Research and Education for Optimizing the Development and Implementation of an Unmanned Aircraft Program at the Nebraska Department of Transportation

FINAL REPORT

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16. Abstract

This report describes the development and implementation of an Unmanned Aircraft System Program at the Nebraska Department of Transportation (NDOT). The project involved the selection and purchase of appropriate UAS and imaging systems for NDOT, education and training for NDOT personnel with classroom and hands-on operation of UAS with the goal of obtaining proficiency and pilot licenses. In addition, the development of policy for the use of UAS within NDOT was accomplished as well as standard operating procedures (SOP) documentation and the development of example case studies of interest to NDOT using the purchased systems and technology.

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Abstract

The use of Unmanned Aircraft Systems (UAS) for monitoring agricultural and natural systems, as well as engineering infrastructure, are becoming mainstream. Many research and commercial applications have been developed using sensors and imagers onboard UAS, that have led to efficiencies in monitoring tasks, including for construction and infrastructure. This report describes the development and implementation of an Unmanned Aircraft System Program at the Nebraska Department of Transportation (NDOT). The project involved the selection and purchase of appropriate UAS and imaging systems for NDOT; education, and training for NDOT personnel, with classroom and hands-on operation of UAS, with the goal of obtaining proficiency and pilot licenses. In addition, the development of policy for the use of UAS within NDOT was accomplished as well as standard operating procedures (SOP) documentation and the development of example case studies of interest to NDOT using the purchased systems and technology.

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Chapter I - Introduction

BACKGROUND AND CONTEXT. It has recently become legal to fly Unmanned Aircraft Systems (UAS) in U.S. airspace for commercial purposes. This stems from the FAA Reauthorization Act that was enacted by Congress and signed into law in 2012, and included a specific, but little-known provision directing the FAA to develop regulations to bring UAS into U.S. airspace by Sept 30, 2015 (actual timeframe was circa August 2016). The confluence of new UAS regulations that allow commercial unmanned aerial operations, and a thriving U.S. economy, indicate that UAS opportunities in surface transportation will expand significantly in the next decade and beyond.

The opening of National Air Space to UAS has the potential to be a "game changer" for the surface transportation industry, much like GPS, GIS, and associated information technologies. UAS will offer an unparalleled opportunity to place sensors, robotics, and advanced information systems at desired locations for increasing productivity, improving efficiency, and enhancing safety of surface transport systems. The commercial market for UAS is expected to triple in the next five years, with a projected increase to $42.5 billion by 2024 from a global perspective. Control of the National Air Space will be achieved through implementation of emerging NextGen technology aligned with Unmanned Aircraft Systems Traffic Management (UTM), which will be based on a GPS foundation.

It is generally accepted that the commercial use of unmanned aircraft, and their associated control and sensor systems, are a relatively recent phenomenon, with the recent promulgation of Federal Aviation Administration (FAA) Part 107 regulations, establishing a new Remote Pilot Certificate (circa August 2016). Nevertheless, there have been some agencies and organizations that have initiated the development and implementation of internal UAS programs to meet their needs. Some of these agencies and organizations include the U.S. Department of Interior, University of Nebraska, North Carolina Department of Transportation, Alabama Department of Transportation, as well as a host of others, that are seeking to define a UAS ecosystem within the given agency/organization.

In addition, the Federal Highway Administration (FHWA) has identified Unmanned Aircraft Systems as one of the innovations on their Every Day Counts (EDC-5) initiatives. The EDC-5 initiatives span 2019 and 2020 and are identified as innovations that can accelerate the delivery of highway projects and foster a culture of innovation within the transportation community.

OPPORTUNITY. These developments present a compelling motivation for the NDOT to develop and implement an in-house unmanned aircraft program. NDOT's pursuit of developing an Unmanned Aircraft Program directly aligns with FHWA identification of UAS as an innovation for the EDC-5 initiative. A conceptual thought diagram is presented in Figure 1, depicting some of the major elements and relational structure, that has been envisioned for the NDOT UAS program.

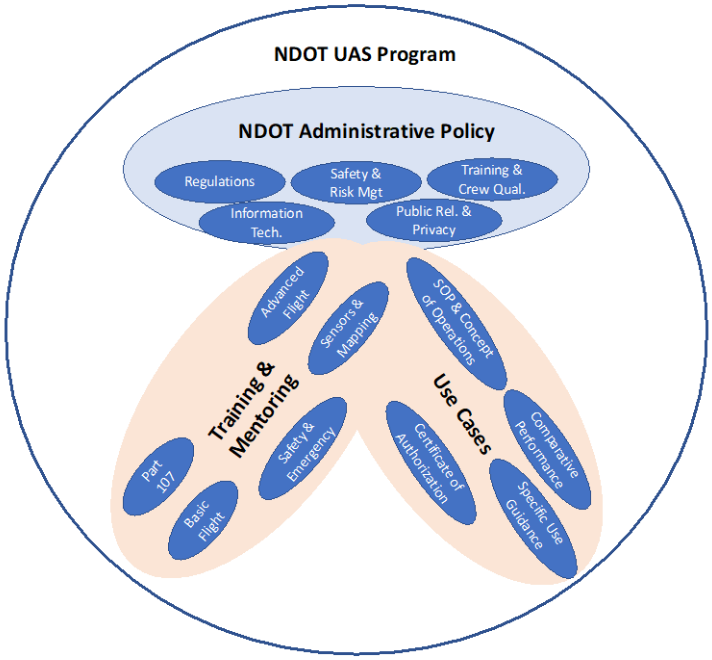


Figure 1. Depiction of UAS Programmatic Elements.

OBJECTIVES. The goal of this project was to conduct research and education to optimize and document the development and implementation of a new unmanned aircraft program for the Nebraska Department of Transportation (NDOT). To accomplish this goal, the Nebraska Unmanned Aircraft Innovation, Research and Education (NU-AIRE) laboratory at the University of Nebraska-Lincoln (UNL) has provided research and education for NDOT so that the Unmanned Aircraft Systems (UAS) Program Manager and affiliated personnel are able to efficiently establish a successful and safe in-house UAS program. This initial phase of the effort included research and education for: 1) Administrative policy development, 2) Training, 3) Operations and 4) Use Case analysis, with literature review as a separate component that underpins the four goals. These four goals have set the stage for subsequent phases of program development, to be determined, based on status and need.

Scope of Report. This report provides a description of the research and education in support of development and implementation of a UAS program within the Nebraska Department of Transportation. Each of the four primary elements of the project, along with the entity that has primary responsibility for completion and contribution to this report are hereby noted. These include description of the training (UNL primary responsibility), policy (NDOT primary responsibility), standard operating procedures (Kansas State University (KSU) primary responsibility) and use cases (NDOT primary responsibility).

Report Structure. The report is organized into sections that include discussion which addresses the five main elements: Literature Review, Administrative Policy, Training, Operations, and Analysis of Use Cases, followed by Conclusions, Recommendations, References, and Appendices.

Limitations of Report. This report is based on the experiences of implementing a UAS program in a statewide department of transportation. It is important to note that each state department of transportation is different, with a different culture, management style, and differing levels of available resources. Thus, this report should be viewed from the context of one department's approach and process of bringing unmanned aircraft technologies into the department.

Chapter II - Literature Review

Research was carried out in three areas involving the review of existing literature. The first was to determine what was involved in successfully petitioning the FAA for a waiver to directly fly over people involved in various NDOT construction projects. It is typical that the collection of data useful to many aspects of a construction activity cannot easily be obtained at target locations without those sites being populated with personnel involved with the construction. Since the FAA prohibits flying an unmanned aircraft over people not directly involved with the flight operation, a desire for a waiver to this requirement exists with state DOTs nationwide. Research revealed that 37 such waivers had been issued by the FAA. Every one of those waivers included a requirement for the use of a very expensive “Para Zero” safety system that would deploy a parachute to recover an aircraft flown over people in the event of loss of control or inadequate thrust for flight.

The second area of research was for the purpose of assisting the NDOT in developing a Standard Operating Procedures (SOP) document that would establish operating requirements for the use of unmanned aircraft by the department. This involved evaluation of many existing SOPs used by DOTs from numerous other states across the country. The development of a draft SOPs document was completed by UNL, and a meeting was conducted to review the document for further refinement based on discussion outcomes. Due to project personnel changes, the draft SOPs document was provided to NDOT by UNL in the initially submitted format, as a framework for subsequent work with KSU.

