, etc.
- Identify who will get the data and when, where it will be stored, and how it will be archived for data distribution.

Demonstration Review – The participants indicated that the flight demonstrations enhanced their knowledge and comfort level in UAS operations. The policies and procedures developed in Scenario 1 were successfully used to guide the demonstrations. However, it is recommended that further training and exercises should be held to test these tools to ensure they will produce safe and successful operational missions.

3 Summary and Recommendations

The Airspace Integration Table Top Exercise was positively reviewed as a successful event. The participants provided effusive praise for the organization and scope of the event. The TTX objectives were met. And the products are prepared to support the long term integration of manned and unmanned aircraft in the state. The participants and organizational team determined that it is feasible to safely integrate UAS in the airspace in disaster response situations with proper policies, procedures, and equipment. Additional TTXs would continue improving safe and effective integration of UAS in the NAS in additional situations, scenarios, and operating environments. Policy and guideline recommendations are provided in the detailed summary below. Both parts of the TTX, the classroom discussion and the live demonstration, were considered essential to accomplish the TTX objectives and evaluate the policy recommendations that were established in the beginning.

3.1 Summary

The following summary analysis of key points observed and discussed during the three day AI-TTX is provided below divided in three categories of feedback: TTX Objectives, TTX Format, and Open Feedback.

- TTX Objectives
    - Coordination of manned and Unmanned aircraft in the airspace was successful:
        - Formal aviation interaction experience was informative. Seeing proper aviation language, coordination, and methods demonstrated the need for robust protocols and structure that many participants had never been directly involved in before.
        - Civilian agencies cannot and will not treat unmanned aircraft systems as expendable resources. This is a different direction from many traditional military UAS operations.
        - Lines of command authority and acceptable degrees of autonomy in the technology are based on Standard Operating Procedures (SOP) and pre-defined policies.

        - Uncertainty about strategies for dealing with hobbyists persists. Including additional amateur operator role players (clubs/associations) in future TTX may help reduce that uncertainty and identify guidance for engagement.
    - Introducing UAS into a variety of scenarios and response conditions provided the context for developing guidance, best practices, and policies to support immediate integration. Several participants are launching UAS programs in 2017 and will use the results of this exercise.
    - Exposure to UAS technologies, UAS-related policies, and integration challenges such as communications and mission planning with small aviation assets provided a learning experience beyond any sales demonstration or promotional video for a UAS product.
    - Although the demo did not yield definitive results regarding UAS-enabled search mission performance, it did yield effective results for safe airspace integration. These results can be incorporated into future training exercises and focus future TTXs targeting search and lifesaving applications.

- <u>TTX Format</u>
    - Everyone appears to like this format and agreed that future TTXs should be scheduled to explore other operating environments, applications of the technology, and related policies.
    - The production materials need to better define various types of "missions" that apply to the scenarios: SAR, Location assessment, and Surveillance.
    - Exercise materials need more detailed content on current procedures, policies, and regulations. With this background, the TTX objectives can better scope which elements are being addressed and available for analysis. For instance, defining Line-of-Sight (LOS) operations and discussing whether or not that is a limitation for responder use that needs to be addressed through technology development or regulatory change. Night flight operations, radio frequency line-of-sight, and use of special imaging technologies are other examples. The

limitations on use of special imaging technologies on UAS in the current state statutes was a known topic of concern and is under assessment for policy change in the current General Assembly session.

- Actual footage of private drone use during Hurricane Mathew was examined and used to consider different procedures and/or policies. This was very useful and could have been brought in earlier in the exercise.

- Open Feedback
  - A Field Training Exercise (FTX) should be scheduled to prove integration concepts and transition recommended policies/guidelines into actual full scale flight operations (UAS and manned). These training exercises can be used to further develop the different qualifications and certifications required for UAS operators in different agencies and roles.
  - The TTX format encouraged Free Thinking and "Informed decision making," including allowing participants to interact with external organizations to gain better support of operations and policy questions. One of the table groups placed a phone call to Fort Bragg Air Operations to discuss access to the local Military Operating Area and restricted airspace operations to augment Scenario 3 learning. Another team submitted a real-time email to the FAA regarding expectations related to waiver approvals.
    - These external interactions are referenced in the results and recommendations. Participants were encouraged to begin any further external discussions with "This is an exercise/drill …"
    - The production team will review whether or not to allow external interfacing in future exercises or to keep the communications continued to the event participants or to make assumptions.
  - Agency responsibilities, liabilities, and autonomy regarding use of commercial services and private citizens offering UAS resources needs to be studied further. Concerns include liabilities, integration into the command and control communications structure, integration into the ICS structure, and whether or

not the policies and guidelines regarding use should be agency specific. Including FAA interaction in this analysis is strongly recommended.

3.2 Best Practices Recommendations

Based upon the game play and feedback from the TTX participants and staff the following recommendations and points-of-emphasis were identified to update the existing Best Practices guidelines (Appendix F) from NCDOT and NGAT specifically for emergency response operations. These recommendations are categorized by the original Best Practices distributed during the AI-TTX and should be considered guidance for UAS program management. **Recommendations marked with a "∗" are "preparedness" recommendations** intended to identify activities that should be done prior to any live event operations; these may include training, planning, or coordination types of activities to be efficient and effective during mission critical operations.

Expectation Management:

- Summary: This practice focuses on four concepts: mission planning, sharing the airspace, equipment life, and documentation requirements.
  - Establish operational thresholds and/or trigger points for UAS asset use and reassignment.
  - Develop an Incident Response Pocket Guide that describes to first responders the capabilities and limitation of UAS use during an incident. Example IRPG is in Appendix H.
  - ∗ Have local TFRs and Special Use Airspace and process specifics (controlling agency, time of use) mapped out and routinely updated to support the potential impacted mission areas within agency's jurisdiction.
  - ∗ Have pre-established and authorized COAs and Part 107 waivers to support mission expectations and potential operations. Examples may include night operations, aircraft larger than 55 lbs, or permission for flights over people.

Standard Operating Procedures:

- Summary: The operational procedures best practice outline internal processes for safe and effective flight operations. This includes roles and responsibilities, mission phases, and emergency procedures. The aim is to document everything that needs to be performed during a mission, so team members are using a standard reference.
- Air Space Control
    - Positive control of all aircraft, including manned and unmanned, must be established prior to any air operations.
    - Any incident requiring more than one aircraft (manned or unmanned) requires the local Incident Commander to identify an Air Boss or equivalent (i.e. Type III Air Support Group Supervisor).
    - Aircraft shall be separated both laterally and vertically and/or by time of entry and departure.
    - The Visual Observer is recommended to confirm visual separation of all aircraft.
    - For large incidents the Incident Commander shall request a Temporary Flight Restriction (TFR) through the FAA. In NC the local Emergency Management Agency can request the TFR on behalf of the Incident Commander.
    - UAS Ground Control Stations should have the aircraft heading (magnetic or true) displayed for the operator. This is how ground crews direct aircraft to a specific location.
    - When coordinating manned aircraft and unmanned aircraft pilots need to keep in mind that manned aircraft typically report altitude in Mean Sea Level and unmanned aircraft use Above Ground Level altitude
- Communications
    - All Ground to Ground communications shall be conducted via the 800 MHz VIPER Network (talk group to be designated by the local Incident Commander).

- All Air to Air, Ground to Air, or Air to Ground communications shall be conducted via the Aircraft band (frequencies determined per FAA regulation).
- Communications between the Incident Command structure and the flight crews should be limited to the IC and the Air Boss (or a single individual if an Air Boss is not required).
- All operational aircraft shall be grounded if there is another aircraft (manned or unmanned) in the airspace with whom communications cannot be established.
- Radio Frequencies should be assigned and documented during preflight planning, including primary and fallback channels.
- All UAS operators should broadcast "UAS launch" in the blind before they begin operations, "UAS activity" every 15 minutes during operations, and "UAS on the ground" at the end of operations.
- Cell Phones can be used as backup for Ground to Ground communications. A phone list should be developed and maintained with critical contacts' direct line information.

Crew Selection:

- Summary: This practice is recommended for setting UAS flight crew requirements including roles and responsibilities, training qualifications, and organizational decision-making hierarchy.

- Training
    - All pilots should obtain a Part 107 Remote Pilot Certificate
    - The Remote Aircraft Pilot, and Air Boss shall obtain a NCDOT UAS Permit. In lieu of a NCDOT UAS Permit, Visual Observers can be provided just in time training by the Mission Commander or Air Boss to support a live operation.
    - Pilots should be trained to North Carolina state and local UAS Policies and Procedures.

            - Pre-Flight Mission Checklist
            - Communication procedures.
        - ∗ Air Boss training includes:
            - At minimum Part 107 Remote Pilot Certificate
            - NCDOT Permit
            - E0986 – NIMS ICS Air Support Group Supervisor
            - Specific NC UAS Policies and Procedures.
- <u>Continuing Education</u>
    - Responsible government agencies shall convene the public safety UAS and manned aircraft operators and stakeholders (Incident Management Teams, Local Law Enforcement, etc.) to discuss policies, procedures, and relevant updates at least annually.
    - Organizations with UAS Programs, in-house or contract services, shall conduct Airspace Integration Exercises (Tabletop, Functional, or Full Scale) at least annually to validate procedures, updating training documents, and verifying desired performance objectives.

Policies:

➢ Summary: If an agency is intending to establish UAS operations this set of practices identifies the policies that should be considered essential for conducting transparent, legal, routine, managed UAS activities. Each policy should be customized to meet an agency's specific needs, but each of these policies should be included for responsible UAS Program Management.

- Have pre-vetted venders, assets, operators documented to ensure safety and adherence to rules and regulations. Use Basic Order Agreements (BOA) or other suitable contracting tools and update as necessary
- Establish a "Volunteer Aircraft Policy" for the agency:
    - Use of volunteer aircraft is at the discretion of the Incident Commander. Local liability policies and procedures apply.
    - All volunteer aircraft may fly under the Part 107 Remote Pilot Certificate

of the Air Boss, Mission Commander, or Air Support Group Supervisor.

- All volunteer aircraft pilots are required to show proof of the commercial NCDOT UAS Permit.
- If a TFR is established, any volunteer aircraft pilots shall have both a Part 107 Remote Pilot certificate and a NCDOT UAS Permit before being authorized to fly mission support.

Data Management:

- Summary: This practice recommends strategies for developing a data architecture to manage information captured during UAS operations using a defined data flow process.
- ∗ There should be standards on data quality, projections, coordinate, and file formats specified during mission planning.
- Video and imagery collected during an incident can be very large (Terabytes). Policies should be in place defining where the data is stored, how long it is to be kept, access permissions, etc.
- ∗ Commercially available products, like Mission Caster used during the TTX, allow for simultaneous, secure viewing of streaming information across multiple devices for us by different rescue resources and purposes. Procedures and distribution network should be in place before an incident occurs.
- ∗ Law Enforcement organizations must have procedures in place to address chain of custody issues for data captured during operational missions.

Public Outreach:

- Summary: Agencies should educate the public about any UAS Program plans including aircraft, sensors, and the types of activities the UAS will perform, expected outcomes and the risk mitigations implemented to ensure public safety. This education process should start early in the decision making process to include public comment opportunities and participation.

- ∗ Run a time-sensitive Public Affairs campaign educating the public on safe operations and consequences of unauthorized interference with manned and unmanned assets PRIOR to events like hurricanes. Add to Public Service Announcements or social media sites.
- Use social media to target hobbyists and other demographics that are buying and using drones to remind them of proper use during events. Communications channels could include Facebook pages, DOT UAS websites, drone club members.
- ∗ Release messages to target audience about rules, changes, legal issues, emergency event restrictions, etc.

Business/Operational Models and Procurement:

- Summary: This practice presents various business and operations models available to public agencies in the State of North Carolina. It includes procedures, best practices and internal processes for managing an agency's UAS acquisition process and flight operations.
- Business and Procurement models were not a focus of the TTX. However, counties, municipalities, and emergency monument agencies were strongly encouraged to evaluate their acquisition and staffing requirements thoroughly before starting a UAS program.

3.3 Miscellaneous Recommendations:

- NextGen Air Transportation (NGAT) Program should maintain a statewide list of local UAS resources and qualifications for public safety agencies to access. This database may be linked to the federal registration program and enable Reverse 911 support and direct communications.
- The state should use NGAT to stay engaged in national discussions regarding draft policies and procedures for ATC UAS "procedural control" concepts, such as sense-and-avoid, equipage mandates, and flight notifications.
- Establish a statewide standard for evaluating UAS crew member qualifications based on certifications, pilot experience (rotary vs fix, manned vs unmanned, etc.), and

capabilities. This program may also provide a classification program for equipment.

  - This program will determine how to recognize certifications from organizations such as NFPA, IACP, commercial training companies, and academic institutions.
  - Equipment vendors may provide info supporting new products that are available utilized and not previously vetted.
  - Vetted and approved service provider vendors may be allowed to assist in public operations if they meet specific qualifications and are current in required authorizations.
  - Official "Flight time" for credentialing should be measured from a device/mechanism that uses an embedded or integrated flight log within the control system for accountability i.e., use a log tracking tool to capture actual training hours such as Skyward 1.0.
- Resolve the confusion in the state statutes related to use of "special imaging technologies" on UAS to clarify whether or not public safety agencies can use thermal imaging sensors.

3.4 Recommendations for Additional Exercises

Based on the observations, results and value of this Airspace Integration TTX, an expansion of the TTX series is recommended to continue to examine key aspects of safe and effective UAS operations to support public safety and economic growth. These TTXs should be tailored to specific agency needs to fulfill preparedness training and familiarization with the new technologies and operational requirements. These TTXs can be organized and planned in the categories below:

- Technical Focus TTXs
  - Command, Control and Communications
  - Data management, retention and distribution
  - Night operations, UAS lighting, conflict with night vision devices and infrared system operations
- Mission Related Functional TTXs
  - Major storm coastal response to look at erosion and impacts on transportation

infrastructure system
    - Wildfire Management
    - Agency specific topical TTX
- Consider an Field Training Exercise (FTX) for UAS Search and Night Ops Integration
    - Phase 1 - UAS search
    - Phase 2 - UAS and Manned search
    - Phase 3 - Add ATC as role players for simulated TFR in MOA or simulated area for both search and rescue (SAR) with UAS and manned aircraft
    - Phase 4 - Proof of airspace integration success/validation via night ops

3.5 Lessons Learned

Following the TTX, the White Cell assembled to compile lessons learned to be applied to future TTX events. A listing of the significant lessons learned is provided below.

- Provide a Short Overview Brief to participants during participant recruitment:
    - Outline TTX objectives and format.
    - Brief overview of current related policies and best practices.
    - Brief quick overview/purpose of the various reference documents.
    - Description of duties of different roles for the exercises.
    - Note recent changes in federal regulations.
- Continue hosting the Pre-TTX Workshop with all participants to begin the interaction and establish relationships between participants.
- Have a HARD COPY Reference Binder at EACH Table or with the Facilitators (easy access).
- Have at least one computer per table with all appropriate software (likely the facilitator).
    - Consider same for one designated briefing computer
    - Dry Run with equipment and connections
    - GIS software, overlays and support provided
- Consider having a cross-section of operators and agencies at each table, but also consider participant level of experience.
- Should roles be better defined and add additional guidance or roles to keep people in the appropriate box?

    - Distribute the materials early! This provides guidance and opportunities for participants to prepare for role playing responsibilities.
    - Move toward HSEEP structure
- Allow the table to decide who fills what role based on Overview Brief.
    - Define enough game play roles so that all participants have a functional identity in the exercise.   This may mean defining more roles than participants, but everybody needs to associate with a role.
    - Break the table into appropriate groups and allow time prior to the scenario exercise to make sure they know what the limits and expectations of the functions are for the roles.
- Provide read-aheads and shared drive access earlier.
    - File management plan/structure/naming conventions
    - Have content ready prior to pre-event workshop
- Provide more white cell guidance and support. Have two white cell members per table (one facilitator and one to record proceedings).
- Provide better White Cell support to observers. They are important contributors in their ability to sit in on all groups and answer detailed questions without disturbing the work of the Table Groups.
- Rehearse flight demonstrations prior to exercise with specific links to TTX objectives.

Summary of Appendices

Appendix A **North Carolina Airspace Integration Exercise Executive Summary**

Appendix B **Participant Guidance and Operational Tasking Exercise Game Play Material**
This content was distributed during the exercise to Blue and Green Cell representatives at each table and key observers to follow along during the scenarios. This reference includes execution steps, guidance, actions, and critical questions to be answered during the exercise. The material is organized for specific participants by cell-type, not table assignment.

Appendix C **AI TTX Participant Roster**
These were registered participants that participated in the TTX, the pre-event workshop, or in external planning sessions.

Appendix D **Scenario Debrief Slides**
These slides include scenario debrief summaries, findings, comments, and imagery from each of the three table groups in the exercise.

Appendix E **Acronym List**
List of acronyms used in the report and during the TTX event.

Appendix F **Reference Library and Glossary**
Documents and terminology referenced during the TTX event, including the NGAT UAS Best Practices.

Appendix G **NGAT UAS Best Practices Guidebook**
Complete set of NGAT UAS Operational Best Practices for general UAS program management guidance.

Appendix H **Exercise Toolbox**
Descriptions of the UAS and software tools available for integration and applications during the game play scenarios.

Appendix I **NC UAS Airspace Integration Exercise Reference Guides**
UAS Reference Information
UAS Incident Response Pocket Guide Template
UAS Best Practices – Integration Response

Appendix A: North Carolina Airspace Integration Exercise Executive Summary

NCDOT Airspace Integration Exercise Series Purpose

NCDOT is leading the statewide safe integration of Unmanned Aircraft Systems (UAS) by sponsoring a series a Table Top Exercises (TTXs) through the NextGen Air Transportation Program (NGAT) at NC State University. These exercises are designed to support the transition of UAS capabilities into response preparedness planning, identify command and control requirements for UAS operations, provide potential users with situational experience with UAS, and provide test cases for evaluating policy and regulations related to UAS management at the state and local level.

Airspace Integration TTX Purpose:

- ❑ Provide an exercise environment to study UAS capabilities and benefits to public safety applications in a post-storm response context.
- ❑ Understanding the airspace integration challenges to enable UAS as a new capability to assist NCDOT, Law Enforcement and Emergency Managers in situational awareness and response activities during a major flood event such as Hurricane Matthew.
- ❑ Support the safe and responsible integration of UAS into the National Airspace System for use by public agencies across North Carolina.

Exercise Objectives:

1. Examine airspace integration issues when UAS are operated in the National Airspace System (NAS) with manned aircraft and other unmanned aircraft.
2. Develop policies and procedures to ensure the safe use of airspace while responding to natural and man-made disasters.
3. Use actual flooding and traffic management information collected during the aftermath of Hurricane Matthew as the ground scenario basis to examine UAS operations.
4. Examine how to best employ UAS to assist public safety officials during dynamic disaster events.
5. Examine the potential to integrate UAS into standard Search and Rescue (SAR) airspace management.
6. Develop guidelines for private and commercial UAS use in disaster response and recovery.
7. Examine and evaluate draft UAS Best Practices for Incident Response.

Exercise Highlights:

- 51 participants from NCDOT, NC Emergency Management, local Emergency Management and Law Enforcement organizations, industry, Virginia DOT and Emergency Management, and others.
- Participants were divided into three groups for scenario game play with an observer group and organizational group watching and injecting information into the exercise.
- A successful demonstration of airspace integration was performed using multiple aircraft, including a tethered aerostat, to evaluate UAS capabilities for Search missions and situational assessment of infrastructure integrity.
- A UAS Reference Guide, Best Practices, and Program Integration Recommendations Template are included as reference materials in the Final Report.

Appendix B: **Participant Guidance and Operational Tasking**

NCDOT and NGAT UAS Airspace Integration Table Top Exercise (TTX) 17 – 19 January 2017

Airspace Integration TTX Game Play Material

This Planning Document provides a compilation of the Guidance, Actions, Instructions, Questions and Scripts which were provided to the TTX participants and observers. The material is organized by TTX Cell with all the intended material which was used during each scenario and game step. Upon completion, the document was segmented into separate documents and provided to each participant according to their assignment.

All guidance provided for earlier scenarios applied to subsequent scenarios. Scenario 1 provided the opportunity to examine airspace integration issues and procedures to set a level of understanding for the two disaster response tactical scenarios. Similarly for the tactical scenarios, the guidance provided in earlier game steps applied to subsequent game steps.

Cell definitions and organizations:

- Blue Cell: Airspace Management Experts. This group of individuals provided each table group with the necessary expertise to effectively manage the airspace during the scenarios. The most experienced Blue Cell representative at each table functioned as the "***Air Boss***" and made final decisions on airspace allocation and direct aircraft in the area through the EOC (Green Cell) or directly to the UAS PIC (Purple Cell). Other Blue Cell representatives at the table assisted in Airspace Deconfliction and SAR aircraft planning.
- Green Cell: State and County Agency representatives with (or anticipating to have) UAS programs filled the role of the EOC. The Green Cell representative at each table with the most emergency response experience functioned as the ***Incident Commander***. The Incident Commander planned and executed the operations for each game step and made assignments of available UAS to the PICs at the table. The ***SAR Mission Commander (SMC)*** and other Green Cell representatives at the table assisted with UAS/manned SAR aviation management and communications.
- Purple Cell: UAS Industry Experts. These participants filled the roles of UAS Aircrew PIC and assisted in the planning and execution of assigned UAS flight operations using the UAS in the TTX Toolkit.
- Observers: Individuals invited to the TTX to observe and assess the actions and decisions of the cells working in each of the three table groups. Observers were not assigned to any table and could roam around in order to gather information and answer the questions provided.
- White Cell: TTX planners and managers who controlled and moderated the actions and discussions at each table. They also recorded and evaluated the actions and discussions of the Blue, Green and Purple cell participants as they responded to the scenarios.

Airspace Management (Blue Cell) Material

I. Scenario 1: Airspace Integration Basics – Moore County

II. Scenario 2: Cumberland County Operational Scenario

Cameron Road
Table 1

Morrozoff Drive
Table 2

Pennystone Drive
Table 3

1. Step 1: Planning During Storm

A. Guidance

1) See airspace integration management policies, procedures and planning documents from Scenario 1.
2) To the maximum extent possible, follow the guidance in the UAS Search and Rescue Addendum to the National/International SAR Manual. In particular, consult Appendix F: Planning Considerations Prior to UAS Operations.
3) To the maximum extent possible, plan for UAS Search and Manned Rescue (USMR) operations.
4) To the maximum extent possible, control UAS/manned airspace integration based on time, altitude and geographic reference.

B. Actions

1) Respond to Incident Commander and EOC requests for UAS airspace .
2) Coordinate airspace to ensure safe integrated operations.

C. Questions

1) Can you effectively conduct integrated manned and UAS operations by segmenting the airspace in time, altitude and geographic reference?

2) To what degree did you use the UAS SAR Addendum in your planning? If not, why not?

2. Step 2: Initial Search and Rescue Operations

A. Guidance

1) Continue guidance from previous scenarios and steps.
2) Assume reliable and effective communications with EOC, manned aircraft and deployed UAS flight crew.

B. Actions

1) Respond to Incident Commander and EOC requests for airspace access as scenario develops.
2) Simulate aircraft check-in and control procedures to direct manned and UAS operations.
3) Receive and respond to airspace incidents and violations.
4) Review and mark up draft Best Practices based on scenario actions and discussions.

C. Questions

1) Were you able to safely execute UAS Search and Manned Rescue (USMR) operations?
2) Were the PIC and VO positions clearly reported by the UAS flight crew and did they safely complete operations maintaining their UAS within visual LOS?

3. Step 3: Extended Search and Rescue Operations

A. Guidance

1) Continue guidance from previous scenarios and steps.
2) Anticipate reactive requests for airspace due to rising flood waters.

B. Actions

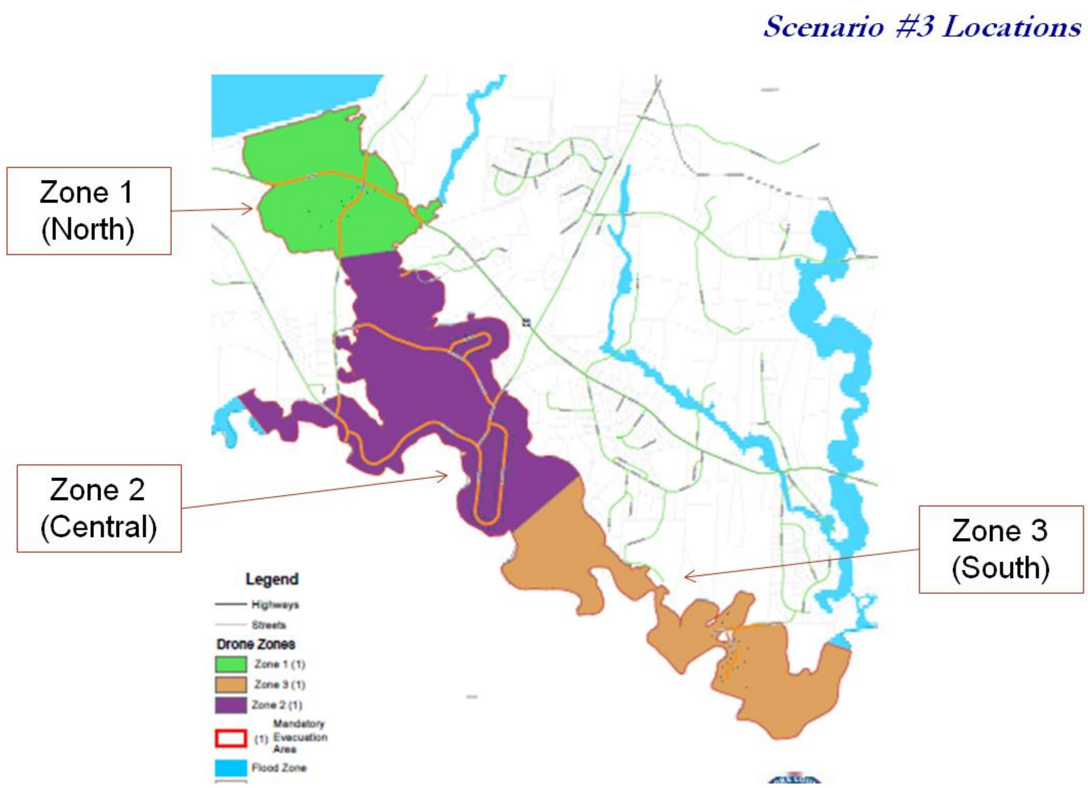
1) Continue actions from Step 2.

C. Questions

1) Was the airspace allocated and safely managed to meet SAR and evacuation route survey requests of the EOC?

2) Were nighttime operations with IR capable UAS requested? Were they approved? If not requested, would you have approved them?

III. Scenario 3: Moore County Operational Scenario



1. Step 1: Planning During Storm

A. Guidance

1) See airspace integration management policies, procedures and planning documents from Scenario 1.
2) To the maximum extent possible, follow the guidance in the UAS Search and Rescue Addendum to the National/International SAR Manual. In particular, consult Appendix F: Planning Considerations Prior to UAS Operations.
3) To the maximum extent possible, plan for UAS Search and Manned Rescue (USMR) operations.
4) To the maximum extent possible, control UAS/manned airspace integration based on time, altitude and geographic reference.

B. Actions

1) Respond to Incident Commander and EOC requests for UAS airspace.

2) Coordinate airspace to ensure safe integrated operations.

C. **Questions**

1) Did you allow commercial UAS to operate under Part 107 or did you require them to operate under the COA?
2) Were there some missions that you would require public UAS over commercial?

2. Step 2: Data Collection and Planning for Potential Dam Breach

A. **Guidance**

1) Continue guidance from previous scenarios and steps.
2) Assume reliable and effective communications with EOC, manned aircraft and deployed UAS flight crew.

B. **Actions**

1) Respond to Incident Commander and EOC requests for airspace access as scenario develops.
2) Simulate aircraft check-in and control procedures to direct manned and UAS operations.
3) Receive and respond to airspace incidents and violations.
4) Review and mark up draft Best Practices based on scenario actions and discussions.

C. **Questions**

1) Did you disapprove any UAS data collection flights? If so, for what reasons?
2) Did the flight crews respond to instructions to clear the airspace for higher priority manned flights?

3. Step 3: Response to Dam Breach

A. **Guidance**

1) Continue guidance from previous scenarios and steps.
2) Anticipate reactive requests for airspace due to rising flood waters.

B. **Actions**

1) Continue actions from Step 2.

C. **Questions**

1) Did you consider allowing operations beyond the limits of Part 107 and locally approve waivers based on the importance of the data to be collected?
2) How did you respond to the ad hoc requests injected into this scenario?

State and County UAS Agencies (EOC - Green Cell) Material

I. Scenario 1: Airspace Integration Basics – Moore County

II. Scenario 2: Cumberland County Operational Scenario

See Map Graphics in Blue Cell Section

Cameron Road Table Group 1	Morrozoff Drive Table Group 2	Pennystone Drive Table Group 3
• Inspire • UX-5 • Airprobe Besra	• Inspire • ZX-5 • Indago • Airprobe Besra	• Inspire • Penguin • Tethered aerostat • Airprobe Wraith

1. Step 1: Planning During Storm

A. Guidance

1) Adhere to "First Protocol of Unmanned Aircraft Use" during this entire TTX, which dictates that UAS will <u>ALWAYS</u> defer to the manned asset and give way, to the point of disposing of the UAS in the most expeditious manner necessary to adhere to the protocol.
2) All UAS will be flown under NGAT COA and all aircraft meet flight worthiness requirements.
3) All UAS flight crew (PICs & VOs) are adequately trained. Assume that they will use their own hearing and reports of visual observers to detect an approaching heavy helicopter in addition to radio communications to maneuver the UAS to give way.
4) To the maximum extent possible, follow the guidance in the UAS Search and Rescue Addendum to the National/International SAR Manual. In particular, review and apply the Risk Assessment Considerations and Environmental Factors (Section 3-2) and Planning Considerations Prior to UAS Operations (Appendix F).
5) Every UAS flight crew is equipped with a ground-to-air aviation radio and tactical communications back to Incident Command and the Air Boss.
6) Safe and efficient ground transportation is available to support UAS flight crews in getting to their designated operating areas.

7) Assign UAS flight crews to collect imagery of either a pre-designated area or requested points of interest;
8) EOC should review & sort UAS data to prevent SAR responder sensor data overload and prioritize the actions of the SAR teams. Relay UAS data to searchers, and provide details of location and physical description of identified points of interest.
9) Assume searchers and UAS teams have a direct radio channel to communicate.
10) Assume searchers have the ability to see imagery and points of interest on a mobile device such as a tablet or laptop.

B. Actions

1) Assess the probable flooding areas and request manned and UAS airspace from Air Boss to support EOC SAR and Evacuation operations.
2) Develop a coordinated SAR plan using the assigned UAS and the manned helos.
3) Plan for UAS Search and Manned Rescue (USMR) operations.
4) Request control of UAS/manned airspace integration based on time, altitude and geographic reference.

C. Questions

1) Did the UAS SAR Addendum provide sufficient guidance for UAS planning? If not, what changes would you recommend?
2) Did you have a sufficient number of UAS with appropriate capabilities to plan your SAR missions?

2. Step 2: Initial Search and Rescue Operations

A. Guidance

1) Continue guidance from previous scenarios and steps.
2) SAR operations will have a higher priority for UAS operations over citizen evacuation route and traffic management survey missions.