The third area of research was in support of night flight within the context of one of the Analysis of Use Cases. This research included topics of night flight equipment requirements, and training requirements. Primary findings of research indicated that necessary UAS equipment includes position lights that are visible at a distance of three miles, along with key elements that should be included in training for night flight.

Chapter III - Administrative Policy

As part of the administration policy work, NDOT developed the foundation of the UAS program built on industry best practices by reviewing other states DOT and government agency policies and SOPs, as well as best practices from within the manned aviation industry. By developing the SOPs along with performing operations and evaluating the use cases, NDOT was able to refine the SOPs based on field experience for what worked within our operation framework. In addition, the more granular detail of operation specific workflows, maintenance, tracking of information related to the flights/location, etc. was defined as part of this process. The initial system consists of electronic forms and spreadsheets, with a goal to move towards a more automated UAS Program technology once the data and workflow requirements were defined. The NDOT SOPs are attached to the research report as “APPENDIX A”.

Chapter IV - Training

Training was completed at the NDOT maintenance facility on South 14th Street, Lincoln, NE. The computer training room was used for all indoor training, except for a segment of indoor flight training that was held at UNL using small UAS as an initial step toward outdoor flight training. A remote area of the maintenance yard was used for all outdoor flight training using the Mavic 2 Zoom aircraft (Figure 2). Teams of two and three learners were established, and each team had the use of their own Mavic aircraft to complete a series of increasingly complex flight maneuvers thereby demonstrating competency.

Figure 2. Mavic 2 Zoom UAS in flight.

The first phase of training included two days of training to prepare participants for the FAA Part 107 knowledge exam. The curriculum is included as an appendix. Upon completion of significant progress on this task, six participants successfully passed their FAA Part 107 Remote Pilot Exam, earning their pilot certificate, thereby allowing them to proceed to phase two of the training.

Phase two of the training involved indoor preparation for Mavic flight, in which the complex flight control system was reviewed (Figure 3), followed by outdoor flight activities including a series of increasingly complex flight maneuvers. A list of the flight maneuvers is included as an appendix. Once each participant successfully completed their sequence of flight maneuvers, and passed the final flight challenge maneuver, they were deemed to be prepared for the next phase of flight training. Participant evaluation of training indicates that participants were quite satisfied with the approach, content, and results.

Figure 3. Indoor training for flight planning and preparation

The third phase of training included a focus on UAS configuration and planning for aerial mapping missions (Figure 3). This included indoor training and review of aerial mapping software. The fourth phase of training was highly integrated with phase three, and involved independent planning and preparations for an aerial mapping flight at the Rogers Memorial Research Farm, located east of Lincoln, NE. Once participants successfully completed flight planning (phase 3), followed by deployment and check flight (phase 4), they were deemed to be prepared for serving as NDOT Remote Pilot in Command (RPIC). There were some challenges in the aerial mapping under phase 3, in which some aircraft did not return usable data. Subsequent flights were conducted by UNL to reproduce and troubleshoot anomalies that occurred during the “Mission Check” evaluation that every NDOT pilot trainee completed as their final qualification test for RPIC qualification. It needs to be noted that all the trainees performed satisfactorily during these check missions, even though some aircraft did not produce usable data. The subsequent test flights by UNL helped to determine that there is a minimum altitude of around 200 feet that is required to secure reliable data, that can be stitched into an aerial map, and a specifically sequenced procedure must be followed with the Mavic 2 Zoom aircraft in order for it to recognize and correctly use the parameters for the Zoom camera, to gather usable data on these types of missions. Feedback was given to the NDOT pilots based on these test flights, and the findings will be used to prevent similar data gathering anomalies with future training classes. Feedback from the participants indicated that the training was very helpful for them in terms of how to plan a mission, followed by deployment and gathering data. An example of an orthomosaic produced with imagery acquired in one of the training flights using the Pix4D software, also used in the training is shown in Figure 4.

Figure 4. Color orthomosaic (left) and digital surface model (right) produced using imagery acquired during a field training flight and processed with the Pix4D software also used in the training.

Chapter V - Operations

Efforts in this category consisted mostly of research and coordination for operations planned for the near future. We conferred with experts at Rocky Mountain Unmanned Systems on the use of the M210 aircraft for NDOT missions including the correct procedures required for operating and configuring **Real Time Kinematic** (**RTK**) equipment to efficiently gather enhanced accuracy location data for missions where survey grade data is desired. In addition, research and test flight were conducted on the use of “Attitude” mode on the Mavic Pro aircraft which is desirable for using that aircraft on future bridge inspection applications. Also, we contacted and coordinated with the Lincoln Airport Tower to obtain permissions and clarify procedures required to fly a 3-D modeling mission on a concrete stockpile located within 100 yards of the final approach course of Runway 18/36 adjacent to airport property. Due to the close proximity of the target area to airport flight operations, special procedures are required to obtain airspace clearance to fly this mission.

Participation in and support for flight operations on two use case missions were completed. The first was an aerial video survey of the entire Lincoln South Beltway Project right-of-way using the Mavic Pro aircraft. Work on this mission revealed the need for additional Visual Observers (VO) for this mission type. Due to the extended linear distances involved and the rolling elevations of the terrain where the beltway will be built, one of the greatest challenges was keeping the aircraft within visual line of sight as required by the FAA. The use of two VOs to assist the RPIC was found to be optimal to conduct this kind of operation. The RPIC is required to go “heads down” quite often during these missions to check on various aircraft parameters. During that time, the VO is responsible for keeping visual contact with the aircraft and can direct the RPIC and assist in helping him regain visual contact.

Flight operations support for the second use case involved the flying of an M210 aircraft to inspect two sign structures as a test and demonstration of the capability of unmanned aircraft for this purpose. An initial meeting was held with bridge inspection personnel to agree on the types of useful data the aircraft could provide, and to select two suitable sign structures for the demonstration. The first was a cantilever sign located on west Van Dorn. A large external monitor was set up at the target locations to allow the inspection crews to adequately see exactly what the aircraft was seeing, and to direct the pilot and camera operator to areas of interest on the structure. Welds and brackets were successfully inspected, and the entire cantilever was evaluated for signs of rusting and spalling (Figure 5). The second structure was a truss sign located on I-80 adjacent to Superior Street. A similar inspection was conducted there with excellent results. Bridge inspection personnel were delighted with the capabilities of the aircraft for this purpose. The adroitness of the platform at providing close-in looks at various components at many different angles was highlighted. It also was determined that the use of an unmanned aircraft mitigated the possible blocking off of lanes and creation of traffic hazards in order to do a direct physical inspection, and eliminated the risk involved in putting an inspector directly on the structure for inspection purposes.

Figure 5 Image acquired in the inspection of the cantilever sign structure to examine welds and brackets for signs of rusting and spalling (top) and zoom in detail of the same image (center and lower).

Chapter VI - Analysis of Use Cases

This project involved NDOT performing a number of different use case evaluations. The goals were to identify areas of opportunity where leveraging UAS processes would satisfy one of the primary drivers for implementation: Efficiency > Better Quality Data > Safety. Once defined, the use cases were further planned in order to perform and vet the results, providing metrics as to how they aligned with the drivers and whether the results proved value in moving towards UAS based processes.

Equipment: NDOT acquired the following platforms/technologies listed below to be used during the use case validation, and subsequent production use of UAS during the duration of this project. Examples are shown in Figure 5. Each was chosen with a specific use case/scenario in mind. All platforms include RGB photographic sensors, however one (the M210) is scalable to accept additional sensors. It was also an initial goal to standardize on a platform (DJI in this case) for consistency of pilot with the platforms. NDOT took care to plan large scale operations and ensured enough batteries were included to keep operations moving throughout the day. In addition, an inverter was installed in the UAS team's vehicle which allowed additional charging during operations. Moving forward, the UAS team will acquire a portable power pack (e.g., Goal Zero) in order to maintain battery charging during vehicle off operations.