B. Actions

1) Incident Commander will conduct an EOC briefing for the table group on all operations planned during the game step.

2) Consider positioning a tethered aerostat with communications repeaters and relays in areas with degraded cell networks and to assist in UHF radio communications. A long endurance fixed wing UAS could also fill this function.
3) Execute operational plans for cooperative UAS Search/ Manned Rescue (USMR).
4) Segment UAS airspace requests by neighborhood.
5) Identify potential L&R sites and positions for PIC & VO.
6) Communicate UAS flight plan to Blue Cell (approval) and Purple Cell (Execution).
7) Assess information provided by UAS flight crews and adapt SAR operations appropriately.
8) Assess AI deconfliction procedures.
9) Assess communication and data reporting procedures with UAS flight crews.
10) Respond to ad hoc requests for UAS operations.
11) If UAS assets are available, request flights to survey evacuation routes and assist in traffic management.

C. Questions

1) To what degree did having UAS available improve the effectiveness of your manned aircraft and swift water SAR response?
2) Can you safely and effectively conduct UAS Search and Manned Rescue (USMR) operations?

3. Step 3: Extended Search and Rescue Operations

A. Guidance

1) Continue guidance from previous scenarios and steps.
2) Anticipate rising flood waters and adjust UAS operations accordingly.

B. Actions

1) Incident Commander will conduct an EOC briefing for the table group on all operations planned during the game step.
2) Execute modified operational plans for cooperative UAS Search/ Manned Rescue (USMR) as required for rising flood waters.

3) Continue actions assigned in Step 2.

4) Review and mark up draft Best Practices based on scenario actions and discussions.

C. Questions

1) How did you assess and execute the ad hoc operation requests injected into the scenario?

2) Would the authorization of BLOS UAS operations improve the SAR response or enable better evacuation route surveys?

III. Scenario 3: Moore County Operational Scenario

See Map Graphics in Blue Cell Section

Zone #1 (North) Table Group 1	Zone #2 (Central) Table Group 2	Zone #3 (South) Table Group 3
• Inspire • ZX-5 • Airprobe Wraith • Tethered aerostat	• Inspire • Penguin • Tethered aerostat	• Inspire • UX-5 • Airprobe Besra • Indago

1. Step 1: Planning During Storm

A. Guidance

1) Continue guidance from previous scenarios and steps.

2) To the maximum extent possible, follow the guidance in the UAS Search and Rescue Addendum to the National/International SAR Manual. In particular, review and apply the Risk Assessment Considerations and Environmental Factors (Section 3-2) and Planning Considerations Prior to UAS Operations (Appendix F).

3) All commercial UAS provided meet Part 107 requirements will be operated by Part 107 Remote Pilots in Command.

B. Actions

1) Assess the probable flooding areas and request manned and UAS airspace from Air Boss to support EOC SAR and Evacuation operations.

2) Develop a coordinated SAR plan using the assigned UAS and the manned helos.
3) Plan for UAS Search and Manned Rescue (USMR) operations.
4) Request control of UAS/manned airspace integration based on time, altitude and geographic reference.
5) In addition to SAR planning, a number of UAS should be deployed to collect imagery on the Woodlake Dam.

C. Questions

1) How did you employ the commercial UAS?
2) Are there any missions where you would only employ public UAS?

2. Step 2: Data Collection and Planning for Potential Dam Breach

A. Guidance

1) Continue guidance from previous scenarios and steps.
2) Allocate available UAS to both SAR missions and Woodlake Dam inspections.
3) Safe and effective ground transportation is available to deploy all UAS flight crews.

B. Actions

1) Incident Commander will conduct an EOC briefing for the table group on all operations planned during the game step.
2) Consider positioning a tethered aerostat with communications repeaters and relays in areas with degraded cell networks and to assist in UHF radio communications. A long endurance fixed wing UAS could also fill this function.
3) Execute operational plans for cooperative UAS Search/ Manned Rescue (USMR).
4) Segment UAS airspace requests by neighborhood.
5) Assign Part 107 commercial assets to missions where they would be best suited.
6) Identify potential L&R sites and positions for PIC & VO.
7) Communicate UAS flight plan to Blue Cell (approval) and Purple Cell (Execution).

8) Assess information provided by UAS flight crews and adapt SAR operations appropriately.
9) Assess AI deconfliction procedures.
10) Assess communication and data reporting procedures with UAS flight crews.
11) Respond to ad hoc requests for UAS operations.
12) If UAS assets are available, request flights to survey evacuation routes and assist in traffic management.
13) Request authority to continue UAS operations as PIC repositions due to rising flood waters.

C. Questions

1) How did the EOC team make SAR UAS assignments?
2) Was there any difference in the quality or quantity of data collected by commercial versus public UAS?

3. Step 3: Response to Dam Breach

A. Guidance

1) Continue guidance from previous scenarios and steps.
2) At the beginning of Step 3, an engineer on-site reported the Woodlake Dam spilling over with significant erosion. He needed to evacuate his position and would no longer be in position to report. No other reports are being received from the dam.
3) Law enforcement has reported rapidly rising waters at the first east/west road south of the dam and has stopped traffic flow.
4) Allocate available UAS to SAR, neighborhood evacuation monitoring and dam stability flights.

B. Actions

1) Incident Commander will conduct an EOC briefing for the table group on all operations planned during the game step.
2) Assign available UAS assets to support dam monitoring, SAR operations and evacuation support.
3) Continue actions assigned in Step 2.

C. Questions

1) How did you prioritize UAS assignments?
2) How did you manage the dynamic requirements for UAS airspace requests in response to the dam breach to support the safe evacuation of the general public?

UAS Expert Industry Support (Purple Cell) Material

I. Scenario 1: Airspace Integration Basics – Moore County

II. Scenario 2: Cumberland County Operational Scenario

See Map Graphics in Blue Cell Section

See UAS allocated to table group in Green Cell Section

See Tool Kit for Assigned UAS Capabilities

1. Step 1: Planning During Storm

A. Guidance

1) Adhere to "First Protocol of Unmanned Aircraft Use" during this entire TTX, which dictates that UAS will ALWAYS defer to the manned asset and give way, to the point of disposing of the UAS in the most expeditious manner necessary to adhere to the protocol.
2) Assume all UAS flight crew (PICs & VOs) are adequately trained. Assume that they will use their own hearing and reports of visual observers to detect an approaching heavy helicopter in addition to radio communications to maneuver the UAS to give way.
3) Assume every UAS flight crew is equipped with a ground-to-air aviation radio and tactical communications back to Incident Command and the Air Asset Manager.
4) To the maximum extent possible, follow the guidance in the UAS Search and Rescue Addendum to the National/International SAR Manual. In particular, review and apply the Risk Assessment Considerations and Environmental Factors (Section 3-2) and Planning Considerations Prior to UAS Operations (Appendix F).

B. Actions

1) Support EOC staff in planning UAS SAR flights.
2) Locate optimum L&R, PIC and VO locations to execute the tasking.

C. Questions

1) Did the EOC use the best available UAS for each mission?
2) What were the difficulties in choosing L&R, PIC and VO locations for the assigned missions?

2. **Step 2: Initial Search and Rescue Operations**

   A. **Guidance**

      1) Continue guidance from previous scenarios and steps.
      2) Assume safe and reliable ground transportation is available for UAS flight crew to and from deployment areas.
      3) Assume reliable and effective communications with Air Boss, EOC, manned aircraft and deployed UAS flight crew.

   B. **Actions**

      1) Respond to EOC tasking for UAS flights at specific locations.
      2) Mark the L&R, PIC and VO locations on GIS (electronic or hard copy) for each mission tasking.
      3) Obtain clearance for flight from Air Boss and follow simulated radio instructions during flight ops.
      4) Accurately simulate the capabilities of the UAS assigned.
      5) Determine the amount of data collected based on UAS assigned, its sensor suite and endurance.
      6) Collect imagery of either a pre-designated area or requested points of interest.
      7) Review all imagery in the mobile command vehicle by laptop while looking for abnormalities that might include odd shapes or colors.
      8) Contact searchers (simulated at EOC) and provide details of location and physical description of identified points of interest.
      9) Report results of flight operations and standby for further tasking.

   C. **Questions**

      1) Were UAS operations unduly restricted?
      2) Were all available UAS deployed on at least one mission? If not, why not?

3. **Step 3: Extended Search and Rescue Operations**

   A. **Guidance**

      1) Continue guidance from previous scenarios and steps.

   B. **Actions**

1) Continue actions from Step 2.

C. Questions

1) How did you monitor for the viability of the selected PIC and VO locations given the progression of the flood waters?

2) Were there any unsafe airspace incidents or potential incidents based on game play decisions? If so, what were they?

III. Scenario 3: Moore County Operational Scenario

See Map Graphics in Blue Cell Section
See UAS allocated to table group in Green Cell Section

See Tool Kit for Assigned UAS Capabilities

1. Step 1: Planning During Storm

A. Guidance

1) Continue guidance from previous scenarios and steps.

2) Locate optimum L&R, PIC and VO locations to execute the tasking.

3) To the maximum extent possible, follow the guidance in the UAS Search and Rescue Addendum to the National/International SAR Manual. In particular, review and apply the Risk Assessment Considerations and Environmental Factors (Section 3-2) and Planning Considerations Prior to UAS Operations (Appendix F).

B. Actions

1) Support EOC staff in planning UAS SAR flights.

C. Questions

1) Were the commercial Part 107 UAS appropriately integrated into the SAR plan?

2) Were there any unreasonable requirements placed on the commercial UAS compared to the pubic UAS?

2. Step 2: Data Collection and Planning for Potential Dam Breach

A. Guidance

1) Continue guidance from previous scenarios and steps.

B. Actions

1) Respond to EOC tasking for UAS flights at specific locations.

2) Mark the L&R, PIC and VO locations on GIS (electronic or hard copy) for each mission tasking. Indicate LOS boundaries.
3) Obtain clearance for flight from Air Boss and follow simulated radio instructions during flight ops.
4) Determine the amount of data collected based on UAS assigned, its sensor suite and endurance.
5) Collect imagery of either a pre-designated area or requested points of interest.
6) Review all imagery in the mobile command vehicle by laptop while looking for abnormalities that might include odd shapes or colors.
7) Contact searchers (simulated at EOC) and provide details of location and physical description of identified points of interest.
8) Report results of flight operations and standby for further tasking.
9) Anticipate the risk of rising flood waters to UAS flight crew and be ready to take action to evacuate.

C. Questions

1) Were there any changes to the planned UAS mission requested during a flight crew deployment?
2) Were you able to remain clear of reported or observed manned aircraft?

3. Step 3: Response to Dam Breach

A. Guidance

1) Continue guidance from previous scenarios and steps.

B. Actions

1) Continue actions from Step 2.
2) If flight crew evacuation is required, consider requesting permission to continue UAS flights while PIC and VO are mobile in their vehicles.

C. Questions

1) What was the most effective method of communicating critical information observed to local searchers and the EOC?
2) Which missions and data requests were the best employment of UAS? Please rank the following: SAR, dam stability monitoring, flood water progression and emergency evacuation route surveys.

Observer Material

I. Scenario 1: Airspace Integration Basics – Moore County

II. Scenario 2: Cumberland County Operational Scenario

1. Step 1: Planning During Storm

A. Guidance

1) Monitor the development of the airspace planning process how it complies with the airspace integration management guidance developed in Scenario 1.
2) Observe the interaction between Green (EOC) Cell managing the emergency and the Blue (Airspace) Cell managing the airspace.
3) Provide comments and recommendations as appropriate and record them in the evaluation form.

B. Questions

1) Was the airspace managed safely?
2) Did the cells allocate the available manned and UAS assets effectively to conduct SAR?
3) Does the concept of UAS Search and Manned Rescue (USMR) have value and can it be safely implemented in most SAR situations?
4) Did the cells use the draft Best Practices in their planning?
1) Did the cells use the UAS Addendum to the National/International SAR Manual in their planning?

2. Step 2: Initial Search and Rescue Operations

A. Guidance

1) Monitor the development of the scenario and how the Green, Blue and Purple Cells coordinate their actions.
2) Assess how the operations planned in Step 1 were executed in Step 2.
3) Look for opportunities where alternative operation decisions could improve airspace safety or disaster response efficiency.
4) Provide comments and recommendations as appropriate and record them in the evaluation form.

B. Questions

1) Was the airspace managed safely?

2) Were the UAS flights executed in accordance with the assigned flight plans?
3) Were communications among the Blue, Green and Purple Cells effective and support airspace safety and SAR efficiency?
4) Were the UAS PIC and VO positioned appropriately?
5) If executed, did the concept of UAS Search and Manned Rescue (USMR) have value and was it safely executed?
6) Did the cells use the UAS Addendum to the National/International SAR Manual in their planning?

3. Step 3: Extended Search and Rescue Operations

A. Guidance

1) Monitor the development of the scenario and how the Green, Blue and Purple Cells coordinate their actions.
2) Monitor the airspace allocation decisions made in response to Incident Commander requests.
3) Look for opportunities where alternative operation decisions could improve airspace safety or disaster response efficiency.
4) Provide comments and recommendations as appropriate and record them in the evaluation form.

B. Questions

1) Did the EOC gather the best available information to support the progression of the flooding?
2) Was the airspace allocated and safely managed to meet SAR and evacuation priorities?
3) How did the participants respond to the ad hoc scenario inject items provided?
4) Would the authorization of BLOS UAS operations significantly improve SAR operations without significantly affecting safety?
5) Did the EOC consider night UAS operations? If so, were they requested and were they approved?
6) What is your estimate of how many more rescues (%) could be made using UAS Search and Manned Rescue (USMR) cooperative operations?

III. Scenario 3: Moore County Operational Scenario

1. Step 1: Planning During Storm

A. Guidance

1) Monitor the development of the airspace planning process how it complies with the airspace integration management guidance developed in Scenario 1.
2) Observe the interaction between Green (EOC) Cell managing the emergency and the Blue (Airspace) Cell managing the airspace.
3) Observe how the Green and Blue Cells incorporate the use of commercial Part 107 UAS.
4) Provide comments and recommendations as appropriate and record them in the evaluation form.

B. Questions

1) Was the airspace managed safely?
2) Did the cells allocate the available manned and UAS assets effectively to conduct SAR and general public evacuation?
3) Did the cells use the UAS Addendum to the National/International SAR Manual in their planning?
4) Did the Blue Cell allow commercial UAS operations under Part 107 or did they require commercial UAS operations under the COA?
5) Were there any additional training or certification requirements discussed or required for the Part 107 UAS?
6) Should commercial UAS be pre-registered/certified with EM jurisdictions? If so, what would their training and operations currency be?
7) If yes to #6, how could they be placed under contract?

2. Step 2: Data Collection and Planning for Potential Dam Breach

A. Guidance

1) Monitor the development of the scenario and how the Green, Blue and Purple Cells coordinate their actions.
2) Assess how the operations planned in Step 1 were executed in Step 2.

3) Monitor for differences in how public and commercial UAS are assigned and operated.
4) Look for opportunities where alternative operation decisions could improve airspace safety or disaster response efficiency.
5) Provide comments and recommendations as appropriate and record them in the evaluation form.

B. Questions

1) Was the airspace managed safely?
2) Were the UAS flights executed in accordance with the assigned flight plans?
3) Were communications among the Blue, Green and Purple Cells effective and support airspace safety and SAR efficiency?
4) Did the cells use the UAS Addendum to the National/International SAR Manual in their planning?
5) How were commercial UAS used? Was there any discernible difference between their operations and those of the public UAS?
6) Would having commercial UAS integrated into the National Guard or Civil Air Patrol provide value in organizing Part 107 responders?

3. Step 3: Response to Dam Breach

A. Guidance

1) Monitor the development of the scenario and how the Green, Blue and Purple Cells coordinate their actions.
2) Monitor the airspace allocation decisions made in response to Incident Commander requests given the dam breach.
3) Look for opportunities where alternative operation decisions could improve airspace safety or disaster response efficiency.
4) Provide comments and recommendations as appropriate and record them in the evaluation form.

B. Questions

1) Did the EOC gather the best available information to support the progression of the dam breach flood waters?

2) Was the airspace allocated and safely managed to meet SAR, dam monitoring and evacuation priorities?
3) What Part 107 waiver conditions could improve SAR operations without significantly affecting safety?
4) How did the participants respond to the ad hoc scenario inject items provided?
5) Did the UAS improve or detract from the emergency response?
6) Based on your observations of the three scenarios, do you concur that the below recommendations made following the 2015 Texas Memorial Day flood should be instituted in North Carolina:
    a) Joint training exercises should be created that involve manned air assets, unmanned aerial systems, and ground-based resources.
    b) All unmanned resources wishing to operate within the state should participate in regularly scheduled joint training exercises and become pre-approved to participate in real-world scenarios.
    c) A list of pre-approved, unmanned resources should be maintained and distributed for use by Incident Commanders.

Exercise Control Group (White Cell) Material

White Cell Guidance

- White Cell planning and execution are the keys to a successful event
  - Gather what is going on at a high level
  - Keep discussion flowing and inject staged information
  - Assist table groups prepare their scenario debriefs using formatted PowerPoint slides
  - **Capture things so they don't get lost – If it's not recorded, it didn't happen**
- Sequence the events to focus on the scenario
  - Develop a list of questions for each cell/table group to examine and report on
  - Establish context for the policy, issues and barrier discussions
  - Discuss "how" a search/collection would be conducted vice conducting one
- Present a set of initial data using an historical event as the baseline
  - Brief what actually happened with resultant metrics (Hurricane Matthew)
  - Conduct the exercise with the allocated UAS to assess how airspace would be safely and effectively managed to accommodate increasing numbers of UAS
- Engage participants and observers on where UAS should be used
- Discuss how best to get UAS and their data in the hands of emergency responders and managers
  - Develop a list of critical questions to examine on a continuing basis
  - Generate analytical data to support expanded use of UAS
- Develop compelling data to justify changes
  - Understand the outcome differential between disaster response with & without UAS
  - Focus on safely managing the airspace to help save lives and property
  - What policy, management and budget changes are required?

I. Scenario 1: Airspace Integration Basics – Moore County

Guidance will be provided during the TTX.

II. Scenario 2: Cumberland County Operational Scenario

1. Step 1: Planning During Storm – Instructions

A. Stimulate intra-cell discussions within Green (planning how to plan UAS support to SAR) and Blue (how are they going to manage the airspace to support integrated manned and UAS operations).

B. Stimulate inter-cell discussions between Green and Blue cells (requesting airspace and developing integrated air operations).

C. Monitor and encourage completion of assigned actions.

D. Let participants do the talking but be ready to redirect discussion during quiet periods and if discussions deviate from the scenario actions.

E. Prompt participants to begin answering questions.

F. Assist Observers. Be ready to answer their questions. Attempt to keep them from participating in table group discussions unless they have important and valid points to inject.

G. RECORD and TAKE NOTES – of the proceedings, decisions, questions raised, and interactions between cells, issues.

2. Step 2: Initial Search and Rescue Operations – Instructions

A. Stimulate inter-cell discussions between Green and Blue cells (requesting airspace and developing integrated air operations).

B. Ensure the geographic locations of simulated flood waters get recorded and used to make SAR and evacuation planning decisions.

C. Ensure locations of UAS Operations (L&R, PIC and VO locations) are recorded.

D. Ensure UAS operations and data collected accurately reflect the capabilities of the UAS allocated to the step.

E. Monitor and record how the cells deconflict manned and UAS airspace.

F. Monitor and encourage completion of assigned actions.

G. Let participants do the talking but be ready to redirect discussion during quiet periods and if discussions deviate from the scenario actions.

H. Prompt participants to begin answering questions.

I. Assist Observers. Be ready to answer their questions. Attempt to keep them from participating in table group discussions unless they have important and valid points to inject.

J. RECORD and TAKE NOTES – of the proceedings, decisions, questions raised, and interactions between cells, issues.

3. Step 3: Extended Search and Rescue Operations

A. Instructions

1) Same as in Step 2.
2) Present inject items for each Table as specified below at the approximate time indicated in the script below.
3) Monitor the discussions near the end of the time period and prepare to transition to stopping discussion and preparing the outbrief slides. (Outbrief slides are key components of the TTX report). Expect that discussions will continue while preparing slides as their thoughts become organized.

B. Injects

1) Table 1 Insert: Unauthorized volunteer helo checks in and reports inbound to search for his stranded boss, family and friends in area assigned to UAS neighborhood SAR search. (Select house nearest flood waters)
2) Table 2 Insert: UAS conducting high priority mission suffers lost link then crashes. Replacement UAS required.
3) Table 3 Insert: Helo required for rooftop rescue in flooded cul-de-sac in neighborhood assigned to UAS. (Select house nearest flood waters) Simulate loss of comms between Air Boss and UAS Flight Crew.

Scenario 2 Script: Day 2 – Wednesday, 18 January

Note: Scenario 2 Briefing Scheduled for 1630 on Day 1

Time	Step	Action
0815		Exercise Play Begins
0815	1 – Planning During Storm	Step 1 Begins
0855	1	Wrap up Step 1 Discussion and Identify Key Points for Debrief
0900	1	Step 1 Ends
0900	2 – SAR Operations	Step 2 Begins
0940	2	Wrap up Step 2 Discussion and Identify Key Points for Debrief
0945	2	Step 2 Ends
0945	3 – Extended SAR Ops	Step 3 Begins
1020	3	Step 3 Inserts (See Table Inserts Below)
1040	3	Wrap up Step 3 Discussion and Identify Key Points for Debrief
1045	3	Step 3 and Exercise Play End
1045		Begin Drafting Debrief Slides
1145		End Scenario 2

Scenario 3: Moore County Operational Scenario

1. **Step 1: Planning During Storm - Instructions**

    C. Stimulate intra-cell discussions within Green (planning how to plan UAS support to SAR) and Blue (how are they going to manage the airspace to support integrated manned and UAS operations).

    D. Stimulate inter-cell discussions between Green and Blue cells (requesting airspace and developing integrated air operations).

    E. Monitor the use of commercial UAS compared to public UAS and what flight rules they invoke on the commercial. Take notes for the discussion period and final report.

    F. Monitor the discussion and planning regarding mission priorities: SAR, Woodlake Dam monitoring, evacuation route planning.

    G. Monitor and encourage completion of assigned actions.

    H. Let participants do the talking but be ready to redirect discussion during quiet periods and if discussions deviate from the scenario actions.

    I. Prompt participants to begin answering questions.

    J. Assist Observers. Be ready to answer their questions. Attempt to keep them from participating in table group discussions unless they have important and valid points to inject.

2. **Step 2: Data Collection and Planning for Potential Dam Breach - Instructions**

    A. Stimulate inter-cell discussions between Green and Blue cells (requesting airspace and developing integrated air operations).

    B. Ensure the geographic locations of simulated flood waters get recorded and used to make SAR and evacuation planning decisions.

    C. Ensure geographic locations of Woodlake Dam UAS flights get recorded.

    D. Ensure locations of UAS Operations (L&R, PIC and VO locations) are recorded.

    E. Ensure UAS operations and data collected accurately reflect the capabilities of the UAS allocated to the step.

    F. Monitor and record how the cells deconflict manned and UAS airspace.

    G. Monitor and record how airspace over anticipated flooding areas from dam breach is requested and managed.

    H. Monitor and encourage completion of assigned actions.

I. Let participants do the talking but be ready to redirect discussion during quiet periods and if discussions deviate from the scenario actions.

J. Prompt participants to begin answering questions.

K. Assist Observers. Be ready to answer their questions. Attempt to keep them from participating in table group discussions unless they have important and valid points to inject.

L. RECORD and TAKE NOTES – of the proceedings, decisions, questions raised, and interactions between cells, issues.

3. **Step 3: Response to Dam Breach**

A. Instructions

1) Same as in Step 2.
2) Present inject items for each Table as specified below at the approximate time indicated in the script below.
3) Monitor the discussions near the end of the time period and prepare to transition to stopping discussion and preparing the outbrief slides. (Outbrief slides are key components of the TTX report). Expect that discussions will continue while preparing slides as their thoughts become organized.

B. Injects

1) Table 1 Insert: PIC sees a car being washed away downstream and believes there is a family trapped inside. Car will pass out of range of UAS sensor range. PIC requests to maintain UAS sensor contact on car with operations beyond the line of sight (BLOS) of both PIC and VO.
2) Table 2 Insert: A group of 3 neighborhood drone hobbyists place 911 call and post Facebook video people in next neighborhood stranded in car with rising water. They report they are continuing area flights to search for more stranded people.
3) Table 3 Insert: A PIC is threatened by rapidly rising flood waters in a critical search area. PIC states his intention to continue the flight from the back of his pick-up truck as he moves to higher ground. The VO does not have visual contact on the UAS.

Scenario 3 Script: Day 2 – Wednesday, 18 January (UAS Demo on Day 3)

Time	Step	Action
1145		Scenario Brief
1230		Exercise Play Begins
1230	1 – Planning During Storm	Step 1 Begins
1310	1	Wrap up Step 1 Discussion and Identify Key Points for Debrief
1315	1	Step 1 Ends
1315	2 – Data Collection & Planning for Potential Dam Breach	Step 2 Begins
1355	2	Wrap up Step 2 Discussion and Identify Key Points for Debrief
1400	2	Step 2 Ends
1400	3 – Response to Dam Breach	Step 3 Begins
1440	3	Step 3 Inserts (See Table Inserts Below)
1455	3	Wrap up Step 3 Discussion and Identify Key Points for Debrief
1500	3	Step 3 and Exercise Play End
1500		Begin Drafting Debrief Slides
1600		End Scenario 3

Scenario 3 Script: Day 3 – Thursday, 19 January (UAS Demo on Day 2)

Note: Scenario 3 Briefing Scheduled for 1145 on Day 2

Time	Step	Action
0815		Exercise Play Begins
0815	1 – Planning During Storm	Step 1 Begins
0855	1	Wrap up Step 1 Discussion and Identify Key Points for Debrief
0900	1	Step 1 Ends
0900	2 – Data Collection & Planning for Potential Dam Breach	Step 2 Begins
0955	2	Wrap up Step 2 Discussion and Identify Key Points for Debrief
1000	2	Step 2 Ends
1000	3 – Response to Dam Breach	Step 3 Begins
1040	3	Step 3 Inserts (See Table Inserts Below)
1055	3	Wrap up Step 3 Discussion and Identify Key Points for Debrief
1100	3	Step 3 and Exercise Play End
1100		Begin Drafting Debrief Slides
1200		End Scenario 3

Appendix D: **Scenario Debrief Slides**

NC DOT and NGAT Table 1

UAS Airspace Integration Table Top Exercise (TTX) 17 – 19 January 2017

Table 1; AKA “A-Team”; AKA “The Best”; AKA “Clearly the Winners”

19 January 2017

1

Hurricane Matthew in Cumberland County

Scenario #2 Locations

2

Scenario 2 Debrief – Table # _1_

Answers to Blue Cell Questions:

- Step 1 Planning
  - Can you effectively conduct integrated manned and UAS operations by segmenting the airspace in time, altitude and geographic reference?
    - **Yes. The operations foot print however, will require the fixed wing uav assets to return to base prior to the manned aircraft from arriving into the initial search area to commence rescue sorties.**
  - To what degree did you use the UAS SAR Addendum in your planning? If not, why not?
    - **I did not use the addendum. I had expert PIC's to rely upon the equipment specs, My knowledge of SAR ops and aviation training.**
- Step 2: Initial Search and Rescue Operations
  - Were you able to safely execute UAS Search and Manned Rescue (USMR) operations?
    - **Yes but with interruption due to an unauthorized manned aircraft that arrived to assist**.
  - Were the PIC and VO positions clearly reported by the UAS flight crew and did they safely complete operations maintaining their UAS within visual LOS?
    - **From the observer locations, the fixed wing UAV could be monitored and not lose LOS. The Inspire may require some LOS loss due to the close proximity to the location. COA's and/or part 107 waivers would allow for limits to be unrestricted.**
- Step 3: Extended Search and Rescue Operations
  - Was the airspace allocated and safely managed to meet SAR and evacuation route survey requests of the EOC?
    - **Ummm Sure**
  - Were nighttime operations with IR capable UAS requested? Were they approved? If not requested, would you have approved them?
    - **Under the current incident, the agency (Fayetteville PD and Cumberland County EOC would most likely be given the Waivers for IR use and night flights. If using a private organization that has the ability to use the systems, they would fall under the umbrella of the SAR and potentially could use for emergency circumstances.**

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Scenario 2 Debrief – Table # _1_

Answers to Green Cell Questions:

- Step 1 Planning
  - Did the UAS SAR Addendum provide sufficient guidance for UAS planning? If not, what changes would you recommend?
    - Neither the IC nor the UAS green person had time to actually read the document. This reading and the other major reading assignments should have been assigned well in advance of the TTX.
  - Did you have a sufficient number of UAS with appropriate capabilities to plan your SAR missions?
    - Yes, based on the mission we had a sufficient number of UAS. However, it would have been better to have been issued the aerostat. It would have been better to have been issued:
      - » Two of each aircraft. If not in-house, then hire a pre-event contractor.
      - » Mission Caster box to transmit image files to a central processing location
- Step 2: Initial Search and Rescue Operations
  - To what degree did having UAS available improve the effectiveness of your manned aircraft and swift water SAR response?
    - The UAS, which are low cost and low risk, identified targets and could deliver items (life jackets, rations, water, meds, first aid, Trac phone,
    - The IC was then able to prioritize the identified targets.
    - The IC then assigned the identified targets and their priority to the manned aircraft, which saved Lives; Time; Fuel
  - Can you safely and effectively conduct UAS Search and Manned Rescue (USMR) operations?
    - Yes, if we do the AI deconfliction and maintain communication with all players.
- Step 3: Extended Search and Rescue Operations
  - How did you assess and execute the ad hoc operation requests injected into the scenario?
    - The family needing rescue on Hwy 301 we handled by:
      - » Verified and cleared the airspace
      - » Communicated and directed UAS to the location.
      - » Reported coordinates to a manned rescue helicopter.
    - The good Samaritan helicopter, was handled by:
      - » Requested for him to leave, but he did not.
      - » Requested Fayetteville ATC to order him out of the TFR, which he reluctantly obeyed
  - Would the authorization of BLOS UAS operations improve the SAR response or enable better evacuation route surveys?
    - The tall pine trees can block the view of ground based observers. However, we have our observers stationed on the roof of the two-story high school. Thus, BLOS is not an issue for the fixed-wing. However the pilot of the Inspire will not be located on the HS roof, but will be on the ground near its area of operation. Thus, the trees would block his line of sight.

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Scenario 2 Debrief – Table # _1_

Answers to Purple Cell Questions:

- Step 1 Planning
  - Did the EOC use the best available UAS for each mission?
    - Yes
  - What were the difficulties in choosing L&R, PIC and VO locations for the assigned missions?
    - Initial L/R sites and POC locations were discussed and planned to be in a safe operating area in anticipation of rising flood waters
    - Secondary location planned in the event of dynamic change
- Step 2: Initial Search and Rescue Operations
  - Were UAS operations unduly restricted?
    - No
  - Were all available UAS deployed on at least one mission? If not, why not?
    - Yes, based on system capabilities.
- Step 3: Extended Search and Rescue Operations
  - How did you monitor for the viability of the selected PIC and VO locations given the progression of the flood waters?
    - Staging PIC locations on top of roof for L/R sites and INSPIRE teams on edge of flood water since they're more mobile
  - Were there any unsafe airspace incidents or potential incidents based on game play decisions? If so, what were they?
    - Yes, A private Helo intruded airspace at low alt without prior clearance. AB was notified and communication to ATC. Helo directed to return to airport; Or, impact would be need for all UAS's to be grounded.

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Scenario 2 Debrief – Table # _1_

- Key Take Aways:
  - *With a small footprint of operations, it may be required to return or land assets while conducting helo rescue ops.*
  - *benefits of this operation allowed for the ux 5 to be used as a "flood" sensor and return it for the analysts leaving 1 fixed wing and vtol to locate targets*
  - *Any ops requiring route searches could be adjusted with some operator delay for programming.*
  - *Communication is Key*
  - *Pre-Planning and having established agreements with Certified and Experienced Operators in place is a must*
- Blue Cell Comments
  - Communication is key with the Airport. A TFR would be required even if it was outside the sfc-4000 5mile ring. The approach or departure end would be close to that location and be would be a conflict with commercial A/C arriving and departing Fayetteville.
  - Because of intrusions of unauthorized aircraft, an extreme hazard to aircrews is imminent. Its imperative that the safety of the search crews take priority over rescues until the hazard has been mitigated or removed. (even if that means the victim succumbs as a result of the hazard)
- Green Cell Comments
  - UAS may not effective immediately post Hurricane based on wind speeds and wrap around bands of wind and rain.
  - Airboss could be regional and not on location, with a Deputy in each county to coordinate flight operations .
- Purple Cell Comments
  - Overall sUAS coordination was completeted with ease
  - Airspace deconfliction with Manned aviation assets was discussed and a plan was put in to action
  - PIC and VO Locations were designated

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Scenario 2 Debrief – Table # _1_

- Airspace Management Issues
  - Close proximity to a Class C Airport.
  - Small footprint for the search area involving and UAV and MANNED A/C
  - Encroachment plan for dealing with Unauthorized aircraft
  - 3 UAS were available and used for different missions
  - Inspire 1 150 ft AGL, UX5 350 ft AGL, Bersa 500 ft AGL
  - Inspire 1 used to recon the area
- Value of UAS
  - Efficient use of economical aviation assets
  - Live streaming video for real time decision making
  - Versatility of different mission equipped systems. High bird, pinpointing, low search
  - UX-5 was not a valuable system for the search and rescue op due to still imagery limitations and processing time.
  - Inspire (VTOLs) extremely valuable for on station close up surveillance for immediate action and follow up surveillance after rescue.
- Recommended Changes to Processes & Procedures
  - Under search rescue operations, immediate waivers for night ops, FLIR, LOS, Moving Vehicle, altitude restrictions automatic.
  - Research night ops, lighting for uav, and conflict with night vision devices.
  - Skills minimums for PICs during emergency SAR ops.
  - Currency requirements per air platform.

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Table Group 1 – Scenario 3 (Moore County)

Assumptions

- All Part 107 waivers have been granted (4 yrs):
  - Waivable sections of part 107
  - Operation from a moving vehicle or aircraft (§ 107.25)*
  - Daylight operation (§ 107.29)
  - Visual line of sight aircraft operation (§ 107.31)*
  - Visual observer (§ 107.33)
  - Operation of multiple small unmanned aircraft systems (§ 107.35)
  - Yielding the right of way (§ 107.37(a))
  - Operation over people (§ 107.39)
  - Operation in certain airspace (§ 107.41)
  - Operating limitations for small unmanned aircraft (§ 107.51)
- Granted a blanket public COA – permits nationwide flights in Class G airspace at or below 400 feet, self-certification of the UAS pilot, and the option to obtain emergency COAs (e-COAs) under special circumstances
- ATC Waiver letter in hand

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Set up

Safety, Logistics, Operations, Teams/Comms

Helos - Moore Co Airport; VOR – Sand Hills; Hospital – Southern Pines

- ID airboss. AB establish flight parameters for manned and unmanned vehicles and teams
  - Establish a formal certification/training program to be an AirBoss (like IC)
- AB to ATC - TFR around Woodlake dam (center point) approval via Fayetteville ATC for 2 nm around Moore Co Airport
- IC identifies civilian personnel and assets at risks and potential rescue/evacuation plans
- Staging considerations
  - Up steam
  - Helos
  - Launch/Recovery issues
  - Media locations for set up and flight parameters
    - Above the dam.
    - Private Golf Course and Housing…need permission
- Comms
  - NG/CG air - UHF
  - Ground – Viper
  - Video streamed live from all UASs via Mission Caster
- *ID specific “teams” (operators and assets) for emergency response*
  - *Validate Certs, pilots, ops, etc*

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Set Up - Staging

Operations – Set up
IC identifies housing and other assets at risk

1% Breach

Operations – No change
Evacuations are encouraged

Full Dam Breach

Operations – No change
Evacuations Mandatory
Emergency Rescue

Car/Civilians Washing Away

- Operations – Wraith picks up image and tracks
- Team X Operator calls IC with sitrep
- AB call to Spin up Helos (airborne in 6min)
- Inspire comes back in sight for stationary loitering/view
- Get Wraith-2 ready for launch (based on power/battery/etc) for live feed SE of rescue
- Helos coming from NW (Moore Co Airport)
- ID coordinates
- Offset UAVs to SE tracks for manned rescue

Scenario 3 Debrief – Table # _1_

Answers to Blue Cell Questions:

- Step 1 Planning
  - Did you allow commercial UAS to operate under Part 107 or did you require them to operate under the COA?
    - No, If they are not already covered under our COA/Part 107 waivers
    - Circumstances did not justify FAA allowances
  - Were there some missions that you would require public UAS over commercial?
    - Yes, with IR capabilities
- Step 2: Data Collection and Planning for Potential Dam Breach
  - Did you disapprove any UAS data collection flights? If so, for what reasons?
    - Yes. All unplanned assets were disapproved. Only vetted assets and pilots.
  - Did the flight crews respond to instructions to clear the airspace for higher priority manned flights?
    - Chris has a gun…yes.
- Step 3: Response to Dam Breach
  - Did you consider allowing operations beyond the limits of Part 107 and locally approve waivers based on the importance of the data to be collected?
    - N/A since we already have all the waivers
  - How did you respond to the ad hoc requests injected into this scenario?
    - Preplanning successfully avoided need to evacuate or restage.

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Scenario 3 Debrief – Table # _1_

Answers to Green Cell Questions:

- Step 1 Planning
  - How did you employ the commercial UAS?
    - Used Blimps for Comms and Monitoring Dam
  - Are there any missions where you would only employ public UAS?
    - Vetted and approved vendors operating as an arm of Public Agency i.e., Under Emergency Services and Privacy concerns – or Data Chain of Custody
    - Should be a standard on quality of data, etc
- Step 2: Data Collection and Planning for Potential Dam Breach
  - How did the EOC team make SAR UAS assignments?
    - AB established teams based on manned and types of unmanned systems/operators and capabilities of team and equipment.
  - Was there any difference in the quality or quantity of data collected by commercial versus public UAS?
    - Commercial provided secured streaming video via Mission Caster
- Step 3: Response to Dam Breach
  - Did you consider allowing operations beyond the limits of Part 107 and locally approve waivers based on the importance of the data to be collected?
    - Already have approved waivers. If we didn't, we would have requested approval via closest ATC
  - How did you respond to the ad hoc requests injected into this scenario?
    - Didn't have any for assets. But policy is no unplanned/vetted assets.
    - Operations: no change until vehicle Ad Hoc scenario to separate manned and unmanned assets

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Scenario 3 Debrief – Table # _1_

Answers to Purple Cell Questions:

- Step 1 Planning
  - Were the commercial Part 107 UAS appropriately integrated into the SAR plan?
    - Yes
  - Were there any unreasonable requirements placed on the commercial UAS compared to the publllllllllic UAS?
    - No. We would only use well vetted and certified/trained assets so shouldn't be much different than public
- Step 2: Data Collection and Planning for Potential Dam Breach
  - Were there any changes to the planned UAS mission requested during a flight crew deployment?
    - Yes, upon location of vehicle.
  - Were you able to remain clear of reported or observed manned aircraft?
    - Yes, reassigned to SE to allow NW helo approach
    - If INPIRE saw it, Wraith overflies and capture location and begins monitoring/live streaming
    - If Wraith saw it, continues operations until helos are airborne and close, then offset SE to provide direction and guidance to helo
- Step 3: Response to Dam Breach
  - What was the most effective method of communicating critical information observed to local searchers and the EOC?
    - Viper radios, manned aircraft VHF – UHF. Secondary would be cell phones
  - Which missions and data requests were the best employment of UAS? Please rank the following: SAR, dam stability monitoring, flood water progression and emergency evacuation route surveys.
    - dam stability monitoring (blimp); SAR (INSPIREs); flood water progression and emergency evacuation route surveys (fixed wings).
    - VTOL platforms with photo only are not conducive to SAR dynamic ops.

NOTE: NO deviation from mission parameters authorized without approval from IC regardless of dynamic events.

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Scenario 3 Debrief – Table # _1_

- Airspace Management Issues
  - *Media staged upstream from dam*
  - *Manned vs Unmanned for rescue*
  - *TFR and airport proximity*
  - *330ft antennas and other obstructions*
    - *Based on Aviation Sectional Map – recently updated?*
- Value of UAS
  - *Live secure streaming*
  - *Economical operation of airborne assets vs manned helo surveillance*
  - *Rapid response, with continuous coverage*
  - *Multiple viewing by interested parties from various locations and data collection*
- Recommended Changes to Processes & Procedures
  - *Establish a formal certification/training program to be an AirBoss (like IC)*
  - *Validate commercial resource certs, pilots, ops, capabilities etc previously*
    - *If additional resources are provided on site, rely on vendor*
  - *Vetted and approved vendors should be allowed to assist in Public operations if they're operating as an arm of Public Agency i.e., Under Emergency Services and Privacy concerns – or Data Chain of Custody*
  - *There should be a standard on quality of data, etc*
  - *Official "Flight time" for credentialing needs to be measured from a device/mechanism that uses an embedded or integrated flight log within the system for accountability*
  - *Public agencies can use whatever they need to use and do whatever they need to do without credentials*
  - *Training standard for EM, ER's, LE should be accredited by a "team" that should be established*
  - *SAR manual 3-5 Qualifying UAS Providers para 1 and 2 proposed change:*
    - *Allow IC to determine if continued use of a Hobbyist's asset is warranted/necessary and SAFE for the Hobbyist to augment the mission (or consider under what circumstances could this be allowed…)*

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Scenario 3 Debrief – Table # _1_

- Key Take Aways:
  - Clear understanding of the placement of resources prior to disaster
  - Proper use of UAVs allow for continuous monitoring of the disaster area while manned assets were safely secured
  - Having a pre-vetted systems to qualify operators and asset resources allowed for seamless integration of commercial and public UAV operations
  - Pre planning for all Waivers via Part 107 (and COAs until they go, thankfully away) by the IC allows for immediate response to dynamic situations
- Blue Cell Comments
  - Under the small size of the operation, limited UAV operations should be taking place when manned aircraft are in the area
- Green Cell Comments
  - Resource and mission tracking should adhere to ICS protocols
  - Commercial personnel don't necessarily know the process like mission briefing and chain of command
- Purple Cell Comments
  - Pre planning is KEY for L/R sites to ensure no significant disruption to mission based on dynamic changes

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NC DOT and NGAT

UAS Airspace Integration
Table Top Exercise (TTX)
17 – 19 January 2017

Table 2 Debrief

19 January 2017

1

Scenario 2 Debrief – Table # 2

- Key Take Aways:
  - SOP needed for manned and unmanned interaction during no communication scenarios
  - Technical rescue teams need training on how to direct / communicate information to incoming aircraft
  - Need a mobile command center for all resources to coordinate operations – commonly referred to as a "war room"
  - Need a standard form that can be used in an ICS structure that identifies all the pertinent details of unmanned resources on an incident (similar to or modification of ICS 220)
  - Determining the scope of the operation is key to determining how unmanned and manned resources will be utilized
  - Daily briefings should be required for all assets on the incident
  - Public Information Officers (PIO) are need to broadcast and distribute information about termination of recreational UAS within the incident airspace (not just TFR)
  - Procedure / decision points for loss of UAS need to be established and approved by IC
  - Airboss training is needed – to be determined at a later time
- Blue Cell Comments
  - Frequency / spectrum coordination and briefing needs to happen prior to the event
  - Based on duration of event, request assistance from adjunct radar ATC system
  - Procedures for how systems enter and exit the airspace should be established on an incident
  - Regular updates are needed for weather forecasts
- Green Cell Comments
  - Incident impact projections (e.g., flood inundation) are needed for short-range planning
  - Determine what assets will fly certain missions and where these resources will be located
  - All Ops to have daily briefings – fueling and relocations to be determined
- Purple Cell Comments
  - Preflight sync meeting or briefing to have CoCs to be delineated ahead of time
  - Provide as many details as possible prior to Ops

2

Scenario 2 Debrief – Table # 2

- Airspace Management Issues
  - If communications are lost, what will be the procedure for UAS operations?
    - Terminate if needed
  - Law enforcement engagement for unauthorized operators
  - Use the UAS to clear routes (on the ground or air)
- Value of UAS
  - Guidance of ground resources
  - Lower risk to manned operational resources
  - More cost efficient in some scenarios
- Recommended Changes to Processes & Procedures
  - Add NORDO procedure
  - See Key Take Aways

3

Scenario 3 Debrief – Table # 2

- Key Take Aways:
  - Concerns of private unauthorized UAS use in emergency operations
  - Approval process is needed for commercial operators
  - Legal document needed for data security acquired from commercial operators
- Blue Cell Comments
  - MOA for restricted airspace to be included in TFR – communication with military range is needed
- Green Cell Comments
  - Trigger points are needed for utilization of resource and assignments
  - Education and enforcement of unauthorized manned and unmanned operators – could be addressed with Public Information Officer involvement
- Purple Cell Comments
  - Centralized flight management between commercial and public assets
  - Clearly defined roles and areas of responsibility

7

Scenario 3 Debrief – Table # 2

- Airspace Management Issues
  - Operating adjacent to military airspace – open communication needed & MOAs
    - Drafting airspace MOA in advance & having these available for "activation" is ideal to expedite approval for emergency operations
- Value of UAS
  - Surveillance, quick response, increases operational options
- Recommended Changes to Processes & Procedures
  - UAS Incident Response Pocket Guide is needed
    - https://drive.google.com/open?id=17nG4mzithxBL8CMHRr31YCPYExauJYh05VuDgZ0xVH0
  - Set a minimum age requirement
  - Additional rules/laws are needed to govern requirements for UAS use and consequences for breaking rules/laws
  - Education for UAS across all sectors is CRITICAL
  - Line of sight restrictions limit potential use and benefits of UAS

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NC DOT and NGAT

UAS Airspace Integration
Table Top Exercise (TTX)
17 – 19 January 2017

Table 3 - Scenario 2

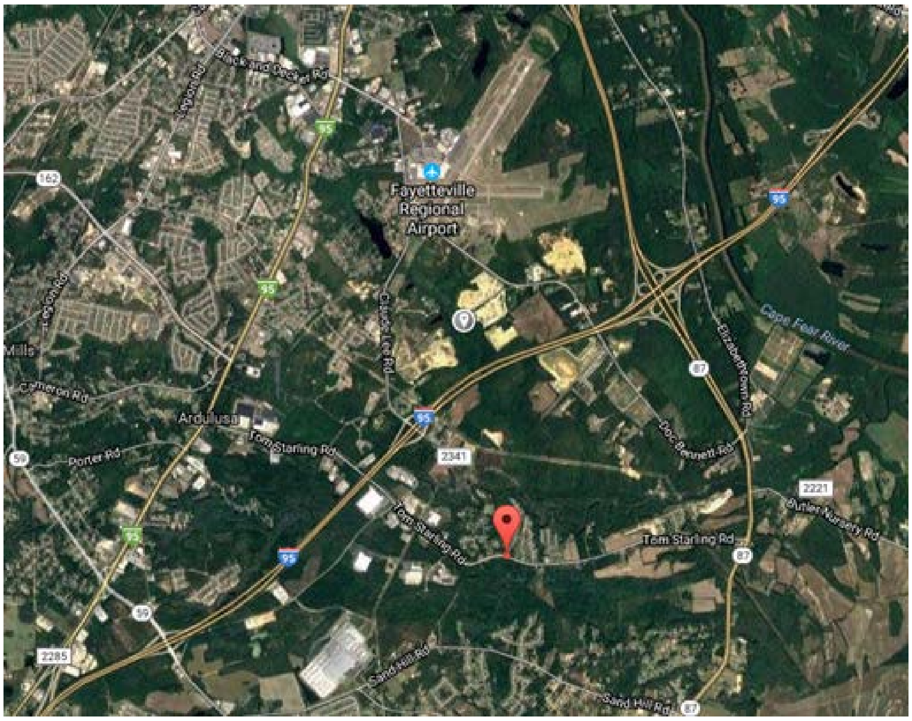
19 January 2017

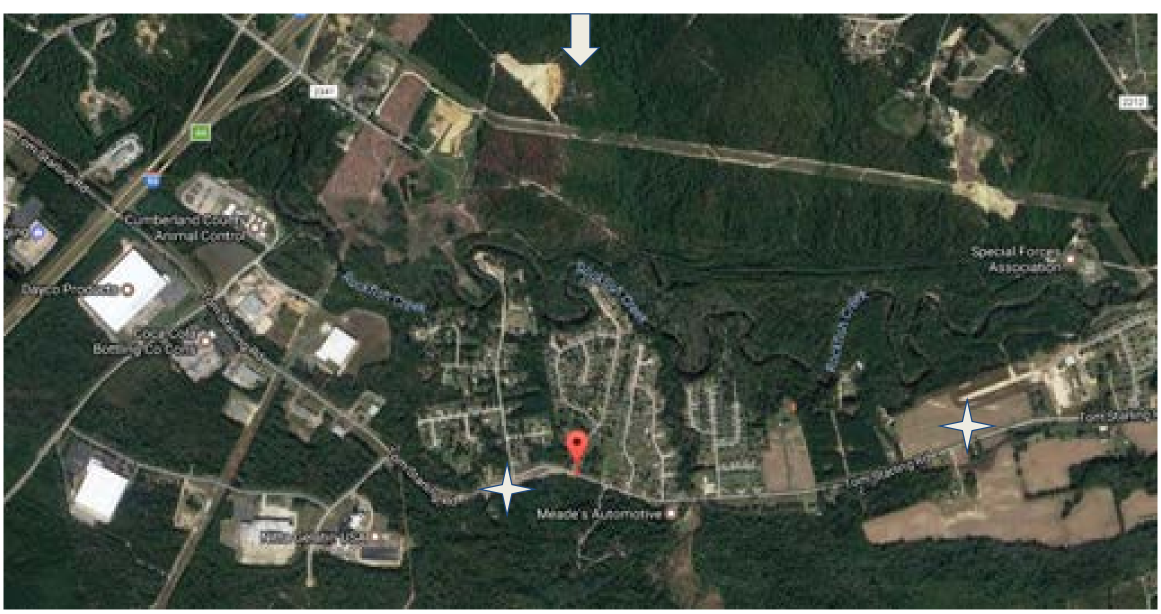
1

Hurricane Matthew in Cumberland County

Scenario #2 Locations

Pennystone Drive 3


Black and Decker Rd
95
162
Fayetteville Regional Airport
Claude Lee Rd
Cape Fear River
Elizabethtown Rd
87
Mills
Cameron Rd
Ardulusa
Tom Starling Rd
Porter Rd
59
2341
Doc Bennett Rd
2221
Butler Nursery Rd
Tom Starling Rd
2285
Sand Hill Rd


2341
2212
Cumberland County Animal Control
Dayco Products
Coca Cola Bottling Co Cons
Rockfish Creek
Special Forces Association
Meade's Automotive
Tom Starling Rd

Scenario 2 Debrief – Table # 3

- Key Take Aways:
  - Develop procedures to ensure safe management of assets
  - Communication procedures are critical to safe management and operational success
  - During emergency situations, regulation (Part 107/COA) waivers can be expedited
- Blue Cell Comments
  - Set up TFR if 3 or more aircraft
  - Deconflict using altitude, location, and time - Airboss directing all operations once IC sends requests.
  - In this case, place Airboss in tower at Fayetteville Airport. Airspace deconfliction - UAS - max altitude given, 15min check in, or relaunch, if loss comms bring down bird.
  - UAS to Airboss communications - PAC - VHF, Viper/ground, Cell, datalink or runner (face to face)
  - Helos staged at airport, UAS teams directed to areas by airboss, launch and recovery sites chosen by UAS teams. UAS locations need to be tracked.
  - Night Ops - Payload, Launch/Recovery area, anti collision lights (if longer than 20min flights), crew selection - night flight experience.
- Green Cell Comments
  - State the mission objectives and refer to Airboss regarding platform capabilities, use and safety considerations
  - Provide radio(s) to Air Branch for support of Comms Plan
  - Regulatory exemptions can be made during emergency operations with coordination through AirBoss and FAA POC
  - Line of sight and Takeoff/Recovery locations are difficult to assess until on location/inflight

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Scenario 2 Debrief – Table # 3

- Airspace Management Issues
  - Operation in Class E surface to 4200 feet airspace requires coordination with Fayetteville airport manager.
  - Rescue operation needed in area of UAS operation.
- Value of UAS
  - Provides site surveys and added situational awareness for SAR.
  - Night operation enables preliminary site assessment
- Recommended Changes to Processes & Procedures
  - Detail procedures for Airboss to request and process UAS regulation waivers.

6

Scenario 2 Debrief – Table # 3

Answers to Blue Cell Questions:

- Step 1 Planning
  - Can you effectively conduct integrated manned and UAS operations by segmenting the airspace in time, altitude and geographic reference?
    Yes, air boss dictated time, altitude, and geographic reference in conjunction with ground
  - To what degree did you use the UAS SAR Addendum in your planning? If not, why not?
    We didn't initially.
- Step 2: Initial Search and Rescue Operations
  - Were you able to safely execute UAS Search and Manned Rescue (USMR) operations?
    Yes, de-conflicted with altitude and position.
  - Were the PIC and VO positions clearly reported by the UAS flight crew and did they safely complete operations maintaining their UAS within visual LOS?
    Yes, UAS crew was directed to an area and the crew requested to operate from a specific location to the Air Boss. Locations need to tracked by all parties.
- Step 3: Extended Search and Rescue Operations
  - Was the airspace allocated and safely managed to meet SAR and evacuation route survey requests of the EOC?
    Yes, Air Boss is de-conflicting via altitude, location, and timing.
  - Were nighttime operations with IR capable UAS requested? Were they approved? If not requested, would you have approved them?
    Payload, Launch/Recovery area, anti collision lights (if longer than 20min flights), crew selection - night flight experience.

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Scenario 2 Debrief – Table # 3

Answers to Green Cell Questions:

- Step 1 Planning
  - Did the UAS SAR Addendum provide sufficient guidance for UAS planning? If not, what changes would you recommend? Yes, Refer to Airboss
  - Did you have a sufficient number of UAS with appropriate capabilities to plan your SAR missions? Yes
- Step 2: Initial Search and Rescue Operations
  - To what degree did having UAS available improve the effectiveness of your manned aircraft and swift water SAR response? Quick to launch, allowed Manned Crews to remain on standby for rescue operations. Cost reduction, fatigue reduction, fuel and maintenance
  - Can you safely and effectively conduct UAS Search and Manned Rescue (USMR) operations?
    Yes, with proper TTP's and Management
- Step 3: Extended Search and Rescue Operations
  - How did you assess and execute the ad hoc operation requests injected into the scenario?
    Coordinated with Airboss to determine appropriate platform and separation
  - Would the authorization of BLOS UAS operations improve the SAR response or enable better evacuation route surveys? Yes; quicker availability depending on resource locations.

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Scenario 2 Debrief – Table # 3

Answers to Purple Cell Questions:

– Step 1 Planning
  - Did the EOC use the best available UAS for each mission?

  All UAS were used appropriately.
  - What were the difficulties in choosing L&R, PIC and VO locations for the assigned missions?

  Unknown flooding of the area location. Questions regarding LOS until on scene.

– Step 2: Initial Search and Rescue Operations
  - Were UAS operations unduly restricted?

  No. FAA restrictions were assumed to be waived if requested through airboss.
  - Were all available UAS deployed on at least one mission? If not, why not?

  No, the blimp was deemed inadequate in the environment given, the penguin was limited due to area size and airspace allocations.

– Step 3: Extended Search and Rescue Operations
  - How did you monitor for the viability of the selected PIC and VO locations given the progression of the flood waters?

  With onsight reports of the PIC and VO
  - Were there any unsafe airspace incidents or potential incidents based on game play decisions? If so, what were they?

  No

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NC DOT and NGAT

UAS Airspace Integration Table Top Exercise (TTX) 17 – 19 January 2017

Table 3 - Scenario 3 Briefing
Moore County

19 January 2017

1

Scenario 3 Execution – Adding Commercial UAS

- Table Group Organization – See Reference Folder
  - Blue Airspace Cell (Air Boss)
  - Green EOC Cell (Incident Commander)
  - Purple UAS Expert Cell
  - Observers
  - White Cell (Planning, Control and Recording)
- Scenario Objectives
  - Examine airspace issues by simulating real world event
  - Guidance, Actions and Questions (Assigned by Cell)
  - Record your actions & thoughts, answer questions → Table Debriefs (See Briefing Template)
- Game Steps
  - Planning (Step 1),
  - Data Collection and Planning for Potential Dam Breach (Step 2),
  - Response to Dam Breach (Step 3)

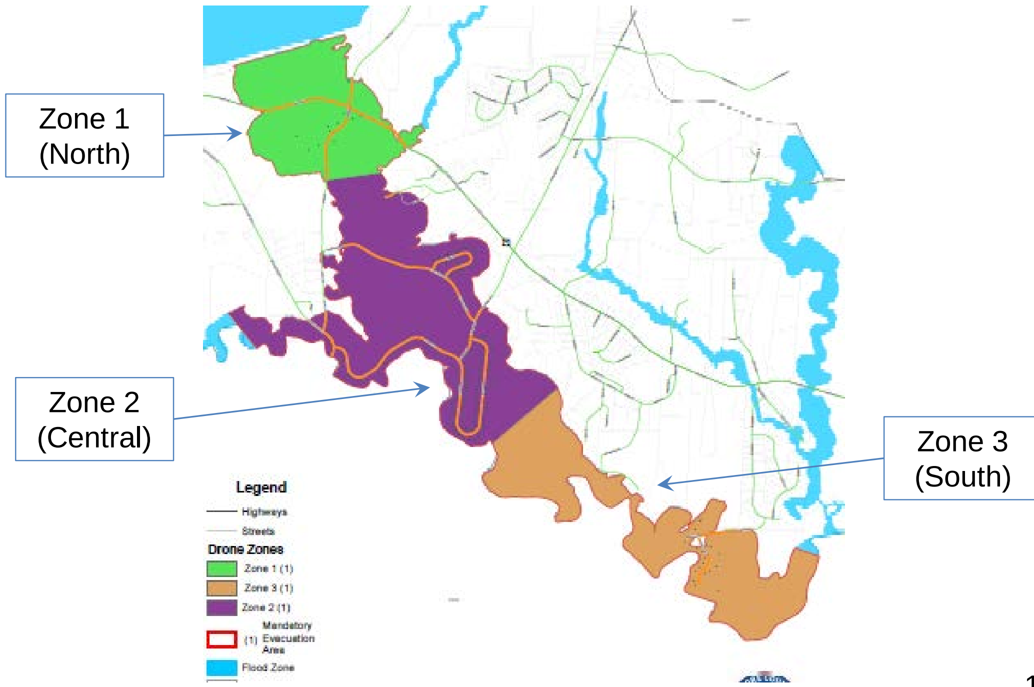
2

Scenario #3: UAS Assets Allocated

Zone #1 (North) Table Group 1	Zone #2 (Central) Table Group 2	Zone #3 (South) Table Group 3
· Inspire · ZX-5 · Airprobe Wraith · Blimp	· Inspire · Penguin · Blimp	· Inspire · UX-5 · Airprobe Besra · Indago

Hurricane Matthew in Moore County

Scenario #3 Locations



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Key Assumptions & Other Instructions

- Assume "Perfect Comms" in Game Play
  - Record your comments on comms issues in the Evaluation Comments
- No time delay in getting UAS Flight Crews (PIC) on station.
  - Simulate appropriate time delay in getting info from Flight Crew to EOC
- **How to organize, authorize and operate Commercial UAS**
- If it doesn't get recorded, it didn't happen
  - Answer questions in the appropriate "cell" Game Play Material Document.
    - Save it on your computer with your last name added to the file name
    - Upload to google share drive or email to us when done on Thursday
  - Complete Evaluation Forms as you go.
  - Time reserved in each scenario to prepare debrief slides
  - Save Outbrief Slides with Table Number in file name in Scenario Folder

Scenario 3 Debrief – Table # 3

- Key Take Aways:
  - UAS operator location is key, especially in emergency operations.
  - Available launch and recovery sites drives asset selection and capability.
  - Operational needs quickly run into regulatory barriers.
- Blue Cell Comments

  Planning Phase - Locate UAS L/R sites and alternate sites. Start defining operational area or potential operational area as defined by CAP maps or lat/longs. Look at potential flood areas. Scout trees heights, towers, powerlines that may not show up on a sectional. Eyes on the ground would be key durings this phase. UAS selection would be critical during this phase based on potential missions and weather limitations. We know that the Indago can operate in raind and some wind. The UX5 would require a large area to land. Comms establishment is critical during this phase, whihc would include testing. Does VHF reach back to IC/Air Boss?

  Operational Phase - Airspace deconfliction by altitiude and location withing predefined box. Waivers to be requested through Air Boss.
- Green Cell Comments

Planning- Define mission/requirements/goals. Designate area of operation/commands post/staging areas/section cheifs/assets needed/shift rotation

Ops- Deploy resources and refer to section cheifs for sustained operation requirements.

Purple Cell Comments

Changes in planned flights likely with dynamic emergency environments

Difference between commercial and public air operations when controlled by an airboss are minimal

Scenario 3 Debrief – Table # 3

- Airspace Management Issues
  - Dealing with Restricted Airspace South of Operations Area.
  - Coordinating multiple UAS operations on a “one-in one-out” procedure.
- Value of UAS
  - Provides support for small focus areas that need individual surveillance/mapping.
  - Allows manned aircraft to focus on critical operation areas.
- Recommended Changes to Processes & Procedures
  - Determine aircraft usage assuming worst case scenarios (PIC evacuation, rising flood waters, etc).

Scenario 3 Debrief – Table # 3

Answers to Blue Cell Questions:

- Step 1 Planning
  - Did you allow commercial UAS to operate under Part 107 or did you require them to operate under the COA?

    It depends on what the agency is set up to operate under. If the agency has a COA then changing the COA parameters in an emergency may be easier. We assumed that a TFR was covering the entire area so operations would be within a restricted airspace.
  - Were there some missions that you would require public UAS over commercial?

    Ideally SAR would be performed by public and mapping and other similar missions by commercial. There may be a chain of custody issue with data during a SAR if looting is observed. The video/photos may be inadmissible in court.
- Step 2: Initial Search and Rescue Operations
  - Did you disapprove any UAS data collection flights? If so, for what reasons?

    Based on UAS limitations. NCGS would allow collection of data because this was a "newsworthy event".
  - Did the flight crews respond to instructions to clear the airspace for higher priority manned flights?