1. Tello: Used for training and motor skill development.
2. DJI Mavic 2 Pro: Small, lightweight, and easy to deploy platform. Chosen mainly for basic use cases including photos and videos. Can be controlled with DJI applications, or multiple 3rd party applications/hardware. Great platform for training and currency exercises.
3. DJI Phantom 4 RTK w/base station: Chosen primarily as NDOT's mapping platform. With the integrated controller, requires the use of DJI's mapping application.
4. DJI Matrice 210 RTK v2.0: Chosen for inspection and mapping purposes with considerations to specifications on wind and temperature and abilities to fly in more adverse conditions over the other two platforms. This system was ordered with multiple controllers, allowing operations to have both a pilot of the UA, as well as a payload operator. Two RGB sensors were included in the package; the X7 with a 24mm lens for a mapping sensor; and the Z30 high zoom camera used for inspection purposes. Crystal Sky controllers were added for the main GSC units.
5. Propeller AeroPoints: NDOT acquired 10 AeroPoints, which are GPS ground control targets. These are tied into a subscription with Propeller leveraging their correction network. We used these for quick, easy GCPs as our UAS team initially did not have access to GPS survey equipment.
6. Processing Software: NDOT used a number of applications to process and analyze UAS data during this effort- including Propeller Aero, Pix4D Mapper,

Bentley ContextCapture, Trimble products, and additional Bentley civil engineering technologies.

Mavic 2

Phantom 4

Matrice 210

Figure 6. Examples of the UAS platforms purchased to support training and operations of the NDOT UAS program.

Several use cases were demonstrated during the project period and are described below, most of them led by NDOT.

1. Use Case #1: Night Flight Operations

Some effort was expended to test a night lighting system that would meet FAA requirements for night flights. The main concept was to set the stage for performing under deck bridge inspections during dark conditions so that UAV onboard spot lighting would be able to illuminate the inspection area of interest and provide for improved visibility of the areas of interest when compared to daylight conditions, as well as to avoid adverse sunlight effects on the UAV sensor system. Night flight regulations require lighting that is visible from a distance of three miles. There is no specification of color. Based on aviation experience, the UNL team modified a Mavic UAS with one white strobe and one red strobe, mounted on aircraft to allow for maximum distance between the lights. Use of two different colors provides visual information on orientation of the aircraft. With aircraft facing forward, the red strobe was placed on the left outrigger, and white was placed on the right outrigger. High intensity Lume Cube 2.0 lighting was mounted to the Mavic to explore intensity of lighting illumination on ground from altitude of 200 feet. Initial testing was focused on ability to retain control of the aircraft at a variety of distances, altitudes, and orientations. In addition, subjective assessment of lighting illumination was conducted. Testing of the two-color night lighting position system was successful, with the pilot in command retaining complete control of the aircraft at an array of altitudes, orientations, and attitudes. The illumination system was determined to be sufficient for likely night missions, with an ability to illuminate large areas of land (diameter of about 150 feet) from an altitude of 200 feet.

2. Use Case #2: Stockpile Measurement

NDOT performed multiple case studies on using data obtained via UAS to perform measurements of quantity. This specific use case focused on measuring a stockpile on a construction site. The results were to help guide NDOT on the accuracy of the measured quantity vs. traditional methods of measurement, as well as the accuracy of the terrain generated from the UAS images vs. GPS shots taken during traditional methods, and the accuracy of the AeroPoints GPS photogrammetry targets.

The test was performed in western Nebraska on an active construction project in February 2020 on a stockpile of soil (Figure 7). The baseline data was gathered with Trimble GPS equipment, using a base station set up for the construction project. A check point was shot on a known control point, showing a difference of DX=0.009, DY=-0.078 and DZ=0.000. For comparison, we set an Aeropoint on the same control point and received the following results after processing through the Propeller network: DX=0.008, DY=-0.112, DZ=-0.009.

The GPS survey consisted of 441 points over an approximate one-acre area to gather sufficient data to build a terrain and measure the stockpile. An additional 25 checkpoints were shot within a 15-acre area of interest that UAS data would be obtained on. Total time to survey and process the data into a terrain file was 3.75 hours. The checkpoints were used to further evaluate the accuracy of the terrain from the UAS deliverables. We chose the size of 15 acres due to it easily being within the bounds of a one battery flight, on all the mission types and platforms we tested.

UAS flights were accomplished using two different platforms, the DJI Mavic 2 Pro as well as the Phantom 4 RTK. We also set out nine additional AeroPoints targets to use as GCPs and set the Phantom 4 RTK base station on a known control point. This configuration allowed us to fly multiple UA at different heights, as well as using different methods to process the data (with or without control). The table below shows the results of our flights and analysis. In the method column, the naming schema is as follows:

E.G. P4 180 RTK (P4= Phantom 4 UA; 180= AGL (180’); RTK= Method of control when processing the data)

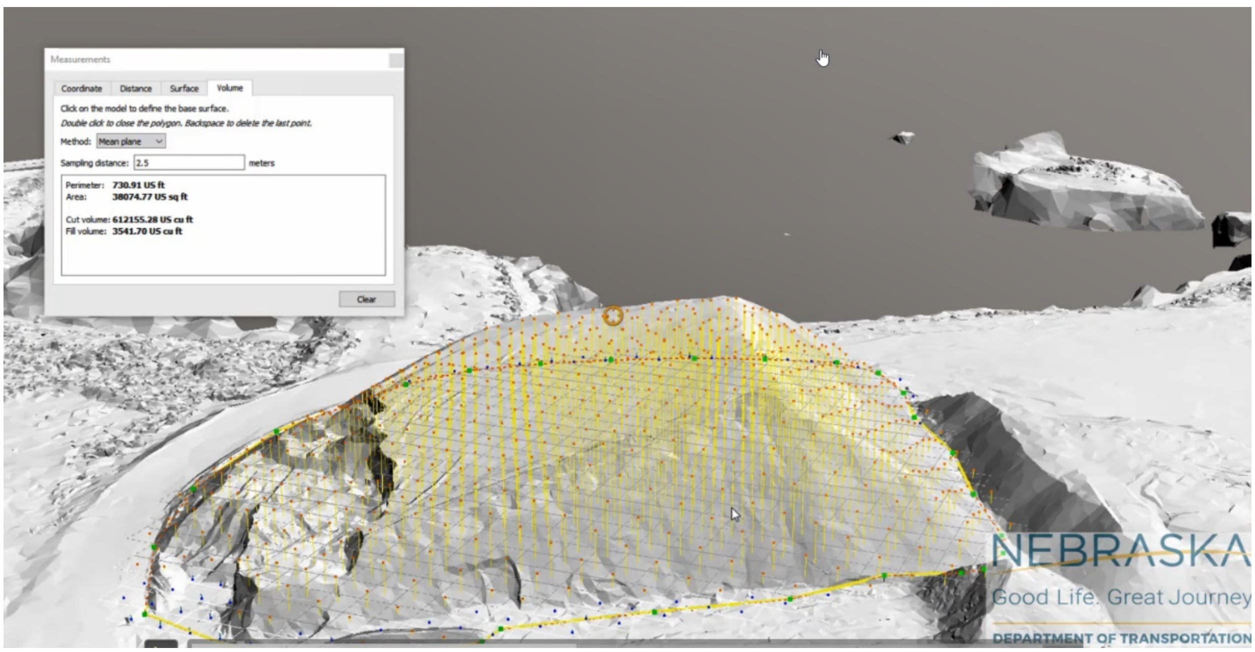


Figure 7. Imagery used in the stockpile volume estimation showing ground truth GPS survey grid points (top) and 3-D rendition of the pile (bottom).

Table 1. Results of comparison of stockpile volume estimates using UAS imagery with measured ground truth surveyed data.

Method	Volume (cu. Yds)	% Diff	*Total Hours	**Acres	Mean Z Diff	Standard Deviation	RMSE	95% V
GPS Survey	7601	-	3.75	1	-	-	-	-
P4 180 RTK	7658	0.75%	3	14	-0.06	0.07	0.09	0.18
P4 300 RTK	7657	0.73%	3	14	-0.48	0.07	0.49	0.96
P4 180 CON	7591	-0.13%	2.5	14	-0.09	0.06	0.11	0.22
P4 300 CON	7600	-0.01%	2.5	14	-0.14	0.07	0.15	0.3
P4 180 GPS	7595	-0.07%	1.5	14	-	-	-	-
P4 300 GPS	7606	0.07%	1.5	14	-	-	-	-
P4 300 PPK	7623	0.29%	2.5	14	NA	NA	NA	NA
M2 180 GPS	7533	-0.89%	1.5	14	-	-	-	-
M2 300 GPS	7625	0.31%	1.5	14				

*Total measured time of staff on site; since UAS operation included a Visual Observer the actual duration to accomplish the data acquisition and human processing time was 50% of reported time.