    Yes. UAS crews would ground if necessary.
- Step 3: Extended Search and Rescue Operations
  - Did you consider allowing operations beyond the limits of Part 107 and locally approve waivers based on the importance of the data to be collected?

    Yes. Because we are operating within a TFR we requested a box to operate within This was defined using CAP maps, Lat/long. and/or RAD/DME TACAN. Requests for waivers would be sent to airboss. All waiver communications through airboss is paramount.
  - How did you respond to the ad hoc requests injected into this scenario?

    Rising floor waters would require the UAS operator to jump in a moving vehicle and set the UAV down ASAP. Operations from a moving vehicle are allowed over sparsely populated areas. This area is sparsely populated designated by VFR sectional.

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Scenario 3 Debrief – Table # 3

Answers to Green Cell Questions:

- Step 1 Planning
  - Did the UAS SAR Addendum provide sufficient guidance for UAS planning? If not, what changes would you recommend? Yes, refer to Airboss
  - Did you have a sufficient number of UAS with appropriate capabilities to plan your SAR missions? Yes
- Step 2: Initial Search and Rescue Operations
  - To what degree did having UAS available improve the effectiveness of your manned aircraft and swift water SAR response? Limited need in our scenario in step 2. We were able to obtain flodd assessments without usung manned assets.
  - Can you safely and effectively conduct UAS Search and Manned Rescue (USMR) operations? Yes
- Step 3: Extended Search and Rescue Operations
  - How did you assess and execute the ad hoc operation requests injected into the scenario? Mission requirement versus platform/aircrew capabilities.
  - Would the authorization of BLOS UAS operations improve the SAR response or enable better evacuation route surveys? Will enhance SAR operations and allow manned aircraft to focus on rescue operations or operation beyond UAS range and station times

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Appendix E: Acronym List

A

14 CFR	Title 14Code of Federal Regulations
4D	Four-Dimensional
ABSAA	Airborne Sense and Avoid
AC	Advisory Circular
ACAS	Airborne Collision Avoidance System
ACS	Aircraft Certification Service
ADIZ	Air Defense Identification Zone
ADS-B	Automatic Dependent Surveillance–Broadcast
AFI	Air Force Instruction
AFPD	Air Force Policy Directive
AFS	Flight Standards Service
AGC	Office of The Chief Counsel
AGL	Above Ground Level
AIM	Aeronautical Information Manual
ALoS	Acceptable Level of Safety
AMA	Academy of Model Aeronautics
AMOC	Alternative Method of Compliance
ANSP	Air Navigation Service Provider
AR	Army Regulations
ARC	Aviation Rulemaking Committee
ASI	Aviation Safety Inspector
ASTM	American Society for Testing and Materials
ATC	Air Traffic Control
ATCAA	Air Traffic Control Assigned Airspace
ATCSCC	Air Traffic Control System Command Center
ATO	Air Traffic Organization
ATS	Air Traffic Service

AVS	Aviation Safety

B

BLOS	Beyond-Line-of-Sight
BOA	Basic Ordering Agreement

C

C2	Control and Communications Link
CDTI	Cockpit Display of Traffic Information
CFIT	Controlled Flight Into Terrain
CFR	Code of Federal Regulations
COA	Certificate of Waiver or Authorization
ConOps	Concept of Operations
CRM	Crew Resource Management
CS	Control Station

D

DAA	Detect and Avoid
DCP	Divert/Contingency Point
DHS	Department of Homeland Security
DOC	Department of Commerce
DoD	Department of Defense
DOJ	Department of Justice
DOT	Department of Transportation
DPE	Designated Pilot Examiner
DSA	Detect, Sense, and Avoid System

E

ExCom	UAS Executive Committee
EO	Electro-Optical

F

FAA	Federal Aviation Administration

FAA ARC	FAA Aviation Rulemaking Committee
FAR	Federal Aviation Regulations
FCC	Federal Communications Commission
FHA	Fault Hazard Analysis
FIR	Flight Information Region
FL	Flight Level
FMRA	FAA Modernization and Reform Act of 2012
FOV	Field of View
FOR	Field of Regard
FPV	First Person View
FRZ	Flight Restriction Zone
FSDO	Flight Standards District Office
FSIMS	Flight Standards Information Management System
FTP	Flight Termination Point
FTS	Flight Termination System
FTX	Field Training Exercise
FY	Fiscal Year

G

GA	General Aviation
GAO	Government Accountability Office
GBSAA	Ground Based Sense and Avoid
GCS	Ground Control Station
GHz	Gigahertz
GMF	Government Master File
GPS	Global Positioning System
GSE	Ground Support Equipment

H

HFOV	Horizontal Field of View
HQ	Headquarters

I

IC	Incident Commander
ICAO	International Civil Aviation Organization
ICAO ASBUs	ICAO Aviation System Block Upgrades
ICAO UASSG	ICAO Unmanned Aircraft Systems Study Group
IFOV	Instantaneous Field of View
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IR	Infrared
ITU	International Telecommunication Union

J

JPDO	Joint Planning and Development Office

L

LIDAR	Light Detection and Ranging
LLP	Lost Link Point
LOA	Letter of Agreement
LOS	Line-of-Sight

M

MASPS	Minimum Aviation System Performance Standard
MHz	Megahertz
MOPS	Minimum Operational Performance Standards
MSL	Mean Sea Level

N

NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NAVAIRINST	Naval Air Systems Command Instruction
NextGen	Next Generation Air Transportation System
NIJ	National Institute of Justice

NIMS	National Incident Management System
NM	Nautical Mile
NOAA	National Oceanic and Atmospheric Administration
NOTAM	Notice to Airmen
NPRM	Notice of Proposed Rulemaking
NSTC	National Science and Technology Council
NTIA	National Telecommunications and Information Administration

O

OPA	Optionally Piloted Aircraft
OSED	Operational Services and Environmental Definition

P

PIC	Pilot in Command
POC	Point of Contact
POC	Probability of Containment
POD	Probability of Detection
POS	Probability of Success
PTS	Practical Test Standards
PUM	Proper Use Memorandum

Q

QRT	Quick Reaction Test

R

R&D	Research and Development
R/C	Radio Control
RD&D	Research, Development and Demonstration
RF	Radio Frequency
RM	Risk Management
RNAV	Area Navigation
RPA	Remotely Piloted Aircraft

RPV	Remotely Piloted Vehicle
RTB	Return to Base
RVSM	Reduced Vertical Separation Minimum

S

S&T	Science and Technology
SAA	Sense and Avoid
SAR	Search and Rescue
SARP	Standards and Recommended Practices
SARPs	Standards and Recommended Practices
SFAR	Special Federal Aviation Regulation
SFRA	Special Flight Rules Area
SGI	Special Government Interest
SM	Statute Mile
SMC	SAR Mission Coordinator
SMS	Safety Management System
SPC	Senior Policy Committee
SRM	Safety Risk Management
SRMD	Safety Risk Management Document
SSI	Sensitive Security Information
STA	Special Temporary Authority
sUAS	Small Unmanned Aircraft Systems

T

TAS	Traffic Advisory Systems
TC	Type Certificate
TCAS	Traffic Alert and Collision Avoidance System
TCRG	Technical Community Representative Group
TOR	Terms of Reference
TSO	Technical Standard Order

U

UA	Unmanned Aircraft
UAR	UAS Automation Roadmap
UAS	Unmanned Aircraft System
UAS-AI	Unmanned Aircraft Systems – Airspace Integration
UAV	Unmanned Aerial Vehicle
USC	United States Code
USCBP	U.S. Customs and Border Protection
USCG	U.S. Coast Guard
USMR	UAS Search and Manned Rescue

V

VFOV	Vertical Field of View
VFR	Visual Flight Rules
VLOS	Visual Line-of-Sight
VMC	Visual Meteorological Conditions
VO	Visual Observer
VTOL	Vertical Take Off and Landing

W

WRC	World Radio Communications Conference

Appendix F: Reference Library and Glossary

References

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FAA MRA: *FAA Modernization and Reform Act of 2012*.

FAA Roadmap: *UAS Roadmap (2013)*.

FAA UAS Plan: *UAS Comprehensive Plan (2013).*

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Glossary

A

Air Traffic Control: A service operated by appropriate authority to promote the safe, orderly, and expeditious flow of air traffic. (FAA AIM)

Air Traffic Service: A generic term meaning:

a. Flight Information Service;

b. Alerting Service;

c. Air Traffic Advisory Service.

d. Air Traffic Control Service: 1. Area Control Service, 2. Approach Control Service, or 3. Airport Control Service. (FAA AIM)

Aircraft: A device that is used or intended to be used for flight in the air. (14 C.F.R.)

Aircraft Certification Service: The FAA Aircraft Certification Service is the office responsible for:

• Administering safety standards governing the design, production, and airworthiness of civil aeronautical products;
• Overseeing design, production, and airworthiness certification programs to ensure compliance with prescribed safety standards;
• Providing a safety performance management system to ensure continued operational safety of aircraft; and,
• Working with aviation authorities, manufacturers, and other stakeholders to help them successfully improve the safety of the international air transportation system. (www.faa.gov)

Airspace: Any portion of the atmosphere sustaining aircraft flight and which has defined boundaries and specified dimensions. Airspace may be classified as to the specific types of flight allowed, rules of operation, and restrictions in accordance with International Civil Aviation Organization standards or State regulation. (RTCA DO-320)

Airworthiness: A condition in which the UAS (including the aircraft, airframe, engine, propeller, accessories, appliances, and control station (CS)) conforms to its type certificate (TC), if applicable, and is in condition for safe operation. (FAA 8900.1)

Airworthiness Certification: A repeatable process that results in a documented decision that an aircraft system has been judged to be Airworthy. It is intended to verify that the aircraft system can be safely maintained and safely operated by fleet pilots within its described and documented operational envelope. (FAA 8900.1)

Airworthiness Statement: Document required from public UAS applicants during a Certificate of Waiver or Authorization (COA) application process which confirms aircraft airworthiness. (FAA 8900.1)

C

Certificate of Waiver or Certificate of Authorization (COA): 1. An FAA grant of approval for a specific operation. COAs may be used as an authorization, issued by the Air Traffic Organization (ATO), to a public operator for a specific UA activity. COAs for civil and commercial operations are only for aircraft that have received an airworthiness certificate from Aircraft Certification Service (AIR). Provisions or limitations may be imposed as part of the approval process to ensure the UA can operate safely with other airspace users. (FAA 8900.1) 2. A COA constitutes relief from the specific regulations stated, to the degree and for the period of time specified in the certificate, and does not waive any state law or local ordinance. (FAA 7210.3)

Chase Aircraft: A manned aircraft flying in close proximity to a UA that carries a qualified observer and/or UA pilot for the purpose of seeing and avoiding other aircraft and obstacles. (FAA 8900.1)

Civil Aircraft: Aircraft other than public aircraft. (4) Civil aviation includes two major categories: (Federal Aviation Regulations FAR Part 91, 110, 121, 125, 135.)

1. Air transport, including all passenger and cargo flights operating on regularly scheduled routes, as well as on demand flights.

2. General aviation (GA), including all other civil flights, private or commercial.

   All air transport is commercial, but general aviation can be either commercial or private. Normally, the pilot, aircraft, and operator must all be authorized to perform commercial operations through separate commercial licensing, registration, and operation certificates. (FAA UAS Plan)

Collision Avoidance: The Sense and Avoid system function where the UAS takes appropriate action to prevent an intruder from penetrating the collision volume. Action is expected to be initiated within a relatively short time horizon before closest point of approach. The collision avoidance function engages when all other modes of separation fail. (SAA)

Communication Link: The voice or data relay of instructions or information between the UAS pilot and the air traffic controller and other NAS users. (RTCA DO-320)

Congested Area: A congested area is determined on a case-by-case basis. The determination must take into consideration all circumstances, not only the size of an area and the number of homes or structures (e.g., whether the buildings are occupied or people are otherwise present, such as on roads). (FAA 8900.1)

Control Station: The equipment used to maintain control, communicate with, guide, or otherwise pilot an unmanned aircraft. (RTCA DO-320)

Cooperative Aircraft: Aircraft that have an electronic means of identification (i.e., a transponder or Automatic Dependent Surveillance—Broadcast (ADS-B) transceiver) aboard in operation. (FAA 8900.1)

Crew Resource Management (CRM): The effective use of all available resources including human, hardware, and information resources. (FAA 8900.1)

Crew Member (UAS): In addition to the crewmembers identified in Title 14 of the Code of Federal Regulations (14 C.F.R.) part 1, a UAS flight crew member includes pilots, sensor/payload operators, and visual observers (VO), but may include other persons as appropriate or required to ensure safe operation of the aircraft. (FAA 8900.1)

D

Daisy-Chaining: The use of multiple, successive observers to extend the flight of a UA beyond the direct visual line-of-sight of any other pilot in command (PIC) or VO. (FAA 8900.1)

Data Link: A ground-to-air communications system which transmits information via digital coded pulses. (RTCS DO-320)

Detect and Avoid: Term used instead of Sense and Avoid in the Terms of Reference for RTCA Special Committee 228. This new term has not been defined by RTCA and may be considered to have the same definition as Sense and Avoid when used in this document. (FAA Roadmap)

Direct Control: The capability of a remote pilot to manipulate the flight control surfaces of the aircraft in a direct fashion using, for example, a radio control box with joystick or a ground control station using conventional type aircraft controls (such as a yoke/stick, rudder pedals, power levers, and other ancillary controls). This infers a one-to-one correspondence between control input and flight control surface deflection. (FAA 8130.34C)

Due Regard: A phase of flight wherein an aircraft commander of a State-operated aircraft assumes responsibility to separate his or her aircraft from all other aircraft. (FAA 8900.1)

E

Exemption: Relief from the requirements of a current regulation as provided for in 14 C.F.R. part 11, General Rulemaking Procedures. (FAA 8130.34C)

Experimental Certificate: A type of Special Airworthiness Certificate issued for the purposes of research and development (R&D), crew training, exhibition, and market survey as defined in 14 C.F.R. part 21, § 21.191 (a), (c), and (f).

(Note: According to 14 C.F.R. part 91, § 91.319(a)(2), experimental aircraft may not be used for carrying persons or property for compensation or hire.)

1) R&D Aircraft. Aircraft testing new design concepts, equipment, installations, operating techniques, or uses for aircraft. Any UAS, including an Optionally Piloted Aircraft (OPA), is eligible for an experimental certificate under this purpose. The proponent may conduct operations only as a matter of research or to determine whether an idea warrants further development. 2) Crew Training. The process of bringing a person or persons to an established standard of proficiency. Crew training is limited to the number of flight crews required by the operator to conduct UAS aircraft operations. 3) Market Survey. Aircraft may be used for the purposes of conducting market surveys, sales

demonstrations, and customer crew training of the manufacturer's customers, as provided in §21.195. (FAA 8900.1)

External Pilot: A UAS pilot who flies from outside a control station with direct visual contact with the aircraft. (FAA 8900.1)

F

FAA Recognized Equivalent: An FAA recognition that a public agency may exercise its own internal processes regarding airworthiness and pilot, aircrew, and maintenance personnel certification and training; furthermore, the agency has determined that its UAS is capable of safe operation in the National Airspace System (NAS) when conducting public aircraft operations under Title 49 of the United States Code (49 U.S.C.) §§40102(a)(41) and 40125. (FAA 8900.1)

Field of View: The angular width of a sensor's visibility, given in degrees, and often distinguished between horizontal (HFOV) and vertical (VFOV); it is a function of the sensor and lens dimensions.

Field of Regard: The area a sensor can cover by physically turning in its mount.

Flight Information Region: An airspace of defined dimensions within which Flight Information Service and Alerting Service are provided.

a. Flight Information Service. A service provided for the purpose of giving advice and information useful for the safe and efficient conduct of flights.

b. Alerting Service. A service provided to notify appropriate organizations regarding aircraft in need of search and rescue aid and to assist such organizations as required. (FAA AIM)

Flight Level: A level of constant atmospheric pressure related to a reference datum of 29.92 inches of mercury. Each is stated in three digits that represent hundreds of feet. For example, flight level (FL) 250 represents a barometric altimeter indication of 25,000 feet; FL 255, an indication of 25,500 feet. (FAA AIM)

Flight Level [ICAO]: A surface of constant atmospheric pressure which is related to a specific pressure datum, 1013.2 hPa (1013.2 mb), and is separated from other such surfaces by specific pressure intervals.

(Note 1: A pressure type altimeter calibrated in accordance with the standard atmosphere:

a. When set to a QNH altimeter setting, will indicate altitude;

b. When set to a QFE altimeter setting, will indicate height above the QFE reference datum; and

c. When set to a pressure of 1013.2 hPa (1013.2 mb), may be used to indicate flight levels.)

(Note 2: The terms 'height' and 'altitude,' used in Note 1 above, indicate altimetric rather than geometric heights and altitudes.) (FAA AIM)

Flight Termination: The intentional and deliberate process of performing controlled flight into terrain (CFIT). Flight termination must be executed in the event that all other contingencies have been exhausted, and further flight of the aircraft cannot be safely achieved, or other potential hazards exist that require immediate discontinuation of flight. (FAA 8900.1)

Flyaway: An interruption or loss of the control link, or when the pilot is unable to effect control of the aircraft and, as a result, the UA is not operating in a predicable or planned manner. (FAA 8900.1)

Formation:

1. Nonstandard Formation. A formation operating under any of the following conditions:

- When the flight leader has requested and air traffic control (ATC) has approved other-than-standard formation dimensions;
- When operating within an authorized block altitude or under the requirements of a letter of agreement (LOA);
- When the operations are conducted in airspace specifically designed for a special activity.

2. Standard Formation. A formation in which proximity of no more than 1 nautical mile (NM) laterally or longitudinally and within 100 feet vertically from the flight leader is maintained by each wingman or UA.

(Note: For more information, refer to the FAA AIM, Order JO 7110.10, Flight Services, and Order JO 7110.65, Air Traffic Control, at http://www.faa.gov/air_traffic/publications/atpubs/PCG/index.htm.) (FAA 8900.1)

I

Indirect Control: The capability of a remote pilot to affect the trajectory of the aircraft through computer input to an onboard flight control system. An example of an indirect control would be the entry of a navigational fix or waypoint on a remote system that, in turn, uploads this information to an onboard flight control computer. The flight control computer then computes the flight control inputs to achieve a flight path to the uploaded waypoint. The onboard system controls the flight control surfaces. (FAA 8130.34C)

Internal Pilot: A UAS pilot who flies from inside a control station without direct visual contact with the aircraft. (FAA 8900.1)

International Civil Aviation Organization (IACO): A specialized agency of the United Nations whose objective is to develop the principles and techniques of international air navigation and to foster planning and development of international civil air transport. (FAA AIM)

Instantaneous Field of View: A measure of the resolution of an EO/IR system; the dimension covered by a single sensor element in an array at range, given by IFOV=D/R. e.g. At a range of 1,000 meters, an IFOV of 10^{-4} would cover 10 cm. For a 1 square meter target this would provide 100 IFOVs on target. (EO/IR Tutorial)

L

Light Detection and Ranging (LIDAR): LIDAR is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses— combined with other data recorded by the airborne system— generate precise, three-dimensional information about the shape of the Earth and its surface characteristics. (http://oceanservice.noaa.gov/facts/lidar.html)

Lost Link: The loss of command-and-control link contact with the remotely piloted aircraft such that the remote pilot can no longer manage the aircraft's flight. (FAA 8900.1)

M

Manned Aircraft: Aircraft piloted by a human onboard. (RTCA DO-320)

Mode: The letter or number assigned to a specific pulse spacing of radio signals transmitted or received by ground interrogator or airborne transponder components of the Air Traffic Control Radar Beacon System (ATCRBS). Mode A (military Mode 3) and Mode C (altitude reporting) are used in air traffic control. (FAA AIM)

Model Aircraft: An unmanned aircraft that is capable of sustained flight in the atmosphere; flown within visual line-of-sight of the person operating the aircraft and flown for hobby or recreational purposes. (FAA MRA)

National Airspace System (NAS): The common network of U.S. airspace; air navigation facilities, equipment and services, airports or landing areas; aeronautical charts, information and services; rules, regulations and procedures, technical information, and manpower and material. Included are system components shared jointly with the military. (FAA AIM)

N

Non-Cooperative Aircraft: Aircraft that do not have an electronic means of identification (e.g., a transponder) aboard or that have inoperative equipment because of malfunction or deliberate action. (FAA 8900.1)

Nonstandard Formation: See Formation, above. (FAA 8900.1)

Notice to Airmen (NOTAM): Time-critical aeronautical information which is of either a temporary nature or not sufficiently known in advance to permit publication on aeronautical charts or in other operational publications receives immediate dissemination via the National NOTAM System. (FAA AIM)

O

Observer: A trained person who assists a UAS pilot in the duties associated with collision avoidance and navigational awareness through electronic or visual means. Collision avoidance includes, but is not limited to, avoidance of other traffic, clouds, obstructions, terrain and navigational awareness. A visual observer (VO) is a trained person who assists the UAS pilot by visual means in the duties associated with collision avoidance. A VO includes the OPA pilot when the OPA is being operated as a UAS. (FAA 8900.1)

Off-Airport: Any location used to launch or recover aircraft that is not considered an airport (e.g., an open field). (FAA 8900.1)

OPA Safety Pilot: The PIC that is responsible for ensuring the safe operation of an Optionally Piloted Aircraft (OPA), whether under remote control or onboard control, for the purposes of overriding the automated control system in the case of malfunction or any other hazardous situation. (FAA 8900.1)

Optionally Piloted Aircraft (OPA): An aircraft that is integrated with UAS technology and still retains the capability of being flown by an onboard pilot using conventional control methods (see OPA Safety Pilot). (FAA 8900.1)

P

Pathfinder: An initial UAS airworthiness certification program that will aid the FAA in the establishment of certification requirements. (FAA Roadmap)

Pilot Duty Period: The period beginning when a flight crew member is required to report for duty with the intention of conducting a flight and ending when the aircraft is parked after the last flight. It includes the period of time before a flight or between flights that a pilot is working without an intervening rest period. (FAA 8900.1)

Pilot in Command (PIC): The person who has final authority and responsibility for the operation and safety of flight, has been designated as PIC before or during the flight, and holds the appropriate category, class, and type rating, if applicable, for the conduct of the flight. The responsibility and authority of the PIC as described by §91.3 apply to the UA PIC. The PIC position may rotate duties as necessary with equally qualified pilots. The individual designated as PIC may change during flight *(Note: The PIC can only be the PIC for one aircraft at a time)*. For an OPA, the PIC must meet UAS guidance requirements for training, pilot licensing, and medical requirements when operating an OPA as a UAS. (4) Pilot-in-command means the person who: 1) has final authority and responsibility for the operation and safety of the flight; 2) has been designated as pilot-in-command before or during the flight; and 3) holds the appropriate category, class, and type rating, if appropriate, for the conduct of the flight. (14 C.F.R. § 1.1)

Proper Use Memorandum (PUM): A memorandum signed annually by an organization's Certifying Government Official. The imagery user organization will submit this memorandum annually. It defines their requirements and intended use, and contains a proper use statement that acknowledges their awareness of the legal and policy restrictions regarding domestic imagery. (AFINST 14-04)

Public Aircraft: 1) An aircraft operated by a governmental entity (including Federal, State, or local governments, and the U.S. Department of Defense (DOD) and its military branches) for certain purposes as described in 49 U.S.C. §§40102(a)(41) and 40125. Public aircraft status is determined on an operation by operation basis. Refer to Part 1, §1.1 for a complete definition of a public aircraft. (FAA 8900.1) 2) Public Aircraft Operation (PAO) is limited by the statute to certain government operations within U.S. airspace. Although these operations must comply with certain general operating rules (including those applicable to all aircraft in the NAS), other civil certification and safety oversight regulations do not apply. Whether an operation may be considered public is determined on a flight-by-flight basis, under the terms of the statute (49 U.S.C. 40102 and 49 U.S.C.

40125) and depends on factors such as aircraft ownership, operator, the purpose of the flight and the persons on board the aircraft. (FAA UAS Plan)

Public Operator: An operator that is classified as government and/or otherwise qualifies for public aircraft operation under 49 U.S.C. §§40102(a)(41) and 40125. Not all flights by a public aircraft operator qualify as a public aircraft operation under the statute. Public aircraft operation status is not automatic for flights conducted by a government entity or a contractor to a government entity. (FAA 8900.1)

R

Remotely Piloted Aircraft (RPA): Alternative term with no legal or regulatory distinction from unmanned aircraft (UA) or unmanned aerial vehicles (UAV). Preferred term of use by ICAO.

RTCA: RTCA, Inc. is a private, not-for-profit corporation that develops consensus-based recommendations regarding communications, navigation, surveillance, and air traffic management system issues. RTCA functions as a Federal Advisory Committee. Its recommendations are used by the FAA as the basis for policy, program, and regulatory decisions and by the private sector as the basis for development, investment and other business decisions. (www.rtca.org)

S

Safety Evaluation: A comprehensive review of an applicant's UAS, OPA, or OPA/UAS and all associated elements of the system. The applicant is expected to provide any and all information necessary to allow the FAA to objectively determine if the aircraft can be safely operated in the NAS. The form of this review is a presentation by the applicant to the FAA. The safety evaluation is a formal review of the information contained in the safety checklist and is performed at the discretion of the FAA. (FAA 9130.34C)

Safety Risk Management (SRM): A formalized, proactive approach to system safety. SRM is a methodology that ensures hazards are identified; risks are analyzed, assessed, and prioritized; and results are documented for decision-makers to transfer, eliminate, accept, or mitigate risk. (FAA 8900.1)

Scheduled Maintenance (Routine): The performance of maintenance tasks at prescribed intervals. (FAA 8900.1)

See and Avoid: When weather conditions permit, pilots operating instrument flight rules or visual flight rules are required to observe and maneuver to avoid another aircraft. Right-of-way rules are contained in 14 C.F.R. § 91. (FAA AIM)

Segregation: Setting apart from other air traffic operations in the NAS. Segregation is not synonymous with required air traffic separation standards. Therefore, segregation does not prescribe or mandate criteria such as vertical, lateral, or longitudinal distances. (FAA 8900.1)

Self-Separation: Sense and Avoid system function where the UAS maneuvers within a sufficient timeframe to remain well clear of other airborne traffic. (SAA)

Sense and Avoid: the capability of an unmanned aircraft to remain a safe distance from and to avoid collisions with other airborne aircraft. (FAA MRA)

Small Unmanned Aircraft: An unmanned aircraft weighing less than 55 pounds. (FAA MRA)

Special Airworthiness Certificate – Experimental Category (UAS): Airworthiness certification for experimental UAS and optionally piloted aircraft. (FAA Roadmap)

Support Equipment: All associated equipment, whether ground based or airborne, used to enable safe operation of the unmanned aircraft. This includes all elements of the control station, data links, telemetry, navigation, communications equipment, as well as equipment that may be used to launch and recover the aircraft. (FAA 8130.34C)

T

Test Range: A defined geographic area where research and development are conducted in accordance with Sections 332 and 334 of the FMRA. Test ranges are also known as test sites in related documents such as the FAA's Screening Information Request. (FAA MRA)

Transponder: The airborne radar beacon receiver/transmitter portion of the Air Traffic Control Radar Beacon System (ATCRBS) which automatically receives radio signals from interrogators on the ground, and selectively replies with a specific reply pulse or pulse group only to those interrogations being received on the mode to which it is set to respond. (FAA AIM)

U

Unmanned Aircraft: 1. An aircraft that is operated without the possibility of direct human intervention from within or on the aircraft. (FAA MRA) 2. A device used or intended to be used for flight in the air that has no onboard pilot. This device excludes missiles, weapons, or exploding warheads, but includes all classes of airplanes, helicopters, airships, and powered-lift aircraft without an onboard pilot. UAs do not include traditional balloons (refer to 14 C.F.R. § 101), rockets, and unpowered gliders. (FAA 8900.1)

Unmanned Aircraft System: 1. An unmanned aircraft and associated elements (including communications links and the components that control the unmanned aircraft) that are required for the pilot-in-command to operate safely and efficiently in the national airspace system. (FAA MRA) 2. An unmanned aircraft and its associated elements related to safe operations, which may include control stations (ground-, ship-, or air-based), control links, support equipment, payloads, Flight Termination Systems (FTS), and launch/recovery equipment. (FAA 8900.1)

V

Visual Line-of-Sight (VLOS): Unaided (corrective lenses and/or sunglasses exempted) visual contact between a pilot-in-command or a visual observer and a UAS sufficient to maintain safe operational control of the aircraft, know its location, and be able to scan the airspace in which it is operating to see and avoid other air traffic or objects aloft or on the ground. (FAA 8900.1)

Appendix G: NGAT UAS Best Practices

DIVISION OF AVIATION
NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

NGAT

NC STATE UNIVERSITY

NC DOT and NGAT UAS Airspace Integration Table Top Exercise (TTX) 17 – 19 January 2017

Airspace Integration TTX Best Practices Guidebook

UAS Best Practices

Best Practices Introduction

The North Carolina State University's (NCSU) NextGen Air Transportation (NGAT) Program has developed a series of Best Practices to guide North Carolina public agencies and user groups in developing safe and effective Unmanned Aircraft System (UAS) programs. These documents outline agency-specific considerations that should be evaluated by the various public agencies in the State of North Carolina. Each agency, or user community, has specific requirements and operations that would benefit from integrating Unmanned Aircraft Systems (UAS) into their programs. These documents provide information to assist agency executives, program managers and operations managers in developing their programs.

Baseline Set of Best Practices

- Expectation Management
- Operational Procedures
- Crew Selection
- Data Management
- Procurement
- Policies
- Communications/Outreach
- Business and Operations Models

The initial release of these Best Practices includes eight integrated documents.

These Best Practices serve to educate and inform state agencies and to assist regulatory commissions with industry wide regulations and recommendations for safe UAS flights. NGAT offers analysis and recommendations tailored to each agency based on the agency's operational needs and available budget.

These Best Practices are based on small UAS (< 55 lbs) and have adopted the existing FAA requirement and designation that the individual responsible for the UAS and its flight safety is the Pilot-In-Command (PIC). This designation applies to both UAS operations under the Part 107 Rule for small operations that requires a PIC to obtain a Small UAS Operator Certificate for a Remote Aircraft License, and also to UAS operations under a Public Certificate of Authorization (COA) that allows the public agency to self-certify the PIC against a set of requirements. NGAT will continue monitoring the evolution of FAA certification requirements and will edit these Best Practices accordingly.

Figure 7: Know Before You Fly Education Campaign Logo

NGAT endorses the use of the *Know Before You Fly* (Figure 7) protocols in these Best Practices. *Know Before You Fly* is an education campaign founded by the Association for Unmanned Vehicle Systems International (AUVSI) and the Academy of Model Aeronautics (AMA) in partnership with the Federal

Aviation Administration (FAA) to educate prospective users about the safe and responsible operation of UAS. The *Know Before You Fly* web address is www.knowbeforeyoufly.org.