Conclusions:

a) All platforms, at all heights and all methods of processing, provided volume measurements within 1% of what was computed using traditional methods. If the end goal is purely a measurement, the results show any method works although the methods that do not use ground control require less time to set up and accomplish.
    a. *The caveat is there is no way to validate the data captured if this is being used for payment. Given payment is a deliverable, the process NDOT would use would include validation of data through checkpoints.
    b. Accuracy of the terrains from the UAS deliverables were within reasonable tolerances. The results from the 300' Phantom 4 mission using the DJI Base station for accuracy was the furthest off, and we feel is not indicative in what we've seen on other use cases that occurred later in our research.
    c. UAS methods gain more value the larger the size of data acquisition is. In this specific use case, if we were purely only measuring the one-acre stockpile there is value, but since we were able to survey 14 acres in less

time than one acre could be surveyed it shows how scaling in size increases value in less time spent collecting data. On small areas, it will be just as efficient to use the GPS equipment rather than the overhead of using UAS.

3. Use Case #3: Borrow Pit Monitoring

The goals of this use case were twofold: 1) monitor a borrow pit using UAS deliverables to compare quantity of material moved for estimates against truck load counts and 2) compare UAS terrain deliverables against traditional surveying methods used to measure borrow pit excavation for payment.

This site was a 20-acre site located central region of Nebraska. The contractor was taking borrow out of this location and submitting truck load counts for estimating purposes only as part of this effort. Since it was contractor owned, there was no final reconciliation required. However, due to the timing and location, it offered an ideal test for borrow pit monitoring for NDOT to gather and report on data in 2020.

NDOT's Geodetic survey team established six temporary control points around the boundary of the area, which we used to benchmark AeroPoints and as control points on some of the missions. We performed a sampling of missions using both the Phantom 4 RTK, as well as the Mavic 2 Pro platforms. Missions were processed using RTK stamped images, GCPs as control, as well as uncontrolled. Missions were again performed at multiple heights in order to compare accuracy results given different workflows/data acquisition times. These were used as GCPs in some instances, and as checks for the AeroPoints on others.

A preliminary survey was done on the 20-acre site by an NDOT survey team using traditional GPS data collection methods with rovers connected to a base station set on a known Control Point. This process was repeated once the topsoil was stripped, and again for a final survey. Incremental check point surveys were accomplished to obtain data to compare terrain files generated from the UAS data on incremental progress surveys. The UAS surveys were completed at the same stages, in addition to incremental progress surveys during construction. The following table illustrates a high-level summary of our results:

Table 2. Comparison of borrow pit volume estimates using UAS imagery with measure loaded truck volumes.

Date of Survey	UAS Volume	Effort Hours	GPS Survey Volume	Effort Hours	Contractor Truck Load Volume Est.	Error/95% V
June 24- Topsoil Stripped	NA		NA		NA	-0.06/0.17
July 22	34,985		-		33,985	-
August 13	55,266		-		52,740	-
September 16	35,765		-		50,520	-
October 7	39,790		-		55,975	-
November 20- Final Survey	2,767		-		0	TBD
Totals	168,948	*2	169,104	**48	193,220	

*2 people- 1 hour on site

**3 people- 16 hours on site

Conclusions:

a. Terrain data created from the UAS survey data aligned very well with traditional GPS collection methods regarding the accuracy against check points, as well as the total volumes moved.
b. Discrepancy from comparing truck count volumes vs. surveyed data was anticipated since they are not measured but used as nominal amounts, but greater than expected. We attribute this to error in data reported since multiple borrow pits were progressing at the same point. Some surveys lined up very well.
c. Time on site was greatly reduced for UAS' surveys over traditional surveys.
d. UAS team did need to wait for no construction personnel to be present in order to survey the site per FAA regulations of Unmanned Aircraft over people. Since we needed a clean break while work was not occurring, this did not impact our operations for this effort.

4. Use Case #4- Construction Project Monitoring with Video and Photos

NDOT has performed a number of missions with the purpose of monitoring construction projects using photos and video in order to document current conditions. One project to highlight involved a new construction project of approximately 10 miles in length, with the majority of the project being new construction across current green space (no existing roadway). Our objectives were to document the conditions preconstruction, during construction at specific to be determined intervals, and a final post construction video.

Given the objectives and scope of this construction project, there were some initial obstacles that needed to be addressed. The first was how to obtain preconstruction video, given both the “non-visual” location of where the roadway would go, in addition to access of the property given fences, tree lines, poor conditions, etc. In addition, we needed to meet FAA regulations maintaining visual line of site with the unmanned aircraft, so given terrain needed to come up with a plan to gather the data. Lastly, we wanted to be able to repeat the missions as close to the original as possible in the future, to make aligning the videos a possibility for evaluating conditions side-by-side (Figure 8).

Figure 8. Screenshot of side-by-side video playback example of the south-beltway alignment and construction.

We determined we needed to get the design data from our CAD platform into a technology we could use to control the unmanned aircraft. Since our mission’s goals were video and/or photos, the Mavic 2 Pro was our chosen platform for this effort. We determined we could use the Litchi application to control the Mavic 2 Pro from an IPAD and devised a process to get the data from CAD, into Google Earth, and from Google Earth into Litchi.

The first step was to do a field visit in order to map out potential launch sites, and proposed flight path start/stop points given a normal ~2000’ distance to maintain visual line of sight with the Mavic 2 Pro. Once we had this data, we stored the flight paths in Litchi based on paths we could perform while maintaining visual line of sight, from points we could access from public property or property already obtained by NDOT as part of this construction project.

Subsequent flights have been made to fly the entire project a number of times. Time to gather data has decreased in time since the first mission, since grading has progressed and its now possible to move along the entire project. The ability to recall the flights from Litchi and reproduce the flight paths has proved valuable in producing similar data for comparisons, as well as easing the operations on the RPIC due to the automated nature of the flights. We will continue these processes over the next few years as this project progresses. We are using video and photos on a number of projects at this time and anticipate this being a staple in easily documenting conditions as needed with high resolution data.

Conclusions:

a. This is a "low hanging fruit" use case (photos/videos) that is a great starting point for new programs.
b. During planning of operations, especially for long term repeatability, consider how meeting FAA regulations will be done (Visual line of site and Operations over People in particular).
    a. Given Operation over People requirements, we have been performing follow up missions on Sundays since that is the only day the contractor is normally not working on this project.
c. Plan out the mission length and duration, and ensure you have battery coverage. We have multiple batteries for the Mavic 2 Pro, and the ability to charge during operations. However, on some missions the weak link has been the controller and/or the IPAD battery. Both of which we were not able to charge without a cease in operations.

5. Use Case #5: Environmental Wetland Monitoring

NDOT's Environmental section monitors wetland mitigation sites for 10 years post construction per current regulations. A component of this monitoring was obtaining yearly imagery to monitor the site. Traditionally, this imagery is collected via piloted airplane and processed with photogrammetry technologies to provide ortho rectified imagery to evaluate changes over time.

NDOT UAS team evaluated the scope of the effort, including geospatial locations of the sites, ability to fly within FAA regulations, and deliverable specifications and determined use case to be an early adopter of our production use of unmanned aircraft. Using the new process would save money and time over the current process, as well as provide better quality data given the high-resolution imagery collected. In 2020, 19 sites were flown across Nebraska with UAS in order to produce the deliverables. In addition, multiple other sites were added that were not part of the yearly monitoring but needed for other purposes.

Conclusions:

a. This is a “low hanging fruit” use case that is a fairly easy integration point using unmanned aircraft, and associated processing technologies to produce the orthro rectified imagery.
b. A combination of the RTK capabilities, and GCPs as necessary, to provide positional accuracy meeting the environmental teams’ needs was used.
c. The new process of using unmanned aircraft afforded the ability for special requests of additional data to be added to scope easily. In addition to traditional mapping, additional video and photos were obtained on multiple sites while the UAS team was onsite. In addition to this, multiple sites were added that would have been more costly to add to scope after the traditional airplane method had met the initial deliverables (easier to deploy the drone team than add scope to an airplane team after their work has finished).

Conclusions

A decision by the NDOT to develop an internal unmanned aircraft program is a significant milestone in the adoption and integration of emerging technologies in departmental activities across many areas of application.