In order to capture developing national level thought on UAS Best Practices, NGAT has engaged the U.S. Department of Commerce's National Telecommunications and Information Administration (NTIA) regarding commercial and private UAS and their privacy, transparency, and accountability issues. NGAT has included some of the group's stakeholder input as a derivative contribution into these Best Practices. These include the following disclaimers:

- These best practices are not intended to supersede the authority of the FAA
- Nothing in these Best Practices should take precedence over the safe operation of a UAS.
- Nothing in these Best Practices should be construed to impede the use of UAS for purposes of emergency response, including safety and rescue responses.
- UAS operators should comply with all applicable laws and regulations. These Best Practices do not replace or take precedence over any local, state, federal, or Constitutional law or regulation. Best Practices are intended to encourage positive conduct that complements legal compliance.
- Nothing in these best practices should be construed to impede the use of UAS for purposes of news or public information services.
- Nothing in these Best Practices should take precedence over the contractual obligations of a UAS operator or the representations of entities contracting UAS operators. However, entities contracting UAS operators should consider these Best Practices when setting the terms of a contract for UAS use, and UAS operators should consider these Best Practices when choosing to accept a contact for UAS use.

The terms "where practicable" and "reasonable" are used frequently in these Best Practices. What qualifies as "practicable" or "reasonable" should depend largely on the resources and circumstances of the UAS operator, the sensitivity of data collected, and the context associated with a particular UAS operation.

The Baseline Best Practices present the basic components necessary to execute a safe and effective UAS program. These best practices articulate the policies, procedures, operations and training requirements for the programs.

Best Practice Format

The following Best Practices are presented using a common format. This format is:

- Introduction
- Key Actors
- Potential Applications (optional)
- Practice Description
- Notional Scenarios (optional)

EXPECTATION MANAGEMENT BEST PRACTICE

Introduction

In order to operate UAS in the civilian airspace system, organizations need to understand the full potential of UAS. The acceptance of UAS by both regulatory bodies and the general public alike hinges on having a defined mission objective, following safety protocols, and undertaking proper maintenance of the equipment. It is critical UAS must be able to integrate seamlessly into the existing airspace environment without posing any risk to other airspace users, persons or property on the ground. Hazards associated with a proposed UAS operation can be identified based on system knowledge, risk analysis, past experience, and lessons learned. This document identifies key practices associated with mission definition, sharing the airspace and reporting logs.

Key Actors

- Flight Crew
- Site Manager
- FAA
- Airport Authority
- Air Traffic Controller
- UAS Insurance Companies
- NCDOT

Practice Description

There are four sections to this practice description: Mission Management, Sharing the Airspace, Equipment Life, and Documentation.

Mission Management

Mission Profiles

When starting a UAS program, identifying specific missions to be performed by the UAS team is critical to establishing a trusted, effective and productive program. A detailed set of mission profiles should be described to scope the initial UAS Flight operations. Those profiles should include the following –

- **Types of missions within scope of program** – crop surveys, crop spraying, surveying, mapping, building inspection, infrastructure inspection, search and rescue, fire management, accident investigation, aerial photography.
- **Size of mission areas** – Small area (Less than 10acres), Moderate Area (10 to 500 acres), Broad area (500 acres and more), Corridor, Structure/facility (Footprint + height)
- **Payload requirements** – Type (Video, spectral, IR), Size (Weight)

These descriptions help determine 1) the type of aircraft needed to accomplish flight operation tasks; 2) crew credentials; and 3) airspace approvals required to complete mission objectives.

Mission definition

Defining each flight mission is the first step to planning a flight operations for schedule. The mission plan should contain all actions, contingencies and goals for the mission objective.

1. **Identify type of mission.**
   The overall mission process starts by defining the target mission (crop surveys, surveying, mapping, building inspection) and selecting the UAS to be used to implement it. Both Fixed and Rotor wing UAS have inherent limitations so understanding the mission objective is critical to selection of the UAS. This should be determined way in advance to the arrival at the flight site.
2. **Define desired outcomes.**
   The second step is to determine the deliverables (images or video) for the flight mission. On the basis of the deliverable, additional special equipment for the UAS will need to be selected. Here the operator needs to identify the specific details of the equipment (Sensors, Spray / dispensing equipment, External loads) that is needed for the mission. This includes the make and model of the equipment and its size, weight, power, specifications, procedures and communication needs.
3. **Define operational environment**.
   - **Perimeter** – It is important for the PIC to know where he/she will be conducting flight operations. The PIC should get information about the flight area from the land owner or agency owning it. Accordingly he/she should plan the flight mission and designate all other areas (take-off, landing, safe area, etc.)
   - **Alerts** – The flight crew should be aware of obstacles or structures that could affect normal flight operations. The PIC should do a sight screening prior to the flight day to know what the terrain will be and plan the fight mission accordingly.
   - **Proximity to an airport** – The PIC should ensure that if any flight operations are conducted near (within 5 miles) to an airport, then written permission from the tower should be obtained. Also the PIC and Observer should be extra cautious for manned aircraft flying in the vicinity.
   - **Altitude** – The height at which UAS flies becomes very important especially if flown above 200 feet or higher because it increases the ability to interfere with commercial aircraft. Under no circumstances should an UAS be flown anywhere near the flight path of a manned aircraft.

- **Command Center** – PIC should plan the command center in an area that will ensure line of sight with the Observer and UAS in the air at all times. This area should be secured and clear of obstacles.

4. **Review capabilities and resources.**

   Before starting the fight operations it is necessary to recheck if all documents and approvals are current.

   - Operator's credentials should be verified and carried by the operator at all times.
   - Inspect the aircraft.
   - Check the flight software is current by regular update checks. If software upgrades are required, the best practice would be to check, download and update prior to arrival at the flight site.
   - Review the FAA approval to conduct operations. That includes COA constraints and requirements. Confirm that the NOTAM is posted.
   - Have the written permissions from the airport authority (if flight operations are conducted within 5 miles of an airport) and land owner (for conducting flight operation on private or state land in NC). For more details refer to Crew Selection and Aircraft Selection of Best Practices.

5. **Develop Mission plan.**

   A mission plan should include of 4 primary sections: a flight plan, a security plan, a data management plan, and a flight schedule.

   - **Flight Plan**

     The flight plan should describe how the UAS will fly during the mission to accomplish the objectives. Any limiting factors such as flight restricted area or obstacles, in the flight environment may alter the intended operation and require modification of the flight plan accordingly. Contingency planning should include safe routes in the event of a system failure, degraded performance, or lost communication link, if such a failsafe exists. Most UAS solutions offer ground control stations that can be used to develop flight plans, configure the UAS, plus monitor the UAS in flight using a telemetry link. Each flight plan is composed of a sequence of stages, such as take-off, departure procedure and others, which must be followed and adhered to in the correct order. Refer to Operational Procedures Best Practices for more information.

   - **Security Plan**

     a) Before the starting the day's flight operations it is a best practice for the PIC to give a safety and security briefing to both the flight crew and other people participating in the flight.

b) At full power, an average sized UAS can exceed 40 mph, so be sure to maintain safe distances between the flight crew, and spectators and the UAS.

c) ‘Safe distance’ from people and property is determined by circumstances, terrain and flight mission. The flight crew is responsible to plan the flight operational perimeter in which the flight area, command center (Ground Station and other necessary equipment’s needed for the flight), safe area, take off, primary landing and emergency landing will be located.

d) If it is a hand launch make sure it will be well clear of others and take all necessary precautions for a catapult launcher as well.

e) Keep the UAS well clear of all people, property and obstacles.

f) Spectators should always be a safe distance away from PIC. The area where the PIC will conduct all flight operations using the ground control station should be secured as a PIC Area.

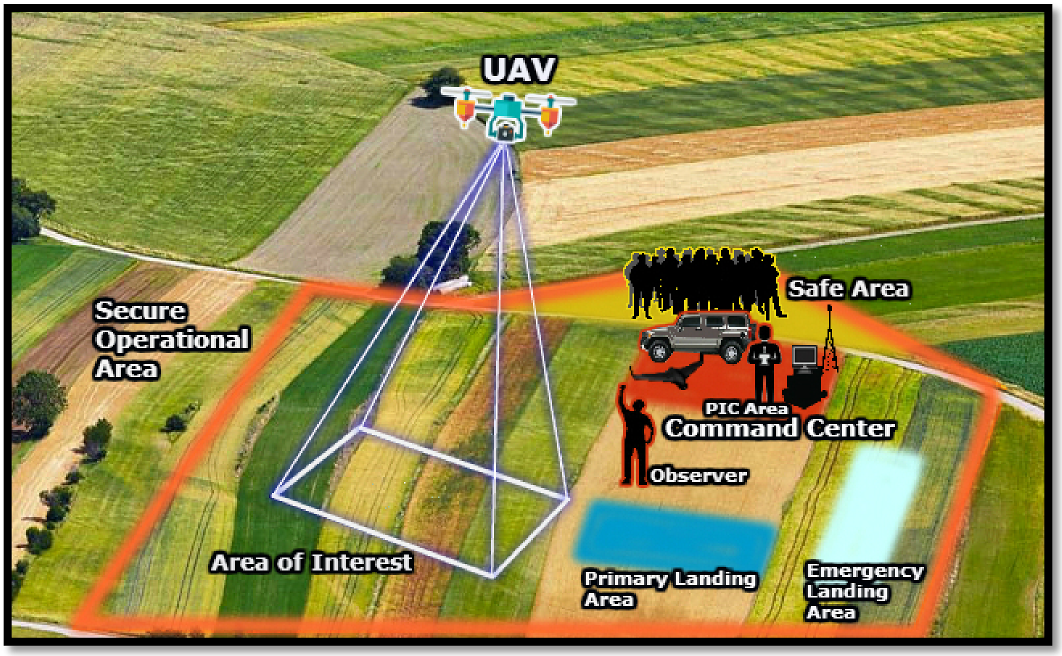
g) Ensure that no one gets between the flight crew operations and the UAS. This can be done by placing cones or using spray paint to mark the operational area and PIC Area.

h) If anyone intrudes beyond what is determined to be the "safe" area, the flight operation should be suspended until control area is considered clear.

i) Having a site manager present can be of great assistance, as he/she can make sure that non-authorized personnel are clear of the flight area at all times.

j) The only people who should be permitted to enter the flight operational perimeter during flight operations should be personnel who are authorized by the PIC.

k) PIC should be aware of any risks at the flight location, including bodies of water, structures, trees, etc. Also prior to take off, PIC should designate a few areas as “safety zones” to safely land the aircraft in case of an unexpected situation.



- **Data Management Plan**
  a) Develop and follow a data transfer and processing plan regardless of

Figure 8: Recommended UAS Mission Planning Elements

single flight or multiple flight operations to accomplish the mission objectives. This will ensure smooth, repeatable and auditable flight operations.
  b) Multiple SD cards and data storage devices may be required for storing flight data.
  c) Data may also be transferred in real time via wireless connectivity.

For more in depth explanation read the Data Management Best Practice.

- **Flight Schedule**
  a) Publish a daily flight schedule prepared bi-weekly or monthly. This way NOTAMs can be posted and appropriate permissions from air traffic authorities, from an airport authority, and land owners may be obtained.
  b) Flight crew and equipment should also be scheduled as part of a resource management plan.
  c) The daily schedule should include perimeter security time, crew arrival time, set up time, additional attendee arrival times, launch time(s), flight time(s), data transfer time, break(s) and departure time. While the schedule is subject to change, having a basic plan provides all participants a reference.

Example of a Mission Plan

Agency the data is for – NC Department of Agriculture

Agency flying for the data – NextGen Air Transportation Program

Flight Location – Lake Wheeler Field

1. **Type of Mission** – Crop survey
2. **Desired Outcome** – To study invasive species weed infestation
3. **Operational Environment**
    a) Perimeter – 1500 acre field, need to scan approximately 500 acres
    b) Alerts - Trees, Power lines and 1 building within the fight operational area
    c) Proximity to an airport – Just touching the 5 NM ring of the Greenville airport.
    d) Altitude – 100 meters
    e) Control Location – close to take-off location in SE corner of field.
4. **Capabilities and Resources**
    - Crew – PIC & Observer Names
    - Aircraft – Trimble UX5
    - Approvals – NCSU COA, Airport & NCSU land usage permission from land owner.
5. **Mission Plan**
    - Flight Plan
        a) Area of interest drawn on the flight computer using Surveying Software.
        b) Winds from 250 degree.
        c) Take-off and landing into the wind.
        d) Total Flight duration – 30 mins with 45 legs
        e) Emergency landing planned.
    - Security Plan
        a) PIC area secure
        b) Site manager present to secure flight operations area.
        c) No additional attendees expected
    - Data Plan
        a) 1 SD card required
        b) SD card reader and Laptop required
        c) Data processing using Trimble Business Center
    - Schedule – NOTAM and permission obtained 2 weeks prior
        a) Crew arrival Time – 9:45am
        b) Setup Time – 30 mins
        c) Launch Time – 10:15am
        d) Recover – 10:47am
        e) Depart – 12:00pm

Mission Planning Valuable Lessons Learned

- Keep it simple
- Things can go wrong so always be prepared for contingencies and immediate action.
- Preplan the flight mission with a site visit or using Google Earth for site familiarization.
- The higher the flight, the more the area the system can map.
- Flying at noon limits shadows.
- Image processing takes lots of computing power. A data processing computer with a fast processor with lots of memory is recommended.
- High quality images equate to high quality analysis, poor images mean poor data.
- Aerial images and analysis need to be correlated with ground data to be effective for surveying and engineering missions.

Sharing the airspace

UAS can be legal airspace users, however, they need to integrate into national airspace in a safe, responsible manner. Routine access to the national airspace system poses a variety of technological, regulatory, workload, and coordination challenges. For everyone's safety, aviation is governed by a stringent set of aviation regulations. A high level of professionalism is expected from every UAS Flight Crew.

UAS do not have completely unrestricted access to airspace use. They must integrate safely with other airspace users, so if safety provisions cannot be made or if operations are such that they negatively impact the safety of other airspace users, the operation cannot be allowed. In controlled airspace, other than Class A, the national policy states that UAS "must not impede, delay, or divert" other operations flying in that airspace. It is imperative that the capability of taking immediate active control of the aircraft by the PIC exists at all times, the same way it does with manned aircraft. The risk of a UAS colliding with another aircraft must be comparable to that for manned aircraft. Vigilance for the purpose of detecting potential collisions must not be relaxed for any aircraft in flight, regardless of the type of flight, type of aircraft or class of airspace in which the aircraft is operating.

Presently the technological focus for increasing air traffic capacity is on collision avoidance systems. The development of sophisticated and robust "sense-and-avoid" systems has been a key focus for the civil UAS sector. Also the Federal Aviation Administration (FAA) has mandated that most aircraft operating in airspace must be equipped with ADS-B Out (Automatic Dependent Surveillance-Broadcast) by Jan 1, 2020 to broadcast the aircraft's GPS-based location in real time, including altitude and velocity information. Also to prevent collisions or accidents, UAS must currently be flown within Line of Sight under current regulations. Visual Line of Sight is termed as being the maximum distance that the PIC (not visual observer) is able to maintain separation and collision avoidance, under the prevailing atmospheric conditions. This is typically less than 1 mile from a ground based observer for a small UAS.

Sharing the Airspace Valuable Lessons Learned

- Manned air traffic has priority.
- Role of the Visual Observer(s) is to maintain the aircraft in the visual line of sight and alert the Pilot in Command (PIC) to any potential flight obstacles.
- ADS-B and other traffic surveillance technology should be used if available.
- For safe operations it is recommended to coordinate with local airports/air service providers if regular UAS operations are close to an airport. This way manned operations like crop dusters and or helicopters stay clear or fly above the flight site. This communication with the local aviation community encourages other airspace users to check NOTAMs, reach out if they have questions, and provide local knowledge.
- Utilization of the FAA B4UFly app.
- Incident response activities with other manned aircraft requires explicit UAS integration coordination with local airspace manager.
- Do not assume anything.

Equipment life

UAS are constructed of foam, kevlar, carbon fiber, wood, plastic or other materials. Just as with manned aircraft, the more they are flown the more wear and tear is expected. Although specific requirements for ongoing inspections, maintenance, and repairs may not be standardized yet, it is recommended to include these important pieces in the routine mission operations. It is important to understand that while the FAA has not yet outlined a formal maintenance program, the notion that airworthiness is a responsibility of the operator is very clearly articulated in Part 107 inspection requirements. It is important for any organization to understand and follow maintenance procedures or consult with a trusted agency who can ensure UAS are properly inspected, repaired, and returned to service in airworthy condition. NGAT has developed an airworthiness assessment process that is recognized by the FAA for approving aircraft for routine UAS operations. NGAT is able to share existing Statements of Airworthiness and develop new ones by working with other agencies. Safety is always first priority, but downtime for the aircraft also means it is not meeting its intended function. Proper UAS maintenance and inspections can avoid costly, or even total airframe losses, in the field.

When considering buying a UAS, it is important to check the warranty and after-sale services agreements. It is also important to check if the spare parts for the UAS are readily available. This is an important consideration because breaking or cracking a wing could take two weeks or more for shipping a replacement. Make sure to either have an inventory of spares, or have a nearby dealer who has a dependable supply of UAS parts.

Another suggested best practice is to protect the investment and organization with UAS insurance. Insurance companies are expecting each organization to have PIC qualifications, operating manuals, maintenance logs and a record of parts or add-ons purchased.

After every flight, if an inspection should reveal any damage, the PIC should authorize the repair of the aircraft. Repairs can consist of two types, non-critical or critical. Non-critical repairs are repairs made to the airframe or components that are not critical to the flight control or function of the aircraft in its assigned mission. Repairs of this nature are patches to covering, replacing fairings or cowlings, or repairs that enhance the mission payload. Critical repairs or those repairs that must be made that directly affect the ability of the aircraft to perform its function and to continue the mission. Typical repairs of this nature would be such as replacing a motor, or replacing a fight control servo.

Documentation

The following are examples of reports, documents, and other materials that may be generated, issued or required for UAS operations -

FAA Documentation

- **Certificate of Waiver or Authorization (COA)**

  For public aircraft operations, the FAA issues a COA that permits public agencies and organizations to operate a particular aircraft, for a particular purpose, in a particular area. The COA allows an operator to use a defined block of airspace, with a specific aircraft and includes special safety provisions unique to the proposed operation. A COA request is prepared and submitted online through the FAA's COA Management Portal. An approved COA is returned after FAA analysis and any constraints, modifications or additional requirements
- **Monthly COA reports**

  Monthly COA reports are required, even if no flights were conducted under an approved COA. The Monthly Operational report is expected to be submitted within 5 business days after end of the reporting month Reporting Requirements. Documentation of all operations associated with UAS activities is required regardless of the airspace in which the UAS operates.

  1. Name of Operator, COA or Exemption number, and Aircraft registration number
  2. UAS type and model.
  3. All operating locations, to include location city/name and latitude/longitude
  4. Number of flights (per location, per aircraft)
  5. Total aircraft operational hours
  6. Takeoff or Landing damage
  7. The number and duration of lost link events (control, performance and health monitoring, or communications) per aircraft per flight.
  8. Equipment malfunctions. Reportable malfunctions include, but are not limited to the following: On-board flight control system, navigation system, powerplant failure in flight, fuel system failure, electrical system failure, and control station failure.

- **Notice to Airmen (NOTAM)** – A NOTAM is a notice filed with an aviation authority to alert aircraft pilots of potential hazards along a flight route or at a location that could affect the safety of the flight. NOTAMs do not restrict airspace, they are a public announcement to the airspace community.
- **UAS Registration** - Registration is required for all unmanned aircraft (UA) operated for non-hobby or non-recreational purposes. An aircraft may be registered only by and in the legal name of its owner. The FAA UAS website for aircraft registration is available from the primary UAS page[4].
- **Airport Authorization –** A written approval from the airport management authority is recommended to fly within 5 miles of an airport. Before calling the airport authority, be sure to have exact location, planned maximum altitude and flight time information ready to process the flight request.

North Carolina Documentation

- **State UAS Operator Permit**
  Under the current state law, all commercial and government agency UAS users must obtain a state UAS Operator permit issued by NCDOT Division of Aviation. This permit is in addition to a federal small UAS Operator Certificate and/or COA Certification that is accepted by the FAA.
- **Land User Authorization**
  A written permission granted by the authorized approving official (state or private) to take off, land and otherwise use their facility (farm, private land, etc.). Such use permit may be issued for single or multiple occasions

Personal (Pilot in command & Visual Observers) Documentation

It is recommended that pilots of unmanned aircraft should document their flights, pilots of manned aircraft are required to document their flight time.

- **Personal Flight Log**
  Each member of the flight crew should keep a record of all flights flown. The log should contain the location flown, time of flight, aircraft used (reference the specific UAS registration number), and a flight ID number.

Organizational Documentation

Every organization should have a UAS fleet management system designed to help keep track of the organization's pilots and UAS fleet, covering all the needs and requirements for maintaining a safe and reliable UAS operation.

[4] FAA Small UAS Registration page: https://registermyuas.faa.gov/

- Flight Crew Log

  The log should contain flight location, date, time of flight, type of aircraft, flight ID number, Crew name (PIC, VO(s), site manager).
- Aircraft Log

  This log should contain location, date, time of flight, PIC, Notes.
- Maintenance Log

  The log should contain date, type of aircraft, reason for maintenance, work done, parts replaced, system tested (yes/no), notes, etc.
- Data Log

  The log should contain Flight ID, location, PIC, type of data acquired, data archive ID, and location.
- Accident Log

  The log should contain date of accident, time of accident, name of injured, accident details, action taken, notes, report ID from FAA/NTSB if applicable, etc.
- Annual Report – Review of UAS program containing data utilization, budget, and lessons learned, etc.

OPERATIONAL PROCEDURES

Introduction

All UAS operators should develop and document operational procedures for their organization that will serve to guide flight operations planning and execution. The operational procedures document best practices and internal processes for safe and effective flight operations. This includes roles and responsibilities, mission phases, and emergency procedures. The aim is to document everything that needs to be done during a mission, so it can act as a reference point for team members. The information below is provided as a guideline for organizations to use in their own development of Operational Procedures specific to their organization and the types of flight operations they conduct. However, not all of these guidelines will apply to all situations. Therefore, use your best judgment and error to the side of safety.

Key Actors

- UAS Operator and/or Pilot in Command (PIC)
- Visual Observer
- Airport Manager
- Air Traffic Controller
- Land owner or designated party for launch and recovery site

Practice Description

There are 8 sections to the practice: Pre-flight Operations, During Flight Operations, Post-flight Operations, Emergency Procedures, Flight Area/Perimeter Management, Accident/Incident Reporting, Flight Crew Communications, and External Communications.

Pre-flight Operations

Preflight activities are the duty of the pilot in command and also the observer either upon arrival at the location or before the start of the flight operation. Activities include inspection of the aircraft, assessment of the operating location, co-ordination with other crew members involved in the operation, and equipment checkouts. All flight operations should be conducted in accordance with an FAA-approved authorization, state and local legal regulations, and the operator's manual for the subject aircraft.

Planning

1. The flight crew should be familiarized with all available information concerning takeoff including, but not limited to the flight authorization constraints, weather conditions, hazards, no fly zones, etc.

2. PIC will ensure the location for take-off and emergency landing is adequate upon arrival at the location. At least one emergency landing area should be identified before the start of operations.
3. PIC should be aware of all surroundings in the event that an emergency landing is necessary. This includes the ability to recover the UAS.

Inspections

1. Before the first flight of the day, verify all batteries are fully charged.
2. Check the airframe for signs of damage, and its overall condition.
3. Check the entire aircraft per the pre-flight inspection instructions in the manual for the specific aircraft to make sure it is in good structural condition and no parts are damaged, loose, or missing.
4. Check the propeller or rotor blades for chips, cracks, looseness and any deformation.
5. Check that camera(s) and mounting systems are secure and operational.
6. Perform an overall visual check of the aircraft prior to arming any power systems.
7. Repair or replace any part found to be unsuitable to fly during the pre-flight procedures prior to takeoff.

Weather

1. Before each flight the PIC and observer should ensure that he/she gathers enough information about the existing and anticipated near-term weather conditions throughout the entire mission environment. As a best practice he/she should utilize FAA approved weather resources to obtain the latest and most current weather conditions.
2. Wind direction plays a major factor in flight operations. Operators should take precautions to ensure that wind conditions do not exceed the aircraft limits stated in the aircraft operations manual/specifications. An anemometer (pocket anemometers are available from a variety of sources) is a low-cost and simple to use tool that can be utilized in order to better estimate the wind speed and determine if it is within the necessary limits of the UAS being flown. Use of an anemometer is highly recommended, in particular in cases where wind conditions and whether they are within limits may be questionable.
3. The PIC should ensure that the flight will occur within the weather requirements specified in their FAA-issued airspace authorization. While the FAA has authorized certain types of operations in particular locations for night-time or beyond line of sight operations, the vast majority of authorizations are for FAA VFR conditions only (refer to FAA § 91.155 Basic VFR weather minimums) and require Visual Line of Sight between the aircraft and the UAS Operator as well as between the aircraft and the Visual Observer at all times.

Checklist

It is a best practice to use a pre-flight checklist to ensure that safety procedures are followed before and during every flight. The checklist is usually integrated into the UAS flight software or can be obtained from the UAS vendor. In case that is not available, a standard Flight Checklist (*Figure 9)* should be made and followed by the flight crew. PIC should utilize the checklist to ensure the highest level of safety. At a minimum, this pre-flight checklist should contain the following:

1. Weather conditions suitable.
2. Check air frame for cracks and check all screws are tight.
3. Propeller(s)/Rotor(s) not damaged and tightly fixed.
4. Propulsion system mounting(s) secure.
5. Batteries fully charged and securely mounted.
6. Communications (datalink) check.
7. Ensure the GPS module (if any) has GPS “fix.”
8. Check mission flight plan.
9. “Return Home” and/or “Emergency Landing” locations (if supported by the particular UAS) are selected, located appropriately, and loaded to the GCS and aircraft.
10. Ensure sensors are calibrated and that the right setting is loaded.
11. Complete flight crew briefing.
12. Ensure the launch site is free of obstacles.
13. Recheck wind direction before launch.
14. Confirm phone number for nearest Air Traffic Control facility in event of emergency.

FLIGHT CHECKLIST

PRE FLIGHT →	DURING FLIGHT →	POST FLIGHT
At office	**After launch**	**After landing**
☐ 333 exemption / COA documents ☐ NOTAM ☐ Local regulations and permissions. ☐ Proximity to the airport. ☐ Weather condition permits flying. ☐ All Batteries Charged ☐ Flight Gear check	☐ Aircraft reached safe altitude. ☐ Confirm observer has the aircraft in sight. ☐ All systems green ☐ Satellite and GPS check ☐ Check Battery remaining	☐ Power down UAV ☐ Remove and safely store batteries ☐ Airframe inspection ☐ Check camera/ sensor to ensure data collected ☐ Transfer data and flight log ☐ Make logbook entry
In the field	**Before Landing**	**Back at office**
☐ Scan area for obstacles, e.g. take-off and landing area. ☐ Wind check ☐ Daily Flight Report filled. ☐ Assemble UAV, ensure screws are tight and propeller check ☐ Sensor/ Camera setting check ☐ Batteries securely mounted ☐ Ensure GPS fix ☐ Confirm Mission flight plan ☐ Operators checklist (Integrated) ☐ RC remote check (if used) ☐ Final airframe inspection ☐ Flight Crew briefings, e.g. flight mission and safety ☐ Wind check again for launch.	☐ Ensure UAV flight done according to mission plan. ☐ Scan landing area for obstacles. ☐ Wind check ☐ Observer briefing for landing ☐ All systems green	☐ Flight and Maintenance Report ☐ Charge Batteries ☐ SD card cleaned and ready to use ☐ Airframe checked ☐ Data processed

*Figure 9: Example of a Flight Checklist**

** This checklist is considered a guide and not definitive checklist for all UAS's. Use common sense when operating UAS's. Consult local UAS agency or vendors to ensure your checklist is appropriate.*

Documentation

Once the PIC confirms the location is safe to fly and becomes familiarized with the surroundings, it is recommended that he/she document all the details in a Pre Flight Report. The Pre Flight Report can often be filled out prior to arrival at the site as a part of mission planning and then signed off by the PIC once on site and the PIC has confirmed that the operation can be conducted safely at the site. In some cases, for example in scenarios where the UAS is to be operated in support of emergency or time-critical operations, it may be necessary to complete the Pre Flight Report (*Figure 10*) after the mission has concluded, however even in these cases, the PIC should confirm that the operation can be conducted safely prior to launch. Furthermore, it is recommended that such a report be completed for each mission regardless of whether it is completed prior to or after the flight as the report serves as an essential piece of documentation associated with the UAS operation.

An example of what the report should contain is:

1. Altitudes to be flown
2. Mission overview
3. Frequencies to be used
4. Planned flight time, including reserve fuel requirements
5. Contingency procedures
6. Pilot Name
7. Observer(s) name(s)
8. Date & Time

PRE FLIGHT REPORT

Documents	
Section 333 / COA	*XXXXX*
NOTAM	*XX/XXX*
Plan	
Call signs & Phraseology	*Loiter, RTL*
Altitude to be flown	*100 meters*
Mission Overview	*Crop data*
Frequencies	*2.4 ghz*
Planned Flight time, including reserve	*30 mins*
Contingency procedure: lost link, divert, etc.	*Return to land*
Hazards unique to the flight being flown	*Variable winds*
Closest Airport	*KRDU*
Emergency Contact	
Law Enforcement	*911*
Closest Tower Frequency	*127.450*
Site Manager	*James B.*
Roles	
Pilot	*Marc A.*
Observer 1	*Rachel J.*
Observer 2	*none*
Data Analyst	*Peter S.*

SAMPLE

*Figure 10: Example of a Pre-Flight Report**

**This report is considered a guide and not definitive report for all UAS's. Use common sense when operating UAS's. Consult local UAS agency or vendors to ensure your checklist is appropriate.*

During Flight Operations

1. The UAS PIC should launch, operate, and recover from preset locations so that the aircraft will fly according to the mission plan.
2. After the UAS is launched, the observer(s) should have a clear view of the aircraft at all times. Observation locations should be selected for the maximum line of sight throughout the planned flight operations area.

3. All flight operations should be conducted using a minimum of one visual observer who is not the UAS Operator to perform traffic avoidance and visual observation to fulfill the see-and-avoid requirement of FAR 91.113 and airspace Right-of-way rules.
4. To ensure the flight is going according to the flight plan, the UAS Operator should communicate with the observer at all times.
5. It is a good habit to let the observer know what the aircraft is supposed to be doing and the altitude of the aircraft above ground level.
6. Flights taking place over populated areas, heavily trafficked roads, or an open-air assembly of people should be avoided. If the mission dictates that flight operations be conducted in such areas, the PIC should ensure that the FAA-issued airspace authorization allows operations in such conditions and that proper coordination with local authorities, property owners and any persons in the operational area has been completed per applicable Federal, State and Local regulations.
7. The observer should make the pilot aware of any possible flight hazards during the flight.
8. Upon any failure during the flight or any loss of visual contact with the UAS, the PIC should command the aircraft back to the recovery location or utilize the built-in fail-safe features to recover the aircraft. Emergency procedures as defined in the specific UAS operator's manual should be followed.

Post-flight Operations

1. PIC should scan the landing area for potential obstruction hazards and recheck weather conditions.
2. PIC should announce to the observer and any other people around that the aircraft is on final approach and inbound to land.
3. PIC should always be prepared to do a "Go-around."
4. Carefully land the aircraft away from any obstructions and people.
5. After landing:
    - Shut down the UAS and disconnect the batteries.
    - Power down the camera or sensors.
    - Visually check aircraft for signs of damage and/or excessive wear.
    - Verify that mission objectives have been met.
    - If imagery or other data are recorded onboard the aircraft during flight, transfer the data as necessary to the GCS or a backup storage device. If all data and imagery is transmitted to the GCS and recorded on the GCS during the flight, then operators may wish to consider backing up the data prior conducting additional flight operations.
    - Enter logbook entries recording flight time and other flight details.
    - In case there are multiple flights to be conducted, repeat checklist steps to prepare the aircraft for launch again.