It is important that management support this type of decision, and that a dedicated individual serve as a focal point, as a key element of integrating UAS into the department. The process is complex, due to the nature of the technology, in which information systems and completely new types of information become available and thus of interest to a broad array of constituents across the NDOT, combined with a regulatory environment that has some degree of stability, and yet is subject to change on a fairly regular basis. It is within the context of this complexity that NDOT reached out to academic entities to secure a level of support and assistance, for which the UAS program manager is to be recognized. The project personnel provided support in development of a policy and standard operating procedures for unmanned aircraft, delivery of both knowledge and flight training, assistance with flight operation, and exploration of use case scenarios. The NDOT has initiated a UAS program that is built on a solid foundation through combination of dedicated program manager and support from the project team.

Recommendations

Based on lessons learned during this project, the following are the recommendations that NDOT has developed for the next steps of the program: Expanded use of UAS at NDOT to include additional pilots geographically located throughout Nebraska to better respond to basic UAS operations.

Expanded UAS equipment to take advantage of additional efficiency gains:

1. Thermal Sensor- Add thermal sensor to M210 package to continue evaluating the use of thermal imagery for detecting bridge delamination, as well as environmental uses in counting/locating bats and birds.
2. LIDAR- Obtain a UAS LIDAR system to expand and integrate aerial LIDAR data into our survey practices; allowing for remote sensing and safer operations where this technology makes sense.
3. Pursue and acquire a UAS Program management technology to log and track all UAS assets (equipment, pilots, missions, maintenance, etc.) that can be configured to align with NDOT UAS SOPs.
4. Pursue a waiver to **§ 107.31 Visual Line of Sight Aircraft Operation** to allow for daisy chaining visual observers to make larger, linear missions more feasible to perform.
5. Develop additional case studies to support the NDOT program, such as highway bridge monitoring and wetland habitat mapping for example, drawing from existing expertise at UNL for these applications.

References

The State of Alabama Department of Transportation (ALDOT). Unmanned Aircraft System Standard Operating Procedures

Texas Department of Transportation. Unmanned Aircraft System (UAS) Flight Operations and User's Manual

Other sources of UAS SOP's and Policy Information:

- North Carolina DOT
- Utah DOT
- Oregon DOT
- Minnesota DOT
- California Transportation (CalTRANS)

Appendices

A. SOP Document

B. Training Materials

1) NDOT Training Booklet with Several Modules
2) Multi-rotor Flight Training Maneuvers

NEBRASKA

DEPARTMENT OF TRANSPORTATION

The State of Nebraska Department of Transportation

Unmanned Aircraft Systems Standard Operating Procedures

Revision Log

Version Number	Date	UAS Program Manager	NDOT Aeronautic Director	Summary
1.0	04/14/2021	Jon Starr	Ann Richart	Initial Version released

DISCLAIMER

NOTICE: The information contained in this publication is subject to revision because of changing government requirements, regulations and operational necessities. No reader should act on the basis of such information without referring to applicable laws and regulations and/or without taking appropriate professional advice. Errors, omissions, misprints or misinterpretation of the contents hereof should immediately be brought to NDOT attention.

Document Revision Procedures:

- The Master Copy of the NDOT UAS Standard Operating Procedures (SOP) is assigned to and maintained by NDOT UAS Program Manager.
- NDOT will maintain both an electronic and hard copy of the SOP.
- Revisions to the SOP manual will be promulgated as required by NDOT UAS management.
    - Proposed modifications from NDOT stakeholders are submitted to the NDOT UAS manager for review.
    - NDOT UAS Manager reviews SOP's as part of bi-monthly (every two months) review of FAA regulations, NDOT policy and SOP's for consistency and improvements to processes.
    - Changes are drafted and reviewed by the NDOT UAS Policy team. This team consists of leadership from the following disciplines, with other SME's (subject matter experts) pulled in as needed:
        - Legal
        - HR/Safety
        - Technology
        - NDOT Aeronautics Manager
        - Project Development (Agreements/Contracts)

Contents

1 Introduction

This document outlines all of the standard operating procedures (SOP) for the State of Nebraska's Department of Transportation (NDOT) Unmanned Aircraft Systems (UAS) flight operations. NDOT focuses on safely integrating unmanned aircraft systems into the National Airspace (NAS). We follow all rules, regulations, policies, and procedures set forth by Federal Aviation Administration (FAA) to safely operate in the NAS. All NDOT administration and staff must comply with the NDOT's UAS SOP.

1.1 Purpose

The purpose of NDOT's UAS Standard Operating Procedures is to establish procedures for NDOT UAS Activities. Additional SOP's may be developed and implemented as FAA authorization or waivers are received, or as deemed necessary by NDOT to accomplish program goals.

NDOT requires the use of SOP's during NDOT UAS Activities. NDOT UAS operations will be conducted in accordance with applicable federal, state, local, and NDOT UAS regulations/ procedures and manufacturer's manuals/limitations. When there are no applicable Federal, State or NDOT guidance; NDOT staff will use their best judgment and recognize that safety is the priority guiding their decisions.

SOP's are specific to execution of operations from an overall organizational standpoint. SOP's, checklists, and use of common terminology creates a system whereby the flight crew can recognize a departure from the normal sequence of events or normal system operations. The use of SOP's will place the flight crew in a position to recognize potential problems and respond to emergency / abnormal situations.

This manual will be kept current by the NDOT UAS Program Manager by using revisions. The manual will be available to all designated flight crew and in presence on all NDOT UAS Operations. Any FAA regulation, State Law or NDOT UAS Policy takes precedence over this manual. Discrepancies found between Regulations, Law and this manual should be brought to the UAS Program Managers attention.

Flight crews are not authorized to deviate from NDOT's flight procedures during NDOT UAS activities unless the deviation is in the best interest of safety. Such deviations shall be reported to NDOT UAS Program Office within 24 hours of the occurrence.

2 Administration

2.1 UAS Program Office Organization

NDOT's UAS Program Office provides overall program management and strategic direction of agency UAS technologies and operations. The office includes a number of dedicated roles that may not be fully staffed during initial phases of the program's implementation. Additional roles, such as RPIC's that fall outside of the formal reporting structure based on functional organization (e.g. Pilots reporting to other divisions/districts) will report to the UAS Program Office for all duties and responsibilities associated with UAS operations and maintenance.

2.2 NDOT UAS Policy

NDOT incorporates an overarching policy (NDOT-OI-50-03) for all NDOT employees and contractors. All personnel conducting UAS operations must read the policy to ensure compliance prior to flight.

2.3 Insurance

NDOT's UAS Program Office will coordinate the insurance coverage as necessary on NDOT's UAS. At a minimum, an Unmanned Aerial Vehicle Endorsement with $1,000,000 per UA will be acquired. Additional insurance considerations will take place on an as needed basis.

2.4 Procurement of Equipment

The procurement of UAS equipment and related technologies will be coordinated through the NDOT UAS Program Office. Requirements will be reviewed and discussed to ensure the equipment meets the requirements and aligns with current agency strategies.

2.5 FAA Registration

All NDOT UAS will be registered with the FAA through the NDOT UAS Program Office at time of delivery of the system once procured. The NDOT program office maintains a high-level FAA DroneZone account, and will register agency aircraft under this general account. All NDOT UASs must have a current registration before any flights occur.

2.6 UAS Inventory

The NDOT UAS Program Office will maintain an inventory of all NDOT owned UAS with at least the following information:

- Year

- Make
- Model
- Type (fixed wing/rotor)
- Weight
- FAA Registration Number and Expiration Date
- Responsible Manager
- Organization Unit

2.7 UAS Logbooks

Each NDOT owned UAS will have a logbook with it at all times, to include the following information at a minimum:

- Copy of FAA registration information
- Copy of NDOT liability insurance
- Current system logs (See UA flight log entries section)

2.8 Facilities

All NDOT UAS equipment will be stored in a secure facility, with limited access. Equipment will be properly logged in and out from the facility by authorized personnel only. Other than short periods of time, no UAS equipment will be left unsecured.

2.9 Communications

Inquiries from the news media must be forwarded to the NDOT Communication and Public Policy Division. Operators/Observers shall follow currently established company policy regarding interactions and inquiries from the media.

2.10 FAA Investigation Reporting

NDOT staff who are contacted by the FAA in response to inquiries on NDOT operations must report the communication to the NDOT UAS Program Manager within 24 hours of the communication. The UAS Program Manager, in coordination with NDOT Human Resources personnel, will perform an internal investigation to gather details of the inquiry and remain in communication with the FAA from NDOT's perspective during any subsequent investigation. The outcome of the inquiry or investigation will be documented in an investigation log.

2.11 Internal Investigations

The UAS program office will perform investigations as needed to ensure compliance with NDOT UAS policy and Standard Operating Procedures. NDOT will take appropriate action to address issues discovered in the course of the investigation, including disciplinary action up to and including termination.

3 Crew Responsibilities and Currency

3.1 Mission Essential Crew Responsibilities

Mission Essential Crew (MEC) members are dictated by the platform and the scope of the operation being performed. It is up to the RPIC to determine the minimum MEC needed for any particular flight. Due to the nature and complexity of most missions, minimum personnel preferred for all missions will be a RPIC and VO. The following decision tree should be used to determine when a VO is required on NDOT UAS missions. If the decision tree leads to VO optional, the RPIC can still require a VO (See Appendix G).

All MEC must read and understand the following sections to understand their responsibilities.

MEC Currency

NOTE: The following procedures only apply to the MEC roles of RPIC (Remote Pilot in Command), AVO (Air Vehicle Operator), and EP (External Pilot). NDOT Flight Instructors, Visual Observers, Payload Operators, and Crew Chiefs, hold separate currency requirements than the MEC Currency listed below. Currency for those roles is found under their specific sections.

All MEC taking part in UAS operations are expected to remain current with crew roles and maintain proficiency with the responsibilities of each position. This can be accomplished by performing more than just the minimum currency requirement and stay up to date on current regulations and practices in the UAS industry.

MEC must meet the qualifications and currency requirements found within the specific documents for which the operations being conducted. These documents include Public Certificates of Authenticity (COAs), Section 44807 Exemptions, CFR Part 107 regulations, and CFR Part 107 waivers/authorizations.

NDOT Initial Currency

All MEC must be current in each category of UAS they operate. NDOT flight operations maintain a list of all current pilots by aircraft category. To qualify as a MEC member the individual must receive training from NDOT's UAS manager or designee and meet requirements to be signed off by the NDOT UAS Manager.

Note: Currency is documented for each MEC by category of UAS. However, it is up to the individual to maintain proficiency in the specific type of UAS they are operating (i.e. being current in the category of multirotor does not necessarily mean you are proficient on all types multirotor UAS)

NDOT Continued Currency

All MEC must receive a biennial NDOT UAS flight review every 24 calendar months for the UAS categories in which they operate. The biennial will consist of at least 0.5 hours of ground school and 0.5 hours of live flight. If more than 24 calendar months have elapsed, the biennial will consist of at least 1.0 hours of ground school and 1.0 hours of live flight. He/she cannot operate that UAS until the NDOT UAS biennial flight review is completed. In addition to currency, it is the responsibility of the RPIC to maintain proficiency in each type of UAS they operate.

Qualifications

Crewmembers must read and comply with regulations of 14 CFR Part 107 and 14 CFR Part 91 that apply to their specific operation. Including but not limited to:

- §107.12, Requirements for a remote pilot cert. with a small UAS rating
- §107.13, Registration
- §107.15, Condition of safe operation
- §107.17, Medical condition
- §107.19, Remote pilot in command
- §107.23, Hazardous operation
- §107.61, Eligibility
- §107.63, Issuance of a remote pilot cert. with a small UAS rating
- §107.64, Temporary certificate
- §107.65, Aeronautical knowledge recency
- §107.67, Knowledge tests: General procedures and passing grades
- §91.3 Responsibility and authority of the RPIC
- §91.13 Careless or reckless operation
- §91.17 Alcohol or drugs
- §91.103 Preflight Actions
- §91.111 Operating near other aircraft.
- §91.113 Right-of-way rules: Except water operations
- §91.115 Right-of-way rules: Water operations
- §91.119 Minimum safe altitudes: General
- §91.123 Compliance with ATC clearances and instructions.
- §91.133 Restricted and prohibited areas
- §91.137 Temporary flight restrictions in the vicinity of disaster/hazard areas
- §91.145 Management of aircraft operations in the vicinity of aerial demonstrations and sporting events
- §91.151 Fuel requirements for flight in VFR conditions
- §91.159 VFR cruising altitude or flight level
- §91.209 Aircraft Lights
- §91.213 Inoperative instruments and equipment
- §91.215 ATC transponder and altitude reporting equipment and use
- Part 91 – Airport/Locations: Special Operating Restrictions

NDOT's policy for fulfilling a MEC role requires all the above and:

- Be a NDOT employee or NDOT contracted staff
- Appropriate medical requirement as stated within any FAA documentation
- Current manned pilot certificate if required
- Current remote pilot certificate if required
- Must have copies of NDOT UAS Policy and NDOT Standard Operating Procedures available on all missions.

3.2 Remote Pilot in Command (RPIC) Responsibilities

The Remote Pilot-in-Command (RPIC) has final authority and responsibility for the operation and safety of flight. The RPIC must be appointed before the flight and hold the appropriate category, class, and type rating, if appropriate, for the conduct of the flight. For the purpose of conducting these procedures, the responsibility and authority of the RPIC as described by applicable 14 CFR §91.3 or §107.19, *Responsibility and Authority of the RPIC*, apply to unmanned aircraft as stated within applicable guidelines. The RPIC may not delegate any of their responsibilities to any another crewmember. The RPIC is ultimately responsible for identification and mitigation of all operational hazards. The RPIC responsibilities also include a thorough preflight inspection of the UAS. Flight operations will not be undertaken unless the UA is found airworthy and no outstanding maintenance exists. The RPIC may be a standalone role or operate as a dual role crewmember; AVO and/or EP. The RPIC may not fulfill the role as VO since this position does not have access to a set of flight controls. If a VO requires training, the RPIC is responsible for ensuring the NDOT VO training has been accomplished.

Rating requirements for the RPIC depend on the operation being conducted. The requirement for the RPIC to hold or not to hold a certain type of rating is based on various factors including:

- The location of the planned operations
- The mission profile,
- The size of the aircraft, and
- Whether or not the operation is conducted within VLOS

The designated RPIC:

- Is responsible for determining whether the UAS is in condition for safe flight.
- May be augmented by supplemental pilots; however, the RPIC retains ultimate responsibility of the flight, regardless of who may be piloting the aircraft.
- May rotate duties as necessary to fulfill operational requirements.
- Must have thorough knowledge of the operational parameters and provisions and retain a copy of appropriate documentation to reference during flight.
- Must be proficient on the UAS being flown.

- Must make radio calls to ATC as required
- Must inform crewmembers of their roles & responsibilities
- Must carry their remote pilot certificate, government issued ID and NDOT RPIC Letter of Authorization whenever UAS operations are being conducted.

The RPIC must conduct pre-mission coordination and pre-takeoff briefing as applicable prior to each launch. The briefing should include but is not limited to:

- Pre-Mission Coordination (See Section 7.8)
- Identify each flight crewmember and duty position assigned
- Roles and responsibilities
- Explain the operational intent or objectives of the flight
- Contents of the specific COA
- Operating conditions: weather or hazards associated with the flight (to include risk score)
- Altitudes to be flown
- Frequencies to be used
- Flight time, including reserve fuel requirement
- Contingency procedures to include lost link, diversions/deviations from the flight plan, and flight termination
- Hazards unique to the flight being flown

3.3 Air Vehicle Operator (AVO)

Responsibilities

The Air Vehicle Operator (AVO) is responsible for the flight when the UAS is being controlled via a ground station. These flights are typically pre-configured and automated flights. Through the ground station, the AVO can control the UAS to perform many different mission profiles. The AVO can also monitor many UAS mission parameters and relay that information directly to Mission Essential Crew. It is the AVO's responsibility for ensuring the appropriate checklists have been followed to ensure:

- Assign or conduct UAS preflight/ airworthiness inspection
- The UAS is configured correctly
- The flight plan is input correctly and is appropriate to this mission
- Battery voltage and/or onboard fuel is adequate for the flight
- Telemetry and GPS signal is acquired and adequate for flight
- Must carry their remote pilot certificate, government issued ID and NDOT RPIC Letter of Authorization whenever UAS operations are being conducted.
- Must carry a current copy of NDOT UAS Policy, NDOT Standard Operating Procedures, and NDOT RPIC Letter of Authorization on all missions.

During flight, the AVO must relay information as often as RPIC requires to all MEC about UAS status. This will require the AVO to monitor aircraft status to include but not limited to:

- Position
- Altitude
- Speed
- Direction of travel
- Distance to next waypoint
- Battery voltage or fuel remaining
- Telemetry
- GPS status
- C2 link strength

The AVO must carry their remote pilot certificate and government issued ID whenever UAS operations are being conducted.