Emergency Procedures

Emergency procedures are specific to each UAS type as designed by the manufacturer. It is the responsibility of the flight crew to be proficient with the aircraft operational manual provided by the vendor before any flight operations are conducted. It is also a best and safe practice to prepare an Emergency Checklist (*Figure 11*) in case of emergencies. The PIC should always be prepared to execute an emergency procedure in instances where there is a lost link, or there are other aircraft or obstructions in the flight path. He/she should brief the flight crew before the start of the flight operations about emergency procedures and have a mission abort site for landing in the case of an emergency. After the aircraft has safely landed, it should be documented for maintenance purposes.

Some possible emergencies due to system failures are as follows:

- Loss of Datalink communications
- Loss of GPS
- Autopilot Software error/failure
- Loss of Engine power
- Ground Control System failure
- Intrusion of another aircraft into the UAS mission airspace

This is not meant to be a comprehensive list as the types of failures and associated emergency conditions vary for different UAS, airspace events, and crew performance.

Many UAS have a number of failsafe options in case of failures or emergency situations. These often include using methods of stabilization and an automated Return to Land (RTL) or Loiter mode. Other features include fail-recovery software. The specific failsafe options available for each type of UAS should be outlined in the UAS documentation (Operator's Manual, Checklists, etc.). These fail-safe mechanisms should be tested during training and currency flights. Flying without these fail-safe mechanisms in working order is not recommended.

An emergency avoidance procedure should be determined before landing. It may be to land immediately, move to a predetermined location and altitude, or another approach, but handling incursions must be assessed for risk mitigation.

Emergency Checklist		
Loss of Data link/ Ground Control System (GCS) Failure	**Autopilot software failure**	**Battery Warnings**
Result of both datalinks lost (no heartbeats) or GCS laptop and radio links fail for more than 10 seconds.	**Result if the autopilot software crashes during flight mode**	**Result of main GCS laptop and radio links fail for more than 10 seconds.**
→ UAV will loiter for 2 minutes (check operators manual for exact time) → If datalink not re-established within this time, flight will terminate and return to land (fail safe setting)	→ Try reconnecting from GCS laptop → RC control should be established and the UAV should be landed. If no RC then flight will terminate and return to land (fail safe setting)	→ If Battery low warning or battery percentage 35% then landing is advised. Use landing zone or alternate landing area. → If Battery percentage 10% for more than 5 seconds then lading or abort sequence is advised. → If 0% then engine shuts down.
Loss of GPS	**Loss of engine power**	**Intruding Aircraft**
Result when UAV loses GPS signal in the flight mode	**Result of airspeed and altitude drop, engine most likely stopped working.**	**Result of another aircraft entering the UAS mission airspace (refer to FAR 91.113)**
→ UAV will automatically loiter around point of GPS lock loss for 20 seconds (check operators manual for exact time) → UAV will navigate to Home waypoint → RC control should be established and the UAV should be landed. If no RC then flight will terminate and return to land (fail safe setting)	→ The UAV will attempt to glide to airfield home (fail safe) → Make sure the UAV is in line of sight at all times.	→ If approaching head-on both aircrafts alter their heading to the right. Same applies to UAVs too → Use FLY here option if available. → Immediately descend the UAV to safe altitude

*Figure 11: Example of an Emergency Checklist**

**This checklist is considered a guide and not definitive checklist for all UAS's. Use common sense when operating UAS's. Consult local UAS agency or vendors to ensure your checklist is appropriate.*

Flight Area/Perimeter Management

The selection of launch and landing sites is based first and foremost on safety. It is the job of the PIC to ensure that all flight operations are within the FAA-issued airspace authorization parameters and UAS flight limits. Flight boundaries, including any restrictions imposed by FAA approvals, nearby airport locations, restricted areas, TFRs, etc. should be reviewed prior to commencing flight operations. In addition, the PIC should identify the following:

1. Primary Take-off and Landing site - Typically the primary landing shall be the same as the launch site however this does not have to be the case for many UAS. The PIC has final authority for any approaches to the primary site and may wave off any approach deemed unsafe.
2. Alternate landing sites - The PIC shall designate at least one alternate landing site. In the event that a wave off is not possible and the primary landing site is deemed unsafe, procedures to utilize the back-up site will be invoked.
3. Mission Abort Sites - The PIC may optionally designate an “abort site” whereby the aircraft may be landed in directly in an emergency situation. The abort site should be located so as to provide

absolute minimal risk if the aircraft is required to vacate airspace in an emergency. If the PIC deems it necessary, the UAS may be flown to this site and landed without regard to the risk to the flight equipment or the unmanned aircraft. The safety of persons, manned aircraft, and surrounding structures should be prioritized over the risk to the UAS equipment.

4. Flight Over populated areas- The PIC should make every effort to select a landing site that minimizes approaches over populated areas.
5. Landing Safety & Crowd control - All landing sites should be maintained and operated in the same manner as the launch sites. A buffer of at least 50 feet should be maintained at all times between aircraft operations and all nonessential personnel (all personnel other than the UAS Operator/PIC and the Visual Observer).

Accident/Incident Reporting

In the case of any aviation accident or incident within the United States, operators should consult Part 830 of the National Transportation Safety Board (NTSB) Regulations. This applies to registered-UAS as well. It is important to understand the regulations so that proper reports and notifications can be prepared following an accident or incident. In general, all accidents and certain incidents must be reported immediately to the nearest NTSB office. Enforcement action can be taken against the operator if notification is not made in a timely manner.

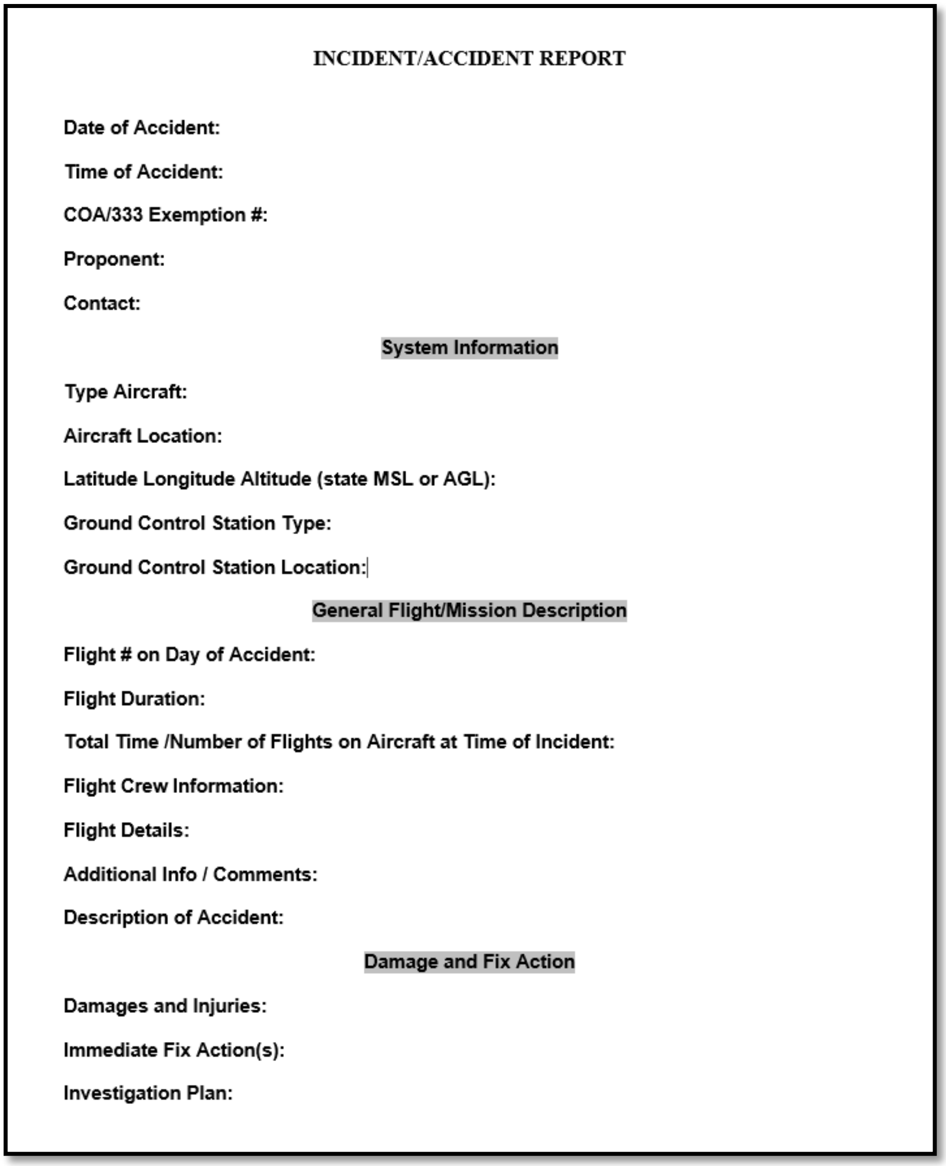
NTSB defines an accident when:

- any person suffers death or serious injury,
- the aircraft receives substantial damage which adversely affects the structural strength, performance, or flight characteristics of the aircraft.

The NTSB defines an incident as an occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations.

Within 10 days after an accident and before additional flights, the operator must provide notification to the FAA (*Figure 12*).

In the event of a lost link or fly away, the PIC should immediately notify the nearest airport tower and state the intentions.



INCIDENT/ACCIDENT REPORT

Date of Accident:

Time of Accident:

COA/333 Exemption #:

Proponent:

Contact:

System Information

Type Aircraft:

Aircraft Location:

Latitude Longitude Altitude (state MSL or AGL):

Ground Control Station Type:

Ground Control Station Location:

General Flight/Mission Description

Flight # on Day of Accident:

Flight Duration:

Total Time /Number of Flights on Aircraft at Time of Incident:

Flight Crew Information:

Flight Details:

Additional Info / Comments:

Description of Accident:

Damage and Fix Action

Damages and Injuries:

Immediate Fix Action(s):

Investigation Plan:

*Figure 12: Accident/Incident Report**

**This report is a sample format of the FAA online accident/incident report.*

Flight Crew Communications

In order to facilitate effective communication, one must understand how the flight management process flows. It is important for the UAS PIC, Visual Observer, and other essential flight personnel to maintain communication at all times. It is also important for the observer and other flight personnel to acknowledge that he/she received a message. This way the flight crew can coordinate flight operations in an organized and effective manner. A proper decision making structure should be identified prior to Pre Flight Operations and should be followed by the flight crew at all times, i.e. PIC, Site Manager, Observer, and Data Analyst. It is a best practice for the visual observer to handle all external radio communications during flight while ensuring the aircraft is in sight.

External Communications

When flight operations are conducted in Class A or D airspace or, when required, in Class E and G airspace, the PIC must establish and maintain direct two way radio communication with the airport manager and airport air traffic controller with prior notice of the flight operation. The information to relay includes:

- The flight's date and time,
- Exact location,
- Maximum altitude of UAS operation for the mission.

For best practices, the PIC should file a NOTAM (Notice to Airmen) with the AFSS (Automated Flight Service Station). It is also best practice to have the local emergency responder's phone number on hand in case of emergencies.

CREW SELECTION BEST PRACTICE

Introduction

The crewmember selection criteria for UAS flight teams are as varied as the unmanned aircraft themselves. Even so, the implementation of a UAS program and the selection of a qualified flight team share many of the same characteristics as manned flight operations. In addition to effectively conducting the UAS mission, it is the duty of the flight crew to protect safety/integrity of the airspace. A UAS flight team should, at a minimum, consist of a Pilot in Command (PIC) and a Visual Observer. Any organization considering using data capture from UAS must determine different ways of analyzing and presenting the data. In cases such as these, it may be desired to include an additional flight team member, a data analyst, whose main task would be to process and analyze the collected imagery or data. The flight crew should work together to accomplish specific mission(s). This requires aviation knowledge, mission data knowledge, and local area coordination. Building a UAS flight crew requires balance of skills, careful review and thorough understanding of expectations.

Key Actors

- UAS Operator
- Pilot in Command
- Visual Observer
- Data Analyst

Practice Description

There are 5 sections to this Best Practice: UAS Operator, Pilot In Command, Visual Observer, Data Analyst, and Training.

UAS Operator

This is the person who is actually manipulating the controls for the unmanned aircraft. This person may be acting in both the UAS Operator and Pilot in Command role, in which case he/she will be required to meet the qualifications of a Pilot in Command, listed below. If the UAS Operator and the Pilot in Command are separate people, then the Pilot in Command is in charge of the operation and is the responsible party with respect to FAA and State regulations.

Recommended minimum qualifications for a UAS Operator are:

- **FAA UAS Certification**.
  Operators should hold a current FAA Remote Aircraft License with a Small UAS Operator Certificate.
- **OEM UAS qualification training**.

Operators should demonstrate proficiency or certification from the manufacturer on a specific UAS platform.

- **State certifications and permits**.

  For operations that occur within the State of North Carolina, all operators conducting commercial or governmental (public aircraft) UAS operations must have passed the North Carolina Unmanned Aircraft Systems (UAS) Operators' Knowledge Test and must possess a valid NC UAS Operator Permit issued by the NCDOT, Division of Aviation[5].
- **UAS Type currency (via pilot logbook) + Continuation Training**

Pilot in Command (PIC)

The Pilot in Command (PIC) is in charge of the operation and is the responsible party with respect to FAA and State regulations. This person may act as both PIC and UAS Operator, however if a separate person acts as the UAS Operator, the UAS Operator acts under the command of the PIC and must follow PIC instructions at all times.

Recommended minimum qualifications for a UAS Operator are:

- **FAA UAS Certification**.

  Operators should hold a current FAA Remote Aircraft License with a Small UAS Operator Certificate or a minimum manned aircraft Sport Pilot License.
- **State certifications and permits**.

  For operations that occur within the State of North Carolina, all operators conducting commercial or governmental (public aircraft) UAS operations must have passed the North Carolina Unmanned Aircraft Systems (UAS) Operators' Knowledge Test and must possess a valid NC UAS Operator Permit issued by the NCDOT, Division of Aviation.

Visual Observer

The role of the Visual Observer is to keep watch on both the UAS being operated as well as the surrounding airspace to maintain the safety/integrity of the airspace and meet "See and Avoid" requirements as outlined in FAR Part 91.113. In an ideal setting, the Visual Observer would possess qualifications similar to the UAS Operator and/or the Pilot in Command. From the crew perspective, this allows for the organization to have the depth required and to possess operational commonality between the crewmembers. Otherwise the recommended qualifications would be the following:

- **UAS Operational Experience and specific platform certifications**

The flight crew should have knowledge of the rules and responsibilities described in –

1. 14 CFR 91.11, Operating Near other aircraft
2. 14 CFR 91.113, Right-of-Way Rules
3. 14 CFR 91.155, Basic VFR Weather Minimums

[5] https://www.ncdot.gov/aviation/uas/

4. Knowledge of air traffic and radio communications, including the use of approved ATC/ Pilot phraseology
5. Knowledge of appropriate sections of the Aeronautical Information Manual (AIM)

Data Analyst

The Data Analyst is the person responsible for processing the images or video from flights. He/she should assist the PIC in preparing the flight plan to accomplish specific mission data objectives. The analyst would be required to be in the field in instances where flight data needs to be quickly processed and analyzed. The recommended qualifications are as follows:

- Subject Matter Expertise for the type of data being collected and analysis to be performed.
- Knowledge of using data processing software appropriate for the planned mission.
- FAA Class II medical Certificate is optional (in case he/she will be involved with the flight operations on the field)

Training

Although UAS flight crews will probably not be hired or assigned as complete, consistent units, individual crew members should be tested and expected to provide examples of their previous work during the selection process. This may include flight demonstrations or the review of a data portfolio. Certification does not mean competency for being able to deliver the expected mission product. More than certifications, application and expansion of UAS knowledge are developed through regular training. Initial and recurrent training requirements help ensure that the flight team has the necessary skills to safely operate in NAS, while capturing various mission objectives. Additionally, job aids should augment training to make sure that the crewmembers have adequate checklists and information to complete their missions safely during each flight. (See Flight Operational Procedures Best Practices) Recurrent training is not limited to actual Operator/PIC/ observer skills but includes knowledge of all pertinent UAS/aviation matters. Currency training should also include Personally Identifiable Information (PII) policy for the complete flight crew to support data management practices.

DATA MANAGEMENT BEST PRACTICE

Introduction

Unmanned Aircraft Systems (UAS) are getting smaller, simpler and cheaper to operate and can carry multiple types of sensors, cameras and surveying technologies. Besides conventional cameras, UAS can also carry high tech sensing equipment such as infrared, thermal imaging cameras, hyperspectral sensors and LiDAR. A typical short UAS flight, for example, could generate about 400 plus high resolution images with a total folder size of 2 GB or more depending on the area of interest and image overlap expectation for final product quality. In addition to mission data (imagery and video), every flight produces flight performance data such as telemetry, weather, traffic, aircraft, and crew performance information that should be recorded with the mission data. Surveying technologies allow different types and large amounts of data to be collected continuously throughout the UAS flight and uploaded to a data repository like the cloud or a server for near-real time analysis. As the amount of available data grows, the problem of managing the data becomes more difficult, which can lead to information overload for an organization. Installing a data management process form the beginning should minimize the impact of growing UAS data streams, while also providing the organization with a repeatable, defendable, reliable structure for processing, archiving, accessing and protecting data.

Key Actors

- UAS Operator
- Pilot in Command
- Data Analyst
- Data Manager

Practice Description

Once the mission objective is set and the appropriate UAS is selected (refer to “Platform Selection” in Policies Best Practice) comes the important part of capturing, storing, collating and processing data. The primary reason to invest in a UAS is to analyze the data it collects. This data could be either raw images, video, environmental conditions (wind, particles) or other data captured with an airborne sensor. There are 2 sections to practice: Data Architecture and Data Flow.

Data Architecture

The mission planning and selection of an area of interest varies from project to project, but even across a variety of UAS mission plans, the output from the UAS remains fairly consistent. Most UAS come with an operational manual for capturing, storing and processing data. Below are some general descriptions of components of a UAS data architecture (*Figure 13*):

- The first step in data collection should be to create a mission plan and fly the UAS. After the flight is flown or during the flight, data (images or videos) is transferred to the Ground Control Station

(GCS) post flight via SD card or in real time via wireless connectivity. The metadata is also attached to the images or a separate flight log is generated for context. Metadata may include georeferencing GPS location information, time data, camera/aircraft attitude information, content descriptions.

- From the GCS the data (images or video with metadata) is uploaded to the cloud or a local permission controlled server for storage. It can also be saved in external hard drive or memory card but this is not recommended for best practices.
- It is recommended to use a "Mission Manager" software package for flight operations. This software should have the capability to store weather, traffic, pilot information along with flight log. This helps in generating flight reports, reviewing flight histories, fleet and crew management.
- For certain UAS configurations, data can be available in near-real-time, providing time-critical, highly-topical information from UAS flights. In order to accomplish this, a UAS with real-time downlink equipment is required.

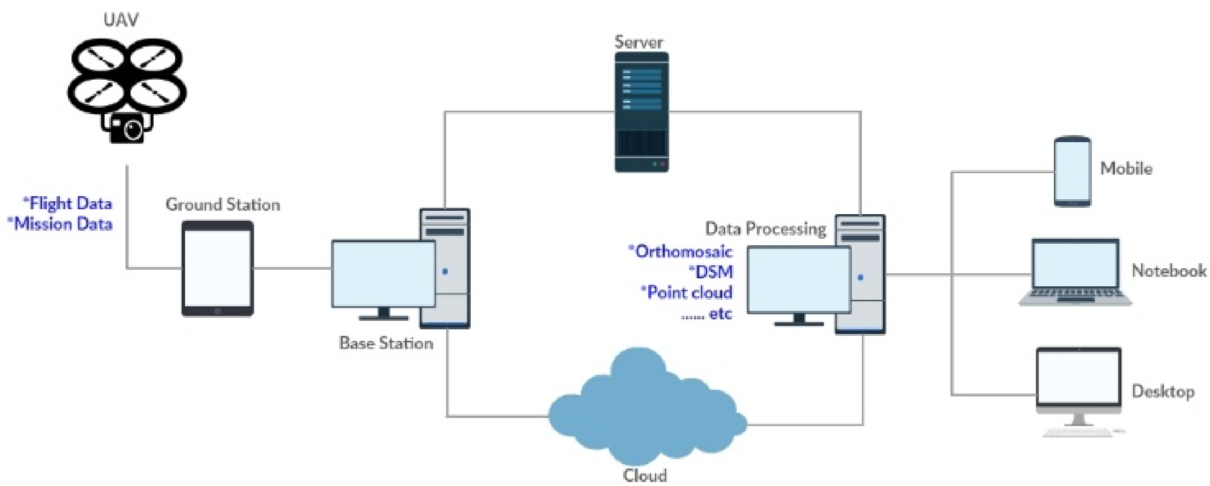


Figure 13: Example UAS Data Architecture

Data Flow

After the flight is complete comes the next step of what to do with the raw images. Raw images need to be processed, analyzed, published and then stored (*Figure 14*). The first step of the data processing is to examine the input datasets and desired product objectives. This helps in choosing the right options for all processing settings as well as to get a rough idea about the processing time. Some details that are important:

- File format (e.g. jpg or tif)
- Number of input datasets
- Type of the used image orientation (EXIF, external file, no orientation)
- Coordinate reference system of reference data (center coordinates of the images)
- Geographic projection for the mission area

Figure 14: UAS Data Flow Diagram

Processing

The most common method of post processing aerial images for surveying or mapping is to stitch them together using commercially available software, such as Trimble Business Center, PIX4D, or Agisoft. Below is a brief explanation some of the critical steps in the processing of UAS data:

- The software will examine for matching points by analyzing all images quickly and accurately.
- Those matching points as well as estimated values of the image position and orientation provided by the metadata are used in a bundle block adjustment to reconstruct the exact position and orientation of the camera for every acquired image.
- Based on this re-establishment the matching points are corroborated and their 3D coordinates calculated.
- Those 3D points are interpolated to form a triangulated irregular network (TIN) in order to obtain a Digital Elevation Model (DEM). At this stage, construction of a dense 3D model increases the spatial resolution of the triangulated data.
- This DEM is used to project every image pixel and to calculate the geo-referenced ortho-mosaic. The ortho-image generated will be devoid of positional and terrain displacement inaccuracies.

For processing video or individual pictures not intended for orthomosaicing, the raw data may need to be processed with a customer viewer or processed through a file conversion tool for further analysis or publication.

Analyzing

It is recommended to have a Data Analyst (see Crew Selection Best Practice) who has a background in the content of mission data for each flight. That may mean a GIS/Remote sensing expert for a survey flight or an agronomist/ spectral imagery expert for a crop health, environmental analysis flight (see example data sets in *Figure 15*). A person with knowledge of using data processing software appropriate for the respective mission is the goal. Identifying points of interest in an image vary greatly according to who is using the imagery, what the expected results are, and what the context of the imagery is such as an accident scene, storm damage, crop health, or infrastructure inspection mission.

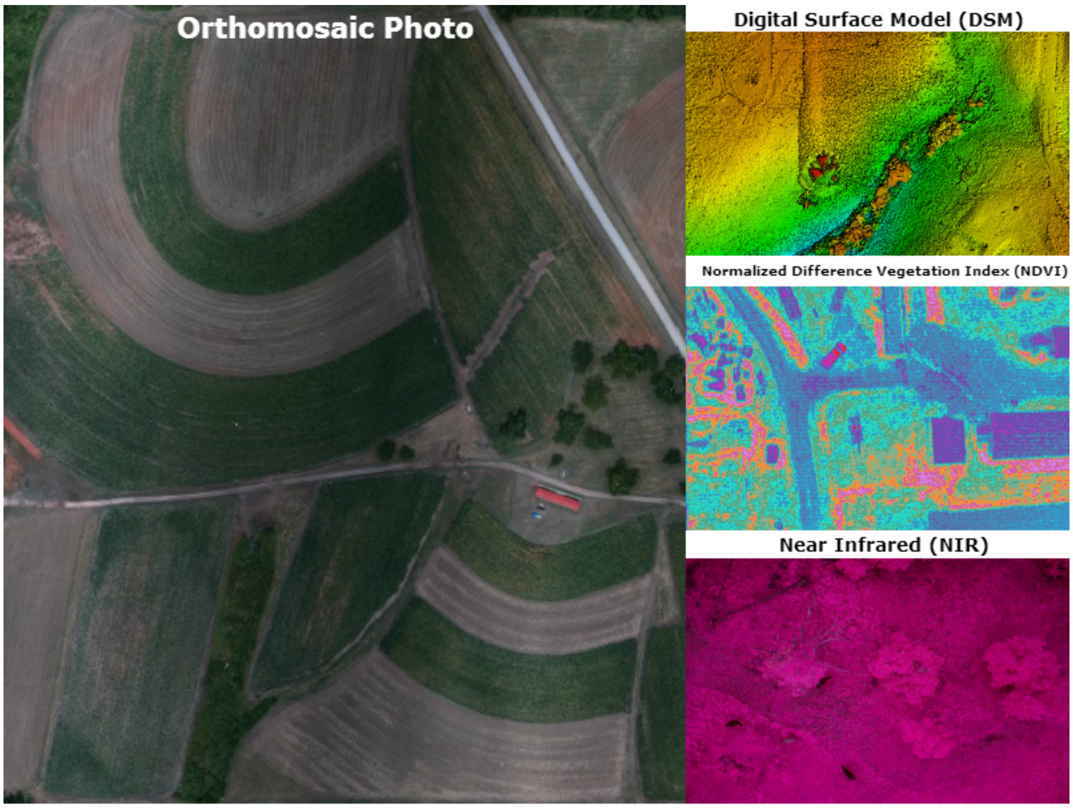


Figure 15: Sample UAS Imagery

Publishing

Once the data is analyzed, the next step is to publish it in a format that is accessible for a client or user to open and distribute through an established process.

Data Storage and Security

The final step in the data management process is defining the long term data storage and security structure for the organization's data. This process may already be defined for other data-centric operations and may just need to be reviewed for UAS data integration. There are four primary components to a data storage and security plan: location, access, permission management, and data lifecycle management.

Location

There are many options for data storage including hardware and cloud-based alternatives. Hardware solutions provide the organization the opportunity to use established servers and IT infrastructure that may streamline the data utilization into existing work flows. Portable hard-drives and memory options also present a localized management strategy with the ability to physically control access. Many new organizations that are experiencing data growth are turning to cloud-based virtual data management options to reduce IT infrastructure and management responsibilities within the organization. Evaluating existing policies and available resources is essential to selecting a long term storage solution. NGAT is prepared to assist with the decision making process and provide alternative solutions.

Access

Related to the location selection, defining the data access process determines how stored data is retrieved. Accessing data may require physical retrieval, fees, and/or special permissions to meet security protocols. Establishing these requirements from the beginning is strongly recommended.

Permissions

Different levels of permissions to access stored data are also recommended. Some users may have access to retrieve and distribute, some may have access to add and remove data from the storage location, some may have access to only certain data sets for analysis, and some may have access to only processed data, not raw data. Explicitly defining permission levels and qualifications for each level provides an audit trail for data management and a level of assurance that data is protected by multiple layers of security.

Lifecycle

Since UAS missions are identified before launching a UAS program, data lifecycles can also be specified early in the program definition. The lifecycle of data is the description of how long data is saved in the data storage solution. There are multiple strategies for managing the data lifecycle process. Periodic strategies require data to be purged on specific time cycle such as every 2 weeks, once a month, or once a year. Other strategies require data from different missions to be retained on different schedules, for instance survey data may be stored permanently, but public safety video is purged the first of every month unless tagged for something specific.

PROCUREMENT BEST PRACTICE

Introduction

Each agency developing a UAS Program should establish a process for acquiring UAS products and supplies. This process should determine the selection criteria that meet the mission objectives and agency resources. These criteria determine sensor and aircraft performance requirements. These requirements provide the data necessary to select the appropriate product to meet the agency UAS Program goals.

Key Actors

- Agency,
- Flight Crew,
- UAS Vendor

Practice Description

There are three sections to this Best Practice: Product Selection, Ownership versus Leasing, and Working with Vendors.

Product selection

Currently there are over 700 manufacturers of UAS systems globally. Many potential UAS users may benefit from acquiring both a fixed wing platform as well as a rotary wing platform, but the selection process should be driven by the mission, budget, and flight crew qualifications. Battery technology is still one of the primary limiting factors in relation to flight time, which may or may not be a factor. One of the other primary considerations is the payload capability of the respective airframe and the various sensors that it is capable of supporting. When purchasing a platform, make sure to know the total cost of operating the system. The cost of the platform may only be a fraction of the total cost (the 'system', including communications, maintenance, other equipment).

Recommended criteria for evaluating UAS products:

- Application specific requirements – What is the scope of the mission sets? What types of data will be collected?
- Processing software capabilities – What software is used to process flight data and mission data?
- Endurance – How long (time) and how far (distance) are the mission requirements?
- Ease of use – How easy is mission planning, autonomous flight, launch and recovery, and data management?
- Payload capacity – How much weight can it carry? How much does it need to carry?
- Cost – What is the total cost of not just the UAS, but also spares, ground equipment, maintenance, transport, etc?
- Customer service and technical support – How good is after-sale support for maintenance and troubleshooting?

How to decide if a fixed wing or rotor wing is most appropriate:

- If the user application requires wider geographic coverage (acres of farm) or needs highly specialized sensors, (multispectral camera, thermal imaging, Lidar, etc.) or needs to operate at higher altitudes, then a fixed wing may be the best solution for what you need.

- If an application needs limited geographical coverage (real estate photography) or has narrowly defined physical constraints (bridge inspections) and needs relatively straight forward data collection sensors (short video and RGB still photography) then a multirotor may fulfill the objectives.

Table 5: Fixed Wing vs Rotary Wing Decision Matrix

		**Fixed Wing** 	**Rotor Wing** 
Characteristics	*Maintenance*	Less complicated maintenance and repair process thus allowing the user more operational time at a lower cost.	Generally more complicated maintenance and repair processes thus decreasing operational time and resulting increases in operational costs.
	Sound	Quiet	Noise at low altitude
Flight Characteristics	*Endurance*	Longer flight durations	Shorter flight durations.
	Speeds	Higher Speed	Lower Speed
	Operational Altitude	Higher Altitude	Lower Altitude
Take-off / Landing area	*Launching Method*	Dependent upon either a launcher (including human) or a runway to facilitate takeoff and landing.	Capability for Vertical Takeoff and Landing (VTOL)
	Obstacle Clearance	Requires obstacle clearance path to climb or descend.	Requires less obstacle clearance to climb or descend.
Payload Capacity		Better sensors and cameras	Greater flexibility with heavier payloads
Uses	*Application*	Aerial mapping and terrain modelling larger areas.	Detail inspections or surveying hard-to-reach areas.

		Topographic surveys which requires the capture of geo-referenced imagery over large areas.	Maneuvering around tight spaces. Small area photography.
Flight Path		3D Waypoint NAV (recommended) Fixed altitude cruise or orbits.	Remotely controlled or 3D Waypoint NAV and the capacity to hover and perform agile maneuvering.
PIC Requirements		GCS Training. Minimal flight skill needed for autonomous operations.	GCS Training. Advanced manual training for remote control operations.

Ownership vs leasing

For agencies, owning a UAS product provides them the flexibility to modify and use at will. Although many agencies do not have the ability to acquire UAS, they still want to take advantage of the technology. An alternative solution for them is leasing. Leasing UAS is an increasingly used practice internationally and is becoming a feasible options in the US. Typically this model is called fee-for-service.

- It is recommended to purchase a UAS if the initial capital investment is below $10,000.
- **Maintenance**. Typically aircraft maintenance is the responsibility of the owner, so leasing removes the burden of maintenance from the purchasing agency.
- **Save Money**. Leasing helps a company to conserve its working capital for its intended purpose. The company could lease the UAS system and pay for the lease rentals out of its operating budget instead of the capital budget.
- **Keeping up with technology**. Leasing helps avoid the risk of ownership, as opposed to purchasing. A key risk of ownership is that of the equipment obsolescence, because of rapid technology changes. The inherent risk of owning technologically-sensitive equipment is that the equipment may become economically useless for the company owning it much earlier than expected. A lease can be written for a term that fits the equipment's usefulness. At the end of the term, the equipment may be returned and a new lease can be written for new equipment that best suits a needs
- **Potential for Ownership at lease end**. If an agency feels that owning the UAS is the preferred strategy at the end of a lease, the agency may negotiate to purchase the equipment.

Working with Vendors

Selecting the right UAS is not simple. Many factors affect this decision, the most important being the UAS vendor. With a little legwork, agencies can learn how accessible vendors are, what standards they are held to, and how long they have been in business. Identifying a vendor with credibility and business stability is recommended for long term satisfaction.

Accessibility – Many UAS companies sell their products through dealers rather than establishing a relationship directly with their customers. Although, working with a local dealer may sound reassuring and convenient, dealers often push certain products and get in the way of valuable relationships between buyers and vendors. Buying directly from a vendor offers many advantages, including clear communication. Important product information does not always make it from the vendor to the buyer and vice versa. Additionally, resolving issues regarding recalled UAS components can be difficult without a direct relationship with a vendor. Moreover, in the end dealers are often helpless, since the power to approve refunds, manage repairs, and implement improvements falls entirely in the hands of the vendor and not the dealer.

ITAR / Export Control Considerations - UAS vendors must be knowledgeable about both the International Traffic in Arms Regulations (ITAR) and the Export Administration Regulations (EAR). In order to capitalize on global markets for the products, staying compliant with U.S. export law will be an essential element of the business. Whether the company involved in UAS products is located in the US or not, it needs to understand ITAR/export controls. Many UAS components, autopilots, related software, launchers, etc. are subject to export controls. ITAR controls can affect the transport of these items, whether the transfer is temporary, for personal use, or part of doing business. Failure to comply with these regulations could end in serious consequences like fines, denial of export privileges, and possible prison sentences for the vendors. ITAR regulations do not encompass all countries export control laws, it only refers to US export control laws. An export is the transfer of anything controlled to a foreign person or country by any means, anywhere, anytime. Commonly exported items are hardware, technical data, software, and defense services. Nothing can be exported from the United States without authorization, which means permission from the United States government

Shipping – Whether it is initial purchase or returns for repair/upgrades, UAS must be shipped from a vendor. Often those vendors are producing and packaging aircraft outside the United States or at least in locations outside North Carolina. Factoring in shipping costs and timelines into delivery and maintenance cycles should be considered in purchasing a system.

Level of Technical Support – It is important for UAS vendors to have good Technical Support available to buyers at all times. When choosing a vendor it is best practice to review the following:

- Does the vendor use an issue tracking system? If not, much time can be wasted updating staff each time customers contact them about a problem.
- Is the technical support team and product development team one in the same? A support staff who specializes is more effective.

- Is their technical support anonymous? Buyers and vendors both risk exposing critical details and privileged secrets to competition when they use internet forums for technical support.
- Are enough people on staff to handle support calls?
- Is system and software training provided with product purchase?

Products for future needs - UAS manufacturers can save money and time when they choose a single-vendor solution. Because the UAS market is dynamic, manufacturers need to implement upgrades and modifications quickly, all at minimal cost to stay competitive. Many times vendors have other vendor partnership for parts and accessories. So it is important to get information of all vendor partners, in case a need arises in the future. Vendors may also offer other complimentary products/ services that increase the performance or value of the UAS solution. For example, a distributor may offer software licenses for analytics tool that can be used to process data from an UAS that did not come with a data processing software tool.

OUTREACH

Introduction

More and more UAS are flying with new capabilities and new operating areas available to users, with flying continuing to increase in frequency in populated areas. Agencies should educate the public about any UAS Program plans including aircraft, sensors, and the types of activities the UAS will perform, expected outcomes and the risk mitigations implemented to ensure public safety. This education process should start early in the decision making process to include public comment opportunities and participation.

Key Actors

- **Agencies**
- **Public**
- **Media**
- **NCDOT**
- **Industry Expert**
- **Law Enforcement**

Practice Description

There are two sections to this Best Practice: Public Awareness/Input and Transparency.

Public Awareness/Input

Agencies that are looking to introduce UAS into their operations should initiate a UAS Awareness Campaign for the local community. Building and maintaining community support for UAS operations is an important process that should involve providing the relevant law enforcement agency notice of upcoming operations. The community should be informed about the agency's goals for a UAS Program to include what types of missions are expected to be flown and how the flight activities could impact the public. The community should be encouraged to ask questions and express any concerns. It is the responsibility of the agency to educate the public on the federal and state rules and regulations under which the agency will fly. For example the FAA's 'No Drone Zone' initiative, designed to raise public awareness of the FAA Notice to Airmen process for prohibiting unauthorized aircraft, including UAS, from flying over or near NFL regular- and post-season football games is a success.

Recommended topics for a public engagement presentation for starting a UAS Program include the following guidelines:

1. UAS Overview –
    - Describe the different types of UAS.
    - Explain the capabilities and limitations.
    - Explain what is a UAV, UAS and drone.

- Explain what UAS authorization options are (COAs, 333 exemptions, Part 107).

2. The aircraft and flight missions –
   - Let the public know which type of aircraft the agency is considering.
   - What sort of flight missions will be conducted? What are the data goals, flight times, notification expectations of these missions?
   - How flight areas and routes will be selected, published and secured.
   - The restrictions and safety standards by which the agency will operate.
3. The flight crew –
   - Introduce to the public the anticipated flight crew. If no selection is made then explain how the selections would be made.
   - What qualifications and training is required.
4. Explain benefits to the Community.
   - Operating costs, safety impacts on agency staff, marketing for the community, situational awareness.
5. Explain the authority by which the agency will operate –
   - FAA approval
   - State approval
   - Local approval (if necessary)

Transparency

The law may not require transparency, but organizational legitimacy now does. It is recommended that every agency has a detailed plan for sharing information concerning UAS operations to both the media and general public.

1. First and foremost, a Communications Plan with those that handle related external communications inside the agency should be established. These should be finalized and ready for distribution well before the agency is prepared to take on its first operational mission. The agency should keep the public informed about the changes that would significantly affect privacy, civil rights, or civil liberties. Information will be provided via the public request process.
2. Publish for the public on an annual basis, a general summary of the UAS operations during the fiscal year, to include a brief description of types or categories of missions flown, the safety standards maintained and the value provided by using UAS.
3. An agency should also have a Public Liaison Officer (PLO) who should be available via email or phone to answer any concerns or questions the people have regarding UAS.
4. Safety and protection of people and property, both on ground and in the air, should be the priority for the agency. To ensure this the agency should create an oversite committee which includes at a minimum the Agency PLO, NCDOT representative, UAS Industry representative, Law Enforcement and local government representative. The oversite committee should ensure that

the agency is maintaining high safety standards. The committee should meet quarterly and should be briefed by the PLO on the progress. The agency should let the committee know if any changes or additions will be made to the proposed program and get the necessary approvals. The committee should review the annual report to assess the efficiency and success of the program.

POLICIES

Introduction

If an agency is intending to establish UAS operations the following processes should be considered essential for conducting transparent, legal, routine, managed UAS activities. Each policy should be customized to meet an agency's specific needs, but each of these policies should be included for responsible UAS Program Management.

Key Actors

- Agency,
- Flight Crew,
- Vendors

Practice Description

There are **eight recommended policies** in this Best Practice. These are NOT example policies, but are the recommendations of what policies to include a UAS Program management structure.

Contracting UAS Services vs Building Internal Capabilities Policy

It is recommended to have policies defined for agencies to determine whether contracting UAS services or building an internal team(s) meets the agency objectives.

Factors to consider are:

- Core mission – It is important to plan in advance what the flight mission is and if it requires a long term commitment. In the long term case, creating an internal flight team may best fit the agency. If it is a short term commitment then contracting an external flight crew may fulfill the agency's needs.
- Flexible staffing – Some agencies have limited staffing and due to budgeting cannot hire more people. In such cases contracting may best suit the agency.
- Specialty services – If an agency is working on a specific flight mission that requires expertise or special equipment, then contracting may be advisable. For example, if an agency has only a fixed wing UAS and their next mission requires rotor wing UAS then contracting may best fit the need.
- Proficiency – Many agencies do not have adequate resources and expertise to train a flight crew, maintain currency (frequent missions) and develop skills. For those agencies contract services are recommended.
- Ownership – Agencies have to understand that there is more to purchasing a UAS than just buying the initial unit. They need to purchase sensors, extra batteries and spare parts. The agency is also required to register all aircraft and have an airworthiness analysis performed [for COA

operations]. Regular maintenance is also required to ensure the UAS stays in working condition. Agencies that are not able to fulfill all these requirements should contract the services.

For more information regarding recommended policies, refer to the NGAT Expectation Management, Crew Selection, and Data Management Best Practices.

Manned or Unmanned Operations Selection Policy

A policy should be established to decide if the flight mission should be conducted using manned aircraft or unmanned aircraft. This policy will detail the evaluation criteria for selecting the solution, the decision makers involved in the selection process, and the process for making the selection.

Table 6: Example of Manned versus Unmanned Decision Analysis

Landfill Inspection Costs		
	Manned Aircraft	**Unmanned Aircraft**
Resource Availability (Crews, aircraft equipment)	Flight Crew (Pilot, Co-pilot) 1 Aircraft with heavy sensor	Flight Crew (Pilot, Observer) 1 UAS with small sensor
Operational Costs (Crews, aircraft, equipment)	Estimated $10,000	Estimated $2000
Desired Products (Resolution, size)	Fly at higher altitudes to cover larger survey areas. Image quality depends on weather. Will require less passes hence less time to cover the area.	Fly at lower altitudes to get high accuracy data. Image quality depends on quality of sensor. Will require more passes hence more time to cover the area
Logistics (Planning time, set up, approvals, weather)	Takes about a week to fly and get the data. Weather can delay it further.	Can be planned and executed in a day or two.
Authority to operate (Locations, conditions)	ATC, nearest airport tower	Land owner for take-off and landing, FAA for airspace access (COA, Part 107)

Access to land policy

Agencies need to ensure that permissions are obtained from private or state land owners before using their facility for UAS flight operations per NC law. A written consent is required and signed from the land owner before conducting any take offs or landings. Agencies should ensure that all flight operations conducted by the flight crew be within the approved procedures. A site safety assessment should be made prior to flight operations to ensure no person and property would be endangered by the UAS.

For more information refer to Expectation Management Best Practice.

Training policy

A policy should be in place for specifying flight crew training requirements. This way the crew stays current with flying proficiency and also with the rules and regulations. Flight crew training requirements should be divided into three phases.

- Pre-ops Training - This phase of preparatory work will take each crew through the online resources, manuals, preparing flight site and maintenance area. This will prepare them before receiving the Vendor Training and flight experience. This also includes NC law review.
- Vendor Training - This training is intensive, hands-on training that includes flying preparation, flying, maintenance, Air Law, flight planning and basic post processing of data. The training concludes with a flight test, issue of certificate and the signing of logbooks.
- Ongoing Training - It is not unusual that crews forget some of their training, or may experience a gap between mission operations. Therefore it is crucial to ensure that they stay current with flight operations and regulatory changes.

For more information refer to Crew Selection Best Practice.

Data management to include handling Personally Identifiable Information

Agencies should have policies in place on how to gather data, store data, process data, and share data. A great importance on the security of all Personally Identifiable Information (PIA) associated with the data should be implemented. There should be strict security measures in place to protect against the loss, misuse and alteration of personal data under the agencies control. Security and privacy policies should be periodically reviewed and enhanced as necessary and only authorized personnel should have access to user information.

Reporting/auditing

Agencies need to ensure that all flights are documented for auditing and required reporting purposes. Agencies should establish policies for documenting all flight operations. This should contain information like type of aircraft flown, name of PIC and Observer, type of sensor used, total images gathered, etc.

For more information refer to Operational Procedures Best Practice.

Equipment Selection policy

Agency should have a set policy that defines the process for selecting a UAS platform. This policy will explain the decision making process for selecting fixed wing or rotary wing type aircraft, specific vendors, and crew requirements.

For more information refer to Procurement Best Practice.

Procurement Policy

Purchasing a UAS should follow existing agency procurement practices. Defining a policy that ensures UAS equipment, data storage, data analysis software, and field support equipment are purchased using agency procurement policies is recommended.

This policy may be expanded to include working with vendors. These vendors may be either UAS equipment providers or UAS service providers. The related policy needs to:

a. Define an evaluation process
b. Align with existing organization rules/policies for working with vendors.
c. Identify the required licenses the training vendors will need to operate under an agency services contract.

For more information refer to Procurement Best Practice.

BUSINESS AND OPERATIONS MODEL BEST PRACTICES

Introduction

This document presents various business and operations models available to public agencies in the State of North Carolina. It includes procedures, best practices and internal processes for managing an agency's Unmanned Aircraft System (UAS) acquisition and flight operations. These best practices are provided as guidelines and are not directive in nature. These guidelines will be incrementally revised based on operational data, trouble reports, cost reports and lessons learned.

The rapid growth in UAS technology development has brought a wide variety of systems to the marketplace. These systems vary widely in their technological maturity, airworthiness, failure rates, failure modes and cost. Many of these systems have been operated without any requirements to file accident reports so the true reliability and liability risks are unknown. Much of the information available is anecdotal with marketing information that does not reflect true system performance.

Individuals and organizations should establish quantitative and qualitative performance requirements prior to system purchase, lease or entering into service contracts. Performance metrics should be gathered to measure actual performance against the stated requirements in order to enable better contracting decisions among all North Carolina agencies in the future.

These best practices will discuss the benefits and limitations of both fixed wing and rotorcraft Unmanned Aircraft Vehicles (UAV). (**Note: This Best Practice will use the term/abbreviation UAV when it relates only to the air *vehicle* component of the UAS.**) The business and operations models presented will include operations with UAS purchased by the agency, UAS leased by the agency and UAS services contracted by the agency through private commercial UAS companies.

Key Actors

- Agency Executive
- Program Manager
- Contracting Authority
- Flight Operations Manager
- Maintenance Manager
- State Industry Regulators

Practice Description

Each agency has specific needs for UAS operations that will be constrained by the agency's budget and personnel staffing levels. This best practice offers three specific business operations models for the types of contracting strategy to accomplish the desired operations. These models are:

1. Operations with UAS purchased, operated and maintained by the agency.
2. Operations with UAS leased and operated by the agency. The UAS maintenance in this case can be accomplished by the agency or by the company providing the leased UAS subject to the terms of the leasing agreement. (These two sub-models are broken out separately in Section VI.)
3. Operations with UAS services contracted through a private commercial UAS company where the UAS company operates and maintains the UAS and delivers the system data as a contract deliverable. In this case, the UAS services company must obtain and provide documentation of FAA approval to operate with their contract proposal.

The pros and cons of each of these models are presented in Section VI. Business and Operations Model Comparisons.

Business and Operations Model Considerations

Within each of the three business and operations models, there are specific UAS design, contracting and operations considerations that each agency should evaluate. These include:

1. Aircraft reliability, maintainability and availability.
   An UAV is constructed of foam, Kevlar, carbon fiber, wood, plastic or other materials. Just as with manned aircraft, the more they are flown the more wear and tear is expected. Although specific requirements for ongoing inspections, maintenance, and repairs may not be standardized yet, it is a best practice to include these considerations when selecting a UAS. It is important to understand that while the FAA has not yet outlined a formal maintenance program, the notion that airworthiness is a responsibility of the operator is very clearly articulated. It is important for any organization to understand and follow maintenance procedures or consult with a trusted agency who can ensure UAVs are properly inspected, repaired, and returned to service in airworthy condition.

2. UAS technology insertion strategy.
   New UAS sensor, navigation, control and data analysis technology is continuously developed and introduced to the marketplace. Buying a UAS that cannot be easily upgraded could reduce system effectiveness over the lifetime of the system. Buying the newest system on the market every year would not be supportable by most agency budgets. An agency could keep pace with technology upgrades to provide best available performance with a leasing or services contract approach to business operations.

3. UAS sensor modularity.
   New technology upgrades can be used in existing UAVs, but only if the mechanical, electrical and data interfaces are well established to support modular updates. This strategy could yield significant performance improvements at a reasonable cost. In addition, some applications could

require multiple sensors to be flown sequentially on the same UAV. A good example of this is precision agriculture remote sensing where it would be beneficial to fly optical, thermal and spectral sensors from a single UAV on a single mission day. Agencies should obtain an expert's assessment on whether particular sensors and subsystems can be effectively integrated into a previously purchased UAV.

4. Aircraft type and how well it supports the agency's mission plan:

Table 7: Pros and Cons of Various Unmanned Aircraft Types

Aircraft Type	Pros	Cons
Fixed Wing	• Good endurance • Largest area coverage • High payload fraction • Many size and performance options	• May require runway • Recovery methods may damage aircraft • Glide range on lost link could take UAV out of operating area
Single Rotor	• Good sensor image GIS • Easily deployed in remote locations • No runway required	• Less endurance compared to fixed wing • Open rotor may cause injury
Ducted Fan (not tethered)	• Good sensor image GIS • No runway required	• Lowest endurance • Lowest payload fraction • Some are gasoline powered and noisy
Multi-Rotor (not tethered)	• Good sensor stability • Good sensor image GIS • Many size and performance options • Easily deployed in remote locations • No runway required	• Less endurance compared to fixed wing (unless tethered) • Low payload fraction • Some have open rotor designs that pose potential injury risk
Tethered Rotorcraft	• Highest endurance if power source is in ground base unit • Excellent data collection capability with data transmitted through fiber to ground base unit. • Good mobility if system has "operator-following" technology. • Good sensor stability • Good sensor image GIS • No runway required	• Cost • Tether and tether management systems are new technologies with reliability to be demonstrated

In each case above (*Table 8*), a competent authority will need to validate the airworthiness of the UAV against the agency's requirements. This can be done by the agency itself, the UAV provider or a third party. The NextGen Air Transportation Program (NGAT) at North Carolina State University has developed an airworthiness assessment process that has been recognized by the FAA for approving routine UAS operations. NGAT is able to share existing Statements of Airworthiness and develop new ones by working with other agencies. Safety is always first priority, but aircraft downtime reduces operational availability and increases agency cost. Proper UAV maintenance and inspections can avoid costly, or even total airframe losses, in the field.

5. Level of pilot/operator certification
   Each agency should evaluate the availability of its most qualified aviators to become UAS PICs when building their agency strategy. These considerations should include

   - How would the assignment of PIC duties affect the agency when an employee is removed from his current duties?
   - What is the total number of flying hours, including training and actual operations?
   - How should the UAS operations staff be structured?
   - Where are the employees located relative to the location of UAS operations?
   - Does the agency have training funds to hire or retrain non-pilots to become their PICs?

6. FAA COA approvals.
   The agency should consider when it needs to commence UAS operations as part of the planning process. An agency should consider taking advantage of COAs already obtained within the State by NGAT or other public agencies if they are applicable in order to minimize the time. If a new COA is needed, an agency has the option of applying for its own COA or could request NGAT to develop and collaborate on the COA application with the agency.

7. UAS control frequency and data frequency management
   An agency should establish a frequency management plan to prevent UAS control interference. Some UAS have the capability to down-link data while the UAV is airborne. In this case, the data link frequencies should also be included in the frequency management plan. Prior to operations, the agency should sample the RF environment at the flight location to determine whether there will be any interference. RF interference could disrupt safe operations or cause the UAV to execute its lost link procedures. Either of these cases could result in operating delays or UAV loss/damage.

   The agency should also check the operating frequencies of UAS prior to purchase/lease. Some UAVs were designed using radios whose operating frequencies have been re-assigned by the Federal Communications Commission (FCC). These UAVs could require an upgrade to their communications prior to obtaining a COA.

8. Integrated budget and contracting schedules.
   The agency should consider establishing an integrated master schedule to include all decision processes and lead times from the point where the agency executives decide to pursue UAS operations to the day of the first UAS flight. Significant lead time could be required for fact-of-

life bureaucratic realities such as budget planning, budget approval, contract solicitations, source selection processes and contract awards. Each agency should consider its individual processes in order to build an accurate schedule to support the desired UAS operations. An agency could mitigate schedule risk with a multi-agency approach to budgeting and contracting.

9. Cooperative agreements with other agencies/jurisdictions

   In order to reduce UAS system operating costs and mitigate schedule or performance risk, agencies could consider cooperative agreements with other agencies or adjacent jurisdictions. A business and operations model strategy could include the purchase or lease of a pool of UAS to be shared by local and state law enforcement and emergency management agencies. This would enable each participating agency/jurisdiction to budget for a portion of the UAS pool operations. In this case, certain processes and priorities should be established in a formal Memorandum of Agreement.

10. Pre-negotiated basic ordering agreement contracts for services on-demand

    Agencies responsible for emergency management, disaster response and public safety may find it difficult to predict the number of UAS required and flight hours required to meet their mission. Acquiring too many UAS would result in a costly over capacity, especially when considering the cost of maintaining aircraft airworthiness and PIC qualifications.

    Some states have entered into agreements with service providers under pre-negotiated contracts such that an event requiring a rapid response to protect lives and property can be achieved. Such contracts have been established for oil and other hazardous material spills where on-call private contractors respond immediately and invoice the government agency once the event is concluded. This could be an effective model for UAS public safety and disaster response scenarios.

11. Past performance on similar operations

    Agencies should share operating and cost performance data in order to build a state-wide data base for use by all agencies in future purchases, leases and/or service contracts. This data base will lead to better UAS strategies and more accurate budget planning.

Cost Considerations

Many of the factors discussed in previous sections have cost implications. As in most system acquisitions, cost is sometimes the dominant factor over schedule and technical performance in building an agency's operating strategy. These cost considerations include:

- Acquisition cost (purchase, lease or service contract)

- Life cycle costs to include maintenance, repair, spare parts and system retesting
  When considering buying a UAS, it is important to check the warranty and after sale services agreements. It is also important to check if the spare parts for the UAV are readily available. This is an important consideration because if you break or crack a wing, it could take two weeks or more for shipping a replacement. Make sure to either have an inventory of spares, or have a nearby dealer who has a dependable supply of UAV parts.

- Level of pilot/operator certification
  - Labor cost of initial qualifications
  - Labor cost of maintaining currency
  - Opportunity cost of taking employee away from other duties to maintain flight certification

- Labor cost to obtain FAA approvals for COAs or Small UAS Operator Certificates under Part 107.

- Insurance costs
  Another suggested best practice is to consider additional UAS insurance. UAS insurance acts like any other insurance policy. If you lose your UAV or get into an accident, the company will cover your damage and liability costs to a certain extent. But the insurance companies want organization to have PIC qualification, operating manuals, maintenance logs and a record of parts or add-ons purchased. Public agencies in the state should coordinate with the state Department of Insurance through their associated Risk Management Office.

Table 8: UAS Operations Model Alternatives

Model	Pros	Cons
Agency Purchase	• System operations under agency control • System always available to agency • Maintain law enforcement evidence chain of custody	• High acquisition cost and maintenance cost • Agency responsible for maintenance • Additional staff required for operations and maintenance • Operators unavailable for other agency tasking • Cost of operator certification
Agency Lease with No Maintenance Agreement	• Lower cost compared to purchase • Technology insertion and system upgrades could be part of the leasing agreement. • Maintain law enforcement evidence chain of custody	• Additional staff required for operations and maintenance • Cost of operator certification
Agency Lease with Maintenance Agreement	• Contractor responsible for maintenance • Technology insertion and system upgrades could be part of the leasing agreement. • Maintain law enforcement evidence chain of custody	• Additional staff required for operations • Cost of operator certification
Services Contract	• All costs rolled into cost per flight hour • Purchase flight hours needed • Purchase hours based on budget • Contractor responsible for maintenance • Contract for new capabilities as technology develops • Contractor provides Section 333 exemption	• Non-agency contractor operations • High cost per flight hour • Data collected by contractor • Need process for law enforcement to collect and maintain evidence chain of custody

1) **Law Enforcement Purchase or Lease with Maintenance Agreement versus Manned Aviation.**
A county with jurisdiction over both rural areas and small towns is considering adding small UAS to its existing aviation program. With anticipated requirements for law enforcement to collect evidence and maintain a chain of custody, it is recommended that law enforcement officials operate the UAS system. Therefore, only purchase and lease options are considered in this scenario to present an appropriate comparison to manned aviation.

   a. System Purchase Considerations

   For this option, the jurisdiction should consider the following factors:

   - How will the system be deployed? If the plan is to deploy a rotorcraft in cars or SUVs, an officer in the unit will need to be a qualified PIC.
   - How many systems will the jurisdiction require?
   - What are the flight missions to be assigned? These would vary depending on the geographic extent of the jurisdiction and types of tasks. In large rural areas, fixed wing UAS may provide better service for search and rescue. In more urban environments, rotorcraft for crime scene mapping might be more appropriate.
   - Does the jurisdiction have an aviation maintenance division that could repair and maintain the UAS? If not, the lease with maintenance agreement could be the better alternative.
   - What is the jurisdiction's topography and how will it affect UAS flights requiring PIC and observers maintaining visual contact on the UAS?
   - Is it possible to share UAS resources with adjacent jurisdictions?

   b. Lease with Maintenance Agreement Considerations

   For this option, many of the above system purchase considerations also apply. The primary differential considerations are:

   - Does leasing a fleet of UAS (fixed wing, rotorcraft or a mix of both) best fit the requirement for the number of UAS and the given budget?
   - What additional staff is required to repair and maintain the desired number of UAS?
   - Will the anticipated number of flight hours drive maintenance costs to an unacceptable level?
   - Will the anticipated number of flight hours lead to early UAS replacement?

The agency should develop a cost comparison given likely scenarios and assumptions to complete a quantitative analysis of the purchase versus lease option.

c. Manned Aviation Considerations

Perhaps the most significant consideration for making the strategic decision to add UAS to a jurisdiction's aviation program is the cost and personnel differential compared to historical manned aviation. A jurisdiction may determine that having an appropriate number of UAS available for simple and routine tasking can reduce the number of manned assets required for public safety. Therefore, it is a best practice to consider UAS as a component of an integrated law enforcement aviation strategy.

For example, a jurisdiction may have one helicopter approaching the end of its service life with another newer helicopter in its inventory. Historical data indicates that operations of both helicopters were required on only a small number of days. Analysis may indicate that purchasing a small fleet of fixed wing and rotorcraft UAS would result in acquisition, operations and maintenance costs at a fraction of those for replacing the helicopter. Further analysis may indicate that using the new UAS for routine and simple tasks would reduce the number of required flight hours on the other helicopter, thereby reducing its operating costs and extending its service life. Under these conditions, the jurisdiction should pursue a strategy of mixed manned and unmanned aviation assets.

2) Emergency Management Purchase versus Services Basic Ordering Agreement.

A county emergency management agency is establishing a new program to have the capability to deploy UAS for search and rescue, disaster response, and emergency preparedness exercises. It has a limited budget and no qualified UAS operators. The emergency management director and staff are considering two options: (a) purchase two fixed wing systems with optical and infrared sensors and two rotorcraft systems with optical and infrared sensors and (b) establish a set of contracts with pre-negotiated costs per flight hour under agency basic ordering agreements.

a. System Purchase Considerations.

- The system purchase considerations listed for law enforcement above also apply to emergency management and should be included in an agency's strategy.
- Does the county have a manned aviation division with the capacity to support UAS operations and maintenance with existing personnel?
- If not, what would be the added cost for hiring and training UAS operators and maintainers?

- Consider multi-jurisdictional shared assets to budget for anticipated number of flight hours. If actual flight costs exceed those budgeted and an adjacent jurisdiction has excess hours, an agreement could help balance year-to-year variances.
- Are federal assets available for major disasters? If so, consideration should be given to operational and communications interoperability with federal assets arriving on scene.
- Does the county have a budget for emergency preparedness exercises? If so, deploying UAS assets will improve response during actual disasters and help gain actual operating, maintenance and cost data to support future budgets. These exercises will provide valuable command-and-control lessons learned for airspace coordination and optimum UAS tactical deployment.

b. Services Basic Ordering Agreement Considerations.

- Contracting for services by organizing local companies with FAA approval to operate might be a more cost effective alternative for agencies with small budgets or without any prior experience with aviation assets.
- Does the county have a contracting mechanism to have private contractors on call for emergency response? If it does, can the contract be expanded to include UAS services companies?
- Some of the system purchase considerations may also apply to the services contract case.

Benefits Estimation

The North Carolina Enterprise Project Management Office has established a Benefits Estimation process[6]. Using this process could be beneficial to agencies as they establish their programs for justifying investment into UAS capabilities and completing annual performance reports.

Agencies should consider comparing the costs and benefits of UAS operations versus manned aviation if the agency's budget and culture supports. Agencies should consider historical data in operations for which UAS would provide beneficial results. When possible, objective metrics should be established for these comparisons. A good example is the cost per acre for manned aircraft agricultural applications compared to anticipated cost for a UAS system.