3.4 External Pilot (EP)

Responsibilities

The primary job of the EP is to fly the UAS using a remote-control transmitter when immediate action may be required, including landings and take-offs, during emergencies or as requested by the RPIC. The EP will maintain visual contact with the aircraft during line-of-sight missions.

The EP will always maintain verbal communication with Mission Essential Crew. The EP will maintain visual contact with the aircraft (excluding BVLOS operations) and will not deviate from planned routes except in instances where there is a more than minimal risk to the UAS, non-participating persons, manned aircraft, or property. The EP's duties include:

- Coordinate with the AVO when taking over control
- Acknowledges when transferring control
- Calling out landings/emergencies or any other deviations from the scheduled flight plan
- Use standard ATC phraseology
- Read back instructions
- Use of radio communication is permitted and, in many cases, may be the best option.
- Must carry their remote pilot certificate and government issued ID whenever UAS operations are being conducted.
    - Must carry their remote pilot certificate, government issued ID and NDOT RPIC Letter of Authorization whenever UAS operations are being conducted.

NOTE: During any unscheduled or unforeseen events, the EP must use his/her own discretion when the safety of the flight is in question. Events may include, but not limited to, items such as:

- Traffic conflictions with non-participatory aircraft

- Unscheduled altitude changes
- Erratic, unexpected air vehicle maneuvers
- Aborted landings

3.5 UAS Flight Instructor (FI)

Responsibilities

UAS Flight Instructors (FI) are responsible for teaching UAS pilots, including unqualified or non-current pilots and employees to fly UAS utilizing a variety of educational and training resources including, but not limited to textbooks, classroom ground instruction, simulators, and flight training.

For training flights, the FI will be qualified as an RPIC and designated as RPIC for the entire duration of the flight operation. Unqualified employees who do not possess an RPIC certificate may be the manipulators of the controls; however, the RPIC must have sufficient override capability to assume control of the UA at all times. AC 107-2 5.2.1 indicates there are a number of ways in which this transfer of control may be conducted.

Under all training situations, the FI is responsible for the safety of the operation. The FI is also responsible for meeting all applicable conditions and limitations as prescribed in 14 CFR 107.

Currency

All FI must be current in the category of aircraft for which they provide flight instruction. To qualify as a FI the applicant must meet the proper minimum criteria requirements and be selected by the NDOT UAS department through an evaluation process.

Once the applicant has received authorization to perform the duties of a FI, he/she will be able to instruct students in that specific category or type of UAS. The category authorization is valid for 24 calendar months. Once that time has elapsed, the individual can renew his/her certificate by completing an FI refresher course with another NDOT FI in the category of UAS in which the renewal is sought.

3.6 Visual Observers (VO)

Responsibilities

The Visual Observer (VO) ensures the UAS is operating safely within the National Airspace. This role is to help mitigate risk for the MEC. Their primary job is to warn the operators about any potential hazards in order to maintain separation with other aircraft. VOs will maintain verbal or electronic communication with the pilot flying at all times. Use of a radio communication is permitted unless restricted by a waiver/COA. NDOT employs the use of a decision tree to determine missions that will require a VO (See Appendix G). RPIC's have the right to require a VO on missions that fall outside of required VO's per the decision tree results. The UAS Program Manager may also require the use of a VO based on mission specific information. Each VO must be briefed on his/her responsibilities during the preflight briefing.

- Depending on the governing set of regulations, the VO may be either ground based, aboard a chase aircraft, or as authorized by the specific COA or flight approval.
- The VO must be able to see the airborne UA at all times, unless EVLOS or BLOS operations are approved.

  NOTE: If a VO loses sight of the unmanned aircraft, notify the pilot flying immediately. If the unmanned aircraft is visually reacquired promptly, the mission may continue. If not, the unmanned aircraft must follow lost link procedures until visual contact is reacquired.

- Relays information between the AVO and EP when necessary.
- Alerts MEC of potential traffic conflicts as they come into view.

Currency

All VOs must have an understanding of Federal Aviation Regulations applicable to the airspace where the UAS will operate. VOs must not perform crew duties for more than one UAS at a time. VOs are not allowed to perform concurrent duties as both RPIC and VO. Each VO must obtain the following to be qualified for the role:

VOs must complete sufficient training to communicate to the MEC any information required to remain clear of conflicting traffic, terrain, and obstructions, maintain proper cloud clearances, and provide navigational awareness. This training, at a minimum, must include knowledge of:

(a) Their responsibility to assist pilots in complying with the requirements of 14 CFR:

- § 107.33, Visual observer
- § 107.37, Operation near aircraft; right-of-way-rules
- § 91.111, Operating Near Other Aircraft
- § 91.113, Right-of-Way Rules: Except Water Operations
- § 91.115, Right-of-Way Rules: Water Operations; and
- § 91.155, Basic VFR Weather Minimums

(b) Air traffic and radio communications, including the use of approved ATC/pilot phraseology outlined in the AIM 4-2; and

(c) Appropriate sections of the Aeronautical Information Manual (AIM).

(d) NDOT VO Training guide

In addition to the responsibilities listed above, NDOT's policy for the UAS VO role requires them to be:

- NDOT staff/employees
- In compliance with the medical requirements in the documents required for that specific flight

Currency

There is no currency requirement for the VO. It is the responsibility of the RPIC to determine if the VO is trained and qualified for the mission.

3.7 Payload Operator (PO)

Responsibilities

The Payload Operator (PO) is responsible for performing the preflight checks for all payloads being used for a particular mission and the associated equipment. The PO assists the RPIC with startup and preflight operations. Their duties will include:

- Informing the RPIC to change course (if required)
- Coordinate with the RPIC to ensure proper imagery is being collected for the mission
- Verify with the RPIC that all steps are being followed according to the UA checklist
- Read back instructions

If a mission does not require a high workload, then the PO responsibilities include making sure that the payload settings are set to the right configuration. Responsibilities include:

- Ensuring the correct payload is installed and functioning properly
- Ensuring the payload is in the correct configuration for the mission
- Ensuring that the payload is able to store or downlink the required data for the mission.

If multiple flights are to occur on the same day, it is recommended that the crew carry multiple memory cards or other storage devices as required to accommodate payload data. NDOT staff must double check the data at the conclusion of a mission to be assured that it is correct and of the required quality.

Currency

There is no currency requirement for the PO. However, it is necessary that the PO is able to help perform all pre-check, launch, and post-flight checklists required by the RPIC. The PO should be familiar with the mission payload and its operation as well.

3.8 Crew Chief (CC)

Responsibilities

The role of the Crew Chief (CC) is to prepare the UAS for flight. Prior to mission deployment, the CC performs all pre-deployment checks and ensures that the aircraft is ready for flight. Often there are maintenance schedules that are to be followed. The CC ensures adherence to the schedules and documented in a logbook and available to ensure adherence by other technicians. If there are outstanding maintenance issues with an aircraft, it is the CC's responsibility to correct them and return the aircraft to service.

Effective CC communication abilities are crucial during the pre-deployment and preflight checklists. The CC should be in constant contact with the RPIC to prepare for takeoff. Additionally, the CC follows all re-launch and post-flight checklists. Duties include:

- Scheduled and unscheduled maintenance of the UAS
- Recording maintenance in logbooks
- Pre-deployment checklist
- Management of takeoff/landing checklists
- Management of ground crew & qualifications
- Proper set up of ground support equipment
- Delegates responsibility to non-essential ground crewmembers
- Follow all applicable checklists for set up of UAS launcher
- Ensure proper configuration of UAV before launch
- Secure aircraft after recovery and perform post-flight inspection
- Read back instructions

Currency

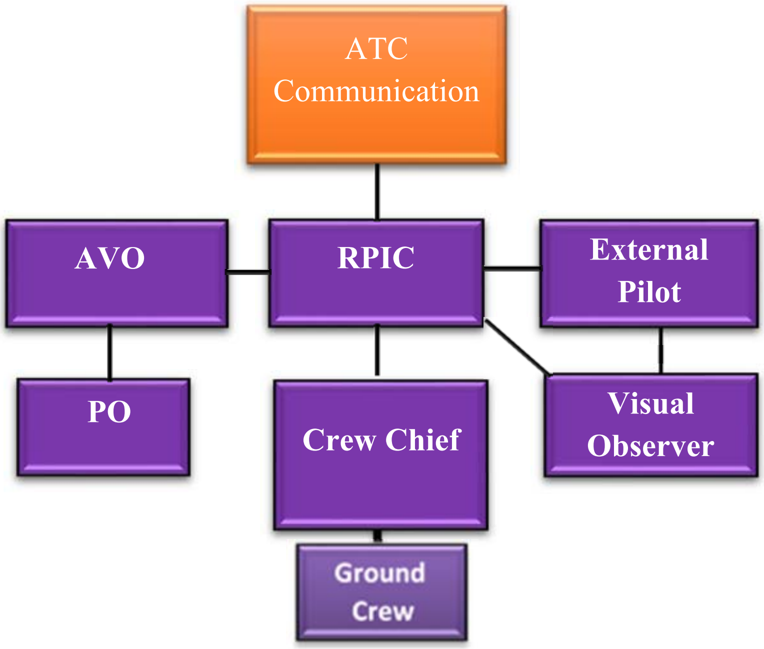
There is no currency requirement for the CC role. However, the CC must be authorized to perform this role by UAS Staff or management. Additionally, the CC should be able to assist with all pre-check, launch and post-flight checklist requirements for the UAS they are responsible for, while in the field.

3.9 Spectators

Spectators may observe designated flight operations. For operations in which more than 10 spectators are present, a designated spectator monitor will be provided. In these instances, the spectator monitor may be a crewmember, but will not be the RPIC, EP, AVO, nor the VO. Spectators should not distract the MEC. A sterile environment around the GCS must be maintained for the MEC during UAS flight operations. Any spectator that interferes with flight operations will be removed from the flight location immediately. Prior to flight operations, the RPIC will ensure spectators receive a spectator briefing. Additional guidance may be found in applicable documents.

4 Communication Procedures

4.1 Structure of ATC Communication (if applicable)



All communication orbits around the Remote Pilot in Command (RPIC). If communication involving Air Traffic Control is necessary, the above diagram shows the communication channels if all roles are filled by individuals. Any safety related issues should be immediately brought up to the appropriate MEC. Since most mission crew sizes are small in nature, the RPIC will be able to receive direct feedback from all crewmembers. Crewmembers should use their best judgment if an issue requires attention.

If needed, the VO can be located at a remote vantage point but must be within 2-way communication of the RPIC.

4.2 Communication Planning

During flight operations requiring 2-way communication, communication will take place between the MEC through use of an electronic device:

- The device can be push-to-talk unless full-duplex is required by waiver/COA
- A reliable back-up communication method will be an alternative device capable of transmitting and receiving at a range no less than the distance between the RPIC and VO(s), such as cell phone or hand-held radio.

Communication during abnormal events and emergencies.

- If no communication response is received within ten (10) seconds on the primary communication device, the backup communication method will be implemented.
- If a complete communication failure occurs, the RPIC and VO(s) will execute the mission specific, pre-flight briefing, "lost communication" procedures consisting of commanding the UAS to RTL.
- Effective communication between MEC is critical.
- Communication links shall be established prior to operations "comm check".
- Contact between MEC will be maintained by one or more of the following in order of preference:
    a. Direct voice communication
    b. 2-way communication device
- Backup communication method will be in place and tested prior to commencing flight operations.
- Airport Communication
    a. The RPIC should monitor the local airport frequency when operating within 5 NM of an airport.
    b. When operating in Class B, C, or D airspace, the RPIC shall establish and maintain direct two-way radio communication with the ATC facilities when required to do so by waiver/COA.
    c. If operating within 2nm of a helipad <u>and conducting BVLOS</u> operations, the RPIC shall coordinate communications prior to flying an UAS with the agency or facility in control of that helipad.

5 General Operations

5.1 Privacy

UAS operators will limit operations to the specific approved purpose of the mission and employ reasonable precautions to avoid capturing images of the public except those that are incidental to the project. Data collected on residential property cannot be the purpose of a mission unless pre-approved by the UAS Program Manager.

5.2 Uniform Policy

NDOT staff performing UAS operations should adhere to NDOT procedures or guidelines regarding appropriate attire for the conditions and site. In addition to the proper clothing, the following are requirements:

1. NDOT issued high-visibility safety apparel that meets the Performance Class 2 or 3 requirements of ANSI 107.
2. Specific site requirements, including but not limited to all Personal Protective Equipment requirements (e.g. Hard Hats). Coordinate with the sites Project Manager or appropriate staff to identify and document the requirements prior to the mission taking place.

5.3 Personal Protective Equipment (PPE)

The operations site is to have safety equipment to control small fires and attend to minor medical incidents. Crew members will be trained in the basic use and maintenance of the safety equipment available at the launch and recovery site.

The launch and recovery site will have:

- One current and charged, 3 lbs. or larger ABC rated fire extinguisher.
- One first aid kit with clean bandages.
- One telephone or mobile phone (charged) with emergency response numbers accessible.
- As necessary, barriers, signs, or cones to indicate zones to non-participating people or vehicles.

5.4 Crew Health

The RPIC and the EP are to have adequate rest before flight to ensure alertness and maximum performance. 8 hours of rest prior to flights is recommended.

Alcohol: All crewmembers cannot consume alcohol or other intoxicants within 8 hours prior to participating as a flight or ground crewmember.

Drugs: Prescription or over-the-counter medicine used by pilots operating NDOT UAS shall be approved for use by an official FAA aviation medical examiner. For additional information, see the following FAA resource linked here.

In addition, when a pilot starts a new medication, he/she should monitor the effects of that medication at least 48 hours before operating aircraft.

Reference Part 107:

- §107.57, Offences involving alcohol or drugs
- §107.59, Refusal to submit to an alcohol test or furnish test results

5.5 Physical Security Plan

NDOT UAS equipment shall be secured while in the possession of employees. This includes, but not limited to:

- Maintaining a secure, locked facility for long term UAS storage.
- Maintaining a check-out log sheet indicating out/in times for the systems.
- Only storing UAS in locked, unattended vehicles for short periods of time during normal business hours.
- Storing UAS equipment in hotel rooms during overnight trips. Locks can be used on the cases to ensure systems and data are secured.

5.6 Loading Equipment

When loading equipment into the vehicle, the RPIC is to inspect all pieces of equipment before leaving the area. All high-value equipment should remain within a proper storage area until the morning of departure. All items should be secured sufficiently, as to remain secure during transport. If aircraft are not in approved transport cases, they should be secured via straps. In addition, foam should be used to cushion the frame of the aircraft between places where rubbing or abrasion may cause damage.

6 Safety Management System

6.1 Safety Climate

Aviation safety relies on a structured system of accountability. An individual's actions impact the overall safety condition of NDOT UAS Activities. The goal of the SMS is to foster an environment where an individual not only understands the importance of safety but takes an active interest in improving safety. NDOT is committed to a safe and healthy workplace.

At a minimum, this means there is:

- A commitment to safety by everyone involved
- Safety-conscious leadership present
- Established communication procedures
- Up-to-date procedures

6.2 Safety Policy

Correct usage of risk mitigation, resource management, and the tools outlined within the SOP's are to be used in an effort to create a reasonably safe airspace. Using proven aeronautical standards from the manned aviation industry adapted to the unmanned community, procedures are built upon FAA's Four Pillars of SMS. The system relies on flight crew personnel following proper operating procedures, exercising aeronautical decision making, conducting risk management, and active reporting.

Safety Policy will focus on:

- Involvement in SMS procedures
- Identification and management of safety risks specific to UAS operations
- Continued education and training programs
- Feedback from operators
- Protection of privacy
- Structured support system
- Shared knowledge/lessons learned platforms
- Monitoring the UAS community to ensure best safety practices are incorporated into the organization.

6.3 High Risk Operations

For operations that are considered high risk, NDOT UAS operations will incorporate Order 8040.6: Unmanned Aircraft Systems Safety Risk Management Policy (SRM) which is one of the main components of the Safety Management System (SMS). Flight crew personnel must follow the policies contained in the SMS for matters relating to safety in NDOT UAS Activities.

6.4 Flight Crew Duties

It is the duty of every member of the UAS flight crew to contribute to the goal of continued safe operations. This contribution comes in many forms and includes operating in the safest manner reasonably practicable and not taking unnecessary risks. Any safety concern, whether procedural, operational, or maintenance related must be identified as soon as possible. Any suggestions in the interest of safety should be made to the UAS Program Office.

6.5 Safety Halt

If any member has reasonable concerns about the safety of an operation, they are obligated to call a "safety halt" to that operation, immediately halting the current operation and putting it in a status of "on hold" pending review. The UAS Program Manager