[6] https://ncit.s3.amazonaws.com/s3fs-public/documents/files/0300-0310-035-C-Benefits-Estimation.pdf

Appendix H: TTX Toolbox

Toolbox Components

System	Role	Description	Sensors	Range/ Endurance	Est Sys Cost
Indago	Demo at Lake Wheeler & TTX	VTOL-Quad Rotor	EO IR +	2km (1nm) / 45 min	$25K +
DJI Inspire	Demo at Lake Wheeler & TTX	VTOL- Quad Rotor	EO	2km (1nm) / 20 min	$3K
Trimble UX5	Demo at Lake Wheeler & TTX	Fixed Wing	EO IR/MSI ++	2km (1nm) / 45 min	$16K ++
Trimble ZX5	Static Display & TTX	VTOL-6 rotor	EO IR/MSI ++	2km (1nm) 20 min	$16K ++
Airprobe Besra	Static Display & TTX	Fixed Wing	EO IR +	2-10km (1-5nm) 15-40min	$ 20K +
Air Probe UAV WRAITH	Static Display & TTX	Fixed Wing/twin eng Catapult Launched	EO/IR/MSI/CHM Live Vid/RTK ++	98km (53nm) 90 min	$25K ++
Penguin C	TTX Only	Fixed Wing (catapult)	EO IR/MSI++	10km (5nm) 20 hours	$ TBD
Generic Aerostat/ Blimp	TTX Only	Dirigible (tethered)	EO IR/MSI ++	Tethered power	$ TBD
Hobbyist DJI Phantom	TTX Only	VTOL-Quad Rotor	EO	2km (1nm) 23 min	$1.5-2K
MissionCaster	Demo & TTX	Data Distribution	n/a	GCS connection	$ TBD
Skyward	Demo & TTX	Data Management	n/a	Internet connection	$3K / year

Indago

FEATURES

- Man packable, compact folding design
- Setup in 60 seconds, airborne in 2.5 minutes
- Whisper quiet, rugged, all-weather capability
- Configurable Failsafe behaviors
- Operation via handcontroller and/or full Virtual Cockpit™ GCS
- Hot-swappable payload options for ISR, search & rescue, inspection and agriculture
- Industry-leading image stabilization with vision tracking

HANDCONTROLLER

- For small UAS; fixed wing and VTOL
- Stand-alone, untethered operation
- Secure digital data link
- Windows 8.1 based operating system
- Onboard recording of HD video and stills
- Small ergonomic design with large outdoor readable touchscreen
- Ruggedized and weather resistant
- Lightweight: 2.7 -3.3 lbs.
- Long run time (4 - 8 hours)

Misc Attributes / Notes

Specifications	
Endurance	Up to 50 minutes with payload
Payload	Multiple, hot-swappable payloads
Range	2-10 km (radio and antenna dependent)
Dimensions	32 x 32 x 7 in (12 x 9 x 7 folded)
Weight	5 lbs. (2,300g) with ION payload
Operating Altitude	10-500 ft AGL (typical)
GCS	touchscreen handcontroller or laptop-based Virtual Cockpit

Indago 2

System Description

- Long Endurance VTOL: 45-50 minutes
- All Weather Capability: Rain, Snow, Heat, Wind, Night Operation
- Rapid Deployment: Less than 3 min
- Low Acoustic Signature
- Single Man Operation Capability
- Man-packable (backpack option)
- Encrypted Digital Datalink
- Service Ceiling: 18,000 ft

Components

- All-digital Indago 2 Air Vehicle
- Rugged Hand-controller with integrated communications
- Wide Variety of Hot-Swappable Payloads
  - DUO+ Combined EO/IR + Laser IR Illuminator
  - ION 30X Optical Zoom
  - Sentera Q 18 MP Precision Mapping Camera
  - Project Lifesaver Beacon Finding Antenna
- Smart Battery, AC/DC Battery Charger
- Rugged Hard Case

Misc Attributes / Notes

- Easy to use intuitive interface
- Built in safety features & Health Monitoring
- Fail-safes for lost comms, low battery, GPS interference
- GPS Denied flight capability
- "Follow Me" flight mode
- Automated Pre-flight self-check
- Unusual attitude recovery

DJI Inspire

System Description

- A quad rotor aircraft designed for aerial photography and filming. Mechanically lifting motor arms give the camera an unobstructed view. Multiple payload configurations provide the Inspire with a wide range of capabilities. Largely carbon fiber construction with rigid plastic body.

Illustration(s) / Photo(s) / Diagram(s)

Components

Weight: 2845 grams without payload (small battery)

Range: Unobstructed controller range 3.1 miles (FCC compliance)

Endurance: approx. 18 minutes (with larger battery)

Speed: Veritcal – 16.4ft/s
Horizontal – 49 mph

Max Operating Alt: Standard – 8200 ft
High Alt Props – 14500 ft

Misc Attributes / Notes

- Vision positioning system for more accurate low altitude and indoor flying capabilities

Payload options
- X3, X5, X5R optical cameras
- XT thermal camera in partnership with FLIR
- NDVI X3 Multispectral sensor

Battery options
- 22.2V 4500 mAh
- 22.8V 5700 mAh +100g

DJI Inspire

System Description

Weight	2935g (Battery Included)
Takeoff Weight	3400g
Hovering Accuracy (GPS mode)	Vertical：0.5m；Horizontal：2.5m
Max Angular Velocity	Pitch：300°/s；Yaw：150°/s
Max Tilt Angle	35°
Max Ascent/Descent Speed	5/4 m/s
Max Speed	22m/s（ATTI mode, no wind）
Max Flight Altitude	4500m
Max Wind Speed Resistance	10m/s
Operating Temperature Range	-10°~40°C
Max Flight Time	Approximately 18 minutes
Indoor Hovering	Enabled by default

Remote Controller
Operating Frequency
922.7 ~ 927.7 MHz (Japan Only)
5.725 ~ 5.825 GHz
2.400 ~ 2.483 GHz

Camera
Total Pixels:12.76M
Effective Pixels:12.4M
ISO Range:100-3200 (video) 100-1600 (photo)
Image Max Size:4000×3000
Lens：9 Elements in 9 groups ,Anti-distortion

Trimble UX5

Data Control Link	
Frequency	2.4GHz
Modulation	Spread Spectrum
Interference Resistance	Robust, channel hopping
Range	Up to 5km
Flight Characteristics	
Climb Angle	30 degrees
Endurance	50 Minutes
Flight Altitude (AGL)	246-2,460 ft
Cruise Speed	80km/h
Operating Wind	Up to 65km/h
Landing Area	50 x 30m
Flight Sensors	
Position Sensor	Single-frequency GPS
Position Update Frequency	5Hz
Attitude Sensor	Multiple MEMS accelerometers
Altitude Sensor	Barometer
Airspeed Sensor	Airspeed pressure sensor
Flight Surface Position Sensors	Digital servos

Table 1 - Trimble UX5 Specifications

Physical Specifications	
Wing	Lifting body, Fixed
Weight	Weight: 5.5 lbs
Wing Span	Wings pan: 39.3 inches
Dimensions	39.3 x 25.6 x 4.1 inches (100 x 65 x 10.5cm)
Airframe Material	Expanded Polypropylene (EPP)
Internal Structure	Carbon-fiber framework
Propulsion System	
Motor Type	Electric brushless
Power Class	650W
Propeller Type	Folding pusher
Propeller Diameter	28cm
Propeller Pitch	8
Speed Control	Switching, high efficiency
Battery	
Battery Type	Lithium Polymer
Cell Count	4*3
Nominal Voltage	14.8V
Capacity	6000mAh
Sensor Payload	
Type	Digital Camera
Resolution	16.1MP
Image Correction	Automated software
Operation	
System Setup Time	5 Minutes
Take off	Automatic from launcher
Landing	Automatic, belly

Trimble UX5

System Description

- A flying wing UAS designed for longer endurance mapping missions. Utilizes a 24 MP mirrorless camera and fixed focal length lens capable of 2 cm GSD at 75 meters. Foam wing with carbon reinforcements and control surfaces. Modular housing holds all critical control components for quick and easy replacement of the body.

Illustration(s) / Photo(s) / Diagram(s)

Components

Weight: 2500 grams

Range: Unobstructed controller range 3.1 miles (FCC compliance)

Endurance: approx. 50 minutes

Cruise Speed: 50 mph

Max Operating Alt: Standard – 16000 ft

Battery:

Misc Attributes / Notes

- Launching via catapult makes the system far more reliable than its hand launched competitors

- The Trimble package includes Trimble Business Center, an image processing software designed specifically for use with Trimble sponsored aircraft.

Hobbyist DJI Phantom

System Description

AIRCRAFT

Weight (Battery & Propellers Included)	1280 g
Diagonal Size (Propellers Excluded)	350 mm
Max Ascent Speed	5 m/s
Max Descent Speed	3 m/s
Max Speed	16 m/s (ATTI mode)
Max Service Ceiling Above Sea Level	19685 feet (6000 m)
Max Flight Time	Approx. 23 minutes
Operating Temperature Range	32° to 104°F (0° to 40°C)
Satellite Positioning Systems	GPS/GLONASS
Hover Accuracy Range	Vertical: ±0.1 m (when Vision Positioning is active) ±0.5 m Horizontal: ±1.5 m

CAMERA

Sensor	1/2.3" CMOS Effective pixels: 12.4 M (total pixels: 12.76 M)
Lens	FOV 94° 20 mm (35 mm format equivalent) f/2.8 focus at ∞
ISO Range	• 100-3200 (video) • 100-1600 (photo)
Electronic Shutter Speed	8 - 1/8000 s
Max Image Size	4000×3000
Still Photography Modes	• Single Shot • Burst Shooting: 3/5/7 frames • Auto Exposure Bracketing (AEB): 3/5 bracketed frames at 0.7 EV Bias • Timelapse
Video Recording Modes	• UHD: 4096x2160p 24/25, 3840x2160p 24/25/30 • FHD: 1920x1080p 24/25/30/48/50/60 • HD: 1280x720p 24/25/30/48/50/60
Max Video Bitrate	60 Mbps
Supported File Systems	FAT32 (≤32 GB); exFAT (>32 GB)
Photo	JPEG, DNG (RAW)
Video	MP4, MOV (MPEG-4 AVC/H.264)
Supported SD Cards	Micro SD Max capacity: 64 GB Class 10 or UHS-1 rating required
Operating Temperature Range	32° to 104°F (0° to 40°C)

DJI Phantom

System Description

- A small quad rotor aircraft designed for consumer grade drone applications and hobbyists.
- Easy takeoff, landing, and control.
- Limited camera and customization capabilities.

Illustration(s) / Photo(s) / Diagram(s)

Components

Weight: 1216g (2.6 lb)

Range: Unobstructed controller range 3.1 miles

Endurance: approx. 20 minutes

Speed: 35 mph

Max Operating Alt: 19000 ft

Video Bitrate: 40 Mbps

Misc Attributes / Notes

Payload options
- 12MP
- Single shot or video

Battery options
- 15.2V 4480 mAh

Phantom 4 has obstacle sensors for autonomous reaction.

Trimble ZX-5

System Description

2km range

20 min Endurance

EO/IR

VTOL

HARDWARE

Type	Rotary wing
Number of rotors	6
Maximum takeoff mass	5 kg (11 lb)
Payload capability	2.3 kg (5 lb)
Dimensions	85 cm x 49 cm (33 in x 19 in)
Material	Carbon frame structure
Propulsion	Electric pusher propeller; 6 brushless motors
Battery	2 x 6600 mAh 14.8 V
Camera	16 MP with interchangeable 14 mm lens
Controller	PC or tablet running Microsoft® Windows® XP operating system or later (Windows 7 or later recommended)
Display	Capable of at least XGA (1024x768) and at least one USB port

SOFTWARE

- Mission planning with option for multiple flights
- Automated pre-flight checks
- Automatic takeoff, flight and landing

OPERATION

Endurance	20 minutes
Flight time without payload	25 minutes
Maximum ceiling	3,000 m (9,843 ft) AMSL
Pre-flight system setup time	5 minutes
Launch and recovery	Vertical takeoff and landing
Weather limit	Stable in winds up to 36 km/h (22 mph)
Control frequency	2.4 GHz
Video frequency	5.8 GHz
Communication and control range	Up to 2 km (1.2 miles)
Live video stream resolution	480i
Recordable video resolution	1080p30

ACQUISITION PERFORMANCE

Image resolution	1.0 mm to 19.5 cm, depending on height above ground level (AGL) and lens
Flight AGL range	5 m to 750 m

Trimble ZX5

System Description

- VTOL System
- Includes a 24 MP camera, which enables you to capture high quality aerial imagery and achieve image resolution down to 1 cm for superior image quality. The ZX5 is equipped to capture live video imagery for inspection applications such as civil infrastructure, utilities, and oil and gas pipelines

Illustration(s) / Photo(s) / Diagram(s)

Components

Weight: 11lb takeoff (5 lb payload)

Range: Unobstructed controller range 1.2 miles (FCC compliance)

Endurance: approx. 20 minutes

Camera: 16MP

Max Operating Alt: Standard – 9,800 ft

Battery: 14.8V

Misc Attributes / Notes

- Integrates with Trimble Business Center Photogrammetry Module and Inpho UAS Master
- Image resolution down to 1mm

Air Probe UAV: Besra

System Description

- A low cost fixed wing, back pack portable, hand launched, with multiple plug and play payloads for a wide range of capabilities and longer endurance that include: Live Video, Mapping Missions (RTK), Infrastructure Inspections, Aerial Photography/Video.
- Designed for one person operations.

Illustration(s) / Photo(s) /

Components

Weight: 2.4 Kg
Range: Unobstructed Controller Range 3.1 miles (FCC compliance); Actual mission range 28 miles)
Endurance: Approx. 45 minutes
Live Video Feed: Greater than 3.1 miles
Wind: Beaufort Scale 4, 11-16 kts.
Cruise Speed: 61 Km/38 mph
Battery: 8AH (50 min) 6.5 AH (45 min)

Misc Attributes / Notes

- Multi-Payload capable: Sequoia, Micasense, ADV Snap MS camera
- Sony RX100M5; Ricoh WG-5; Ricoh GRII;
- RTK precision positioning
- Chemical & radiological sensing capable
- FLIR Vue Pro R & HSN 120A Thermal cams
- Laptop and AP mission planning and ops

Air Probe UAV: Wraith

System Description

- A twin engine fixed wing, catapult launched / parachute landing, Dual Bay, multiple plug and play payload for a wide range of mission capabilities requiring long endurance. Live Video feed, Mapping Missions (RTK/PPK), Infrastructure Inspections, Aerial Photography/Video/Sensing on the same mission. 90 minutes flight time.

Illustration(s) / Photo(s) /

Components

Weight: 4.0 Kg / 8.8 lbs.
Wingspan: 1.9m / 6.2 ft
Cruise: 64 Km/40mph; Max: 84kts/52mph
Flt Alt: 30-121m (FAA); Ceiling 3000m/9800’
Range: Unobstructed Controller Range 3.1 miles (FCC compliance); Actual range 53 mi.
Endurance: Approx. 90 minutes
Live Video Feed: Greater than 3.1 miles
Wind: Beaufort Scale 6 (11-16 Kts.)
Rain: Beaufort Scale 4 – Visible light shower

Misc Attributes / Notes

- Multi-Payload capable:Sony Nex 7; Sony 5100/6000 (24.3 mp); Thermal; Various Multispectral cameras; Chemical & radiological sensors, RFID tracking
- Nose/Side and Tail Payload bays
- RTK-PPK precision positioning: 2cm
- Laptop and AP mission planning /ops
- ATOL; Waypoint navigation; Failsafe routines
- 10 Channel Auto-Frequency hopping

Penguin C

System Description

- A long-endurance, long range unmanned aircraft system designed for flight endurance of over 20 hours and operation radius of over 60 miles. When equipped with advanced Epsilon EO payloads, Penguin C is one of the most capable surveillance and inspection UAS available on the market.

Illustration(s) / Photo(s) / Diagram(s)

Components

Weight: 49.6 lbs

Wingspan: 10.8ft

Range: Unobstructed controller range 60 miles

Endurance: approx. 20 hours

Cruise Speed: 37-43 knots

Max Operating Alt: Standard – 15000 ft

Engine Type: 28cc, fuel injection

Takeoff: Pneumatic Catapult

Misc Attributes / Notes

- Payload Specs
  - Day/night gyro stabilized
  - Target tracking, electronic stabilization, moving target indicator
  - Motorized retract
- Data Link
  - 2.3GHz
  - Up to 12 Mbps
  - 128 bit AES encryption
- Crew
  - 2 people

Penguin C

System Description

100km range

20 hr Endurance

EO/IR (customizable payload)

Catapult Launch/ Parachute Recovery

Aircraft Specifications	
Wingspan	3.3 m/ 10.8 ft
MTOW	21.5 kg / 47.5 lbs.
Endurance	20 hours
Range	100 km/ 60 miles
Cruise speed	19-22 m/s / 37-43 knots
Max level speed	36 m/s / 70 knots
Ceiling	4500 m / 15 000 ft MSL
Takeoff	Pneumatic Catapult, fully autonomous
Maximum takeoff altitude	3000m /10 000 ft AMSL
Recovery	Parachute recovery, airbag
Operational temperature	-10° C to +40° C
Anti- icing measures	Heated Pitot- static tube. Flight in icing conditions is not approved.
Environmental protection	< 5 millimeters/hour rain
Propulsion System	
Engine type	28 cc EFI
Temperature control system	Automatically controlled via mechanical flap
Fuel type	95 Octane, oil mix
Generator system	80W onboard generator system

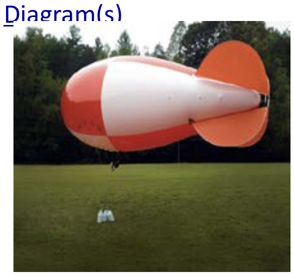
Payload Specifications	
Payload type	Day/night gyro stabilized
EO sensor	Sony FCB
IR sensor	FLIR Tau 640 LWIR Camera
Advanced features	Target tracking, Electronic Stabilization, Scene Steering, Real-time mosaicking, PathTrack software, Video on the map
Mounting	Motorized retract with anti-vibration damping
Data Link Specifications	
Datalink	2.4 GHz or 2.3 GHz
Link Rate	Up to 12 Mbps
Encryption	128 bit AES / 256 bit AES
Flight Control System	
Autopilot type	Piccolo, Cloud Cap Technology
Ground Control Station	
Type	Portable, Dual touchscreen displays
Ground control software	Piccolo Command Center, Penguin Copilot
Ground Data Terminal	
Type	Tracking high gain directional antenna with magnetometer
Mounting type	Tripod
Catapult System	
Type	Portable pneumatic, 6000 J launch energy
Packed Size	1313 x 704 x 543 mm
Typical fill time	~ 15 min
Packed Weight	110 kg

Aerostat: Blimp Works SSI-21

System Description

Aerostat + DJI Inspire 1 + MissionCaster = 8 hours of flight time & persistent ISR asset to stream securely over 4G LTE networks

Illustration(s) / Photo(s) / Diagram(s)



Components

- Aerostat with adjustable payload mount system for various payloads
- DJI 1 Inspire payload
- Tether line
- Helium Inflation Hose
- MissionCaster

Aerostat Specifications

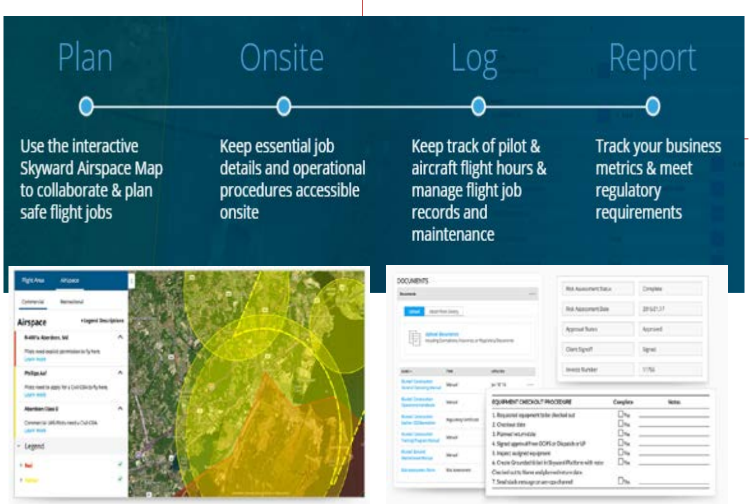
Length: 21' long
Diameter: 7' diameter
Volume: 430 cubic feet
Net Lift: 16.5 pounds
Materials: 3.5 mil polyurethane film body, film &
fiberglass rod tail fin system
Construction: heat sealed, adhesives
Lifting gas: Helium

SkyWard

System Description

- An organizational tool that enables mission planning, crew management, and flight operations records to be kept electronically.

Illustration(s) / Photo(s) / Diagram(s)



KSI MissionCaster / MissionKeeper

System Description

- A portable, battery powered device that enables real time video streaming to the internet over cellular networks.
- Unlocks connectivity in the most LTE-challenged network environments. Delivering data over multiple SSIDs utilizing patent pending technology through multiple cellular antennas.

Illustration(s) / Photo(s) / Diagram(s)

Components

MissionCaster: Hardware

- Just plug in, turn on the power and stream high-quality H.264-encoded video. Delivers a MISP compliant transport stream complete with KLV metadata directly to MissionKeeper via LTE, WiFi, and Ethernet.

MissionKeeper: Software

- A pure cloud-based, highly secure, intuitive, collaborative environment for video and data regardless of source. Accessible from desktops, laptops, tablets, and smartphones.
- Chat, Share, Schedule, View on a map

Misc Attributes / Notes

- Accepts inputs from virtually any remote platform. HDMI, SDI, analog, digital, composite or VGA.
- MissionCaster Lite was designed with DJI customers in mind. MissionCaster Lite harnesses the power of the DJI platform allowing video and data to be broadcast via an LTE-enabled tablet connected to your DJI controller.

Appendix I: NC UAS Airspace Integration Exercise Reference Guides

1) UAS Reference Information
2) UAS Incident Response Pocket Guide Template
3) UAS Best Practices – Integration Response

UAS Reference Information

FAA Part 107 Small UAS Rule Highlights

Aircraft less than 55 lbs

Visual Line of Sight only*

Daylight only*

Max airspeed: 100 mph*

Max altitude: 400′ AGL*

Requires preflight inspection

No careless and reckless operations

Visual Observer is optional

1 aircraft per 1 operator*

Aircraft registration # required

Aircraft must not operate over anyone not involved in the operation*

Operations in Class B,C,D and E airspaces require ATC permission

Can fly in Class G airspace without ATC permission

No transportation of hazardous materials

Transportation of products for compensation are allowed, under some stipulation

Operator must hold Remote Pilot Certificate

Operator is vetted by TSA

Operator must report accident within 10 days

Operator must be minimum 16 years old

FAA Website for Part 107, including requesting waivers and locating testing centers:

https://www.faa.gov/uas

** These rules are subject to waiver by FAA*

NC UAS Permit Program

This permit is required in addition to the FAA Remote Pilot Certificate.

Ensures understanding of NC laws related to UAS Operations

1. Download Study Guide,
2. Take test,
3. Receive score immediately online
4. Apply for Permit
5. Print Permit

25 questions

Commercial and Government UAS Operators required to pass the test.

No state agency is required to approve a UAS program or purchase as along as FAA requirements are met and the NCDOT UAS permit is issued.

If a Temporary Flight Restriction is established, any "volunteer" UAS pilots should have both a Part 107 Remote Pilot certificate and a NCDOT UAS Permit before requesting authorization to fly mission support for a government agency.

Key Contacts

FAA FSDO
https://www.faa.gov/about/office_org/field_offices/fsdo/?state=nc

Greensboro - 336-369-3900
Charlotte - 704-319- 7020

FAA South Regional Operations Center
(404) 305- 5180

FAA Law Enforcement Assistance Program
(202) 267-4641 or (202) 267- 9411

FAA Systems Operations Support Center (SOSC)
(202) 267-8276 | q-ator-hq-sosc@faa.gov

NCDOT UAS Program Office
Basil Yap
(919) 814- 0572 or 989-814-0550
https://www.ncdot.gov/aviation/uas/

NC Emergency Management UAS Team
Curt Johnson | (919) 948- 7837

NGAT Flight Operations Manager
Tom Zajkowski | (919) 814- 8523

North Carolina - UAS Airspace Integration Exercise

UAS Best Practices - Incident Response

Rules and Policies

Have pre-established and authorized Certificates of Authorization or FAA Part 107 Waivers and flight crews to support mission expectations and potential operations.

The local Incident Commander should identify an Air Boss for any incident requiring more than one aircraft

Aircraft must be separated both laterally and vertically and/or by time of entry an departure.

Use of a Visual Observer is recommended to confirm visual separation of all aircrafts.

For large incidents the Incident Commander should request a Temporary Flight Restriction (TFR) through the FAA.

Start outreach early in the decision making process to include public comment opportunities and participation.

Certifications

All pilots should obtain a FAA Part 107 Remote Pilot Certificate.

Pilots should be trained to North Carolina state and local UAS Policies and Procedures, including holding an NCDOT UAS Commercial or Government Operators Permit

Recommended Air Boss training includes: Part 107 Remote Pilot Certificate, NCDOT Permit, E0986 National Incident Management System (NIMS) Incident Command System (ICS) Air Support Group Supervisor, and Specific NC UAS Policies and Procedures.

Conduct Airspace Integration Exercises annually to validate procedures, update training documents, and verify performance objectives.

Planning Your Program

Evaluate business and procurement models for acquisition and staffing requirements thoroughly before starting a UAS program.

Develop a UAS Incident Response Pocket Guide.

Have local Temporary Flight Restrictions, Special Use Airspace, and process specifics mapped out and routinely updated to support the potential impacted mission areas within the agency's jurisdiction.

Have pre-vetted vendors, assets, and operators documented to ensure safety and adherence to rules and regulations.

Establish a "Volunteer Aircraft Policy" for the agency to address unofficial and not-authorized aircraft.

Agencies should educate the public about any UAS Program plans including aircraft capabilities, sensors, and the types of activities the UAS will perform, expected outcomes, and the risk mitigations implemented to ensure public safety. This education process should start early in the decision making process to include public comment opportunities and participation.

Run a time-sensitive Public Affairs campaign educating the public on safe operations and consequences of unauthorized interference with manned and unmanned aircraft PRIOR to events like hurricanes.

Communications

All Ground to Ground communications should be conducted via the 800 MHz VIPER Network.

All Air to Air, Ground to Air, or Air to Ground communications should be conducted via the Aircraft band.

Communications between the Incident Command Structure and the flight crews should be limited to the Incident Commander and the Air Boss.

Radio Communication range, potential interference threats, and limitations should be identified during mission planning.

Radio Frequencies should be assigned and documented during the preflight planning, including Primary, Alternate, and Contingency channels.

UAS lost link procedures should be documented, practiced, and quickly accessible during flight operations.

All Operational Aircraft shall be grounded if there is another aircraft in the airspace with whom communications cannot be established.

Data Management

There should be standards on data quality, projections, coordination, and file formats specified during mission planning.

Policies should be in place defining where the data is stored, how long it is to be kept, access permissions, etc.

Law Enforcement organizations must have procedures in place to address chain of custody requirements.

North Carolina - UAS Airspace Integration Exercise

UAS Incident Response Pocket Guide Template

1. Flight Planning Checklist

- ☐ Description of operating area
- ☐ Air traffic approval needed / clearance provided?
- ☐ Identify minimum and maximum elevations in flight area
- ☐ Identify proximity to structures, above ground utilities, etc.
- ☐ Identify line of sight limitations
- ☐ Identify launch, landing, and ditch locations
- ☐ Obtain Landowner permission, as required
- ☐ Cordon required or potential crowd control concerns identified, if necessary
- ☐ Public Right of Way considerations
- ☐ Establish Communication plans
- ☐ Weather Conditions
- ☐ Others (agency specific)...
- ☐ Risk Rating Matrix score calculated (#15)

2. UAS Operator Mobilization Checklist

a. Logistics
   i. Water
   ii. Food
   iii. Clothes
   iv. Etc. (Transportation)
b. Incident order information
   i. Who/what agency is in command
   ii. Reporting location
   iii. Equipment ordered
c. Equipment / Accessories
   i. Chargers
   ii. Batteries
   iii. Cables
   iv. Etc. (Radios, Enviromental Protection)

3. List of "Watch Out" Scenarios when using UAS in conjunction with Manned Systems

a. Manned aircraft are unaware of UAS on scene.
b. UAS operators are unaware of manned aircraft on scene or en route.
c. Manned aircraft operators do not expect to have direct communication with UAS operators.

4. FAA Rules Decision Tree Diagram

You want to be a UAS Operator?

↓

Determine your type of mission(s): Your Concept of Operations

↓ Select Aircraft for Mission

↓ Select Payload/Sensors for Mission

↓

Determine which rules meet operating needs*

** Government Operators can use either*

Public Operator Rules

(14 CFR Part 91 with a COA)

- Requires detailed ConOps and specific ATC services
- Self Certification of crew and aircraft
- Requires UAS Registration
- More work up front for more flexible access to airspace

Civil Operator Rules

(14 CFR Part 107)

- Requires UAS Registration
- Requires Pilot Certification
- Less burdensome to fly immediately but less flexible airspace access

5. How to Communicate with the Public about Private UAS Use During an Incident Response

a. Establish standard strategies for shutting down unauthorized operations

6. Guidance on Establishing a TFR and When/Where a TFR is Needed

7. Guidance for UAS Operations Near/Adjacent to Military Installations

8. Guide for Calculating Imagery Resolution Based on Sensor Capabilities and Platform Above Ground Heights

9. Matrix of Available Platforms and Sensors and their Capabilities that are available for mission assignment

10. Decision Tree Scenario Examples that End in Recommended Platforms and Sensors Given Various Conditions

a. Wildfire
b. Hurricane
c. Flooding
   i. Dam Breach
d. Search & Rescue

11. Checklist for Hand Off of Operations to/from Manned and Unmanned Systems During Incident

12. Guide for Dispatchers Corresponding with Citizens Reporting Emergency Needs Detected by Private/Personal UAS

a. What is your name?
b. What is your contact information?
c. What is your location?
d. Thank citizen for their assistance
    i. Be disarming
    ii. Be non-confrontational
    iii. Be complementary
e. Provide citizen with information about legalities of their UAS operations
f. Ask the citizen to cease operations, if necessary
g. Provide the citizen with non-emergency contact information if they have any additional/follow-up questions

I'M S.A.F.E. Checklist

Illness - Do I have any symptoms?

Medication - Have I been taking prescription or over-the-counter drugs?

Stress - Am I under psychological pressure from the job? Worried about financial matters, health problems, or family discord?

Alcohol - Have I been drinking within 8 hours? Within 24 hours?

Fatigue - Am I tired and not adequately rested?

Emotion - Am I emotionally upset?

13. Checklist of Principles and Practices for Public Release and Protection of Operational Data Collected by UAS

14. Checklist of Principles and Practices for Aquiring Services and Securing Data Collected by Contracted/Private Commercial Vendor

a. Does vendor have proof of necessary training and certifications?
b. Are they insured?
c. Background checks as needed for scope of operations.
d. Possibly having a standard form / legal document for commercial vendors to sign and agree to data security, sharing, etc. before they begin operations

15. Flight Operation Risk Rating Matrix

		Severity of the potential injury/damage				
0-5 = Low Risk 6-10 = Moderate Risk 11-15 = High Risk 16-25 = Extremely High Unacceptable Risk		Insignificant damage to property, equipment, or minor injury **1**	Non-reportable injury, minor loss of process, or slight damage to property **2**	Reportable injury, moderate loss of process, or limited damage to property **3**	Major injury, single fatality, critical loss of proccess/ damage to property **4**	Multiple fatalities, catastropic loss of business **5**
Likelihood of the hazard happening	Almost Certain **5**	**5**	**10**	**15**	**20**	**25**
	Will Probably Occur **4**	**4**	**8**	**12**	**16**	**20**
	Possible Occur **3**	**3**	**6**	**9**	**12**	**15**
	Remote Possibility **2**	**2**	**4**	**6**	**8**	**10**
	Extremely Unlikely **1**	**1**	**2**	**3**	**4**	**5**

16. Special Authorizations for Civil UAS Operators During an Emergency

a. In case of an active or imminent emergency, Civil UAS operators can contact the Systems Operations Support Center (SOSC) to obtain a Special Governmental Interest (SGI) COA granted they meet the following standards:
   i. They must secure support from a governmental entity participating in the response, relief, or recovery effort, to which the proposed UAS operations will contribute
   ii. Proponents must provide justification sufficient to show the standard process is not feasible (e.g., urgent need to fly a response mission within 14 days or less).

b. Qualifying proponents must contact the SOSC by phone at 202-267-8276 for assistance and a backup request should be sent to the SOSC via email at 9-ator-hq-sosc@faa.gov. Requests should be initiated with the SOSC as far in advance as practicable and the SOSC will determine if the request meets all necessary SGI criteria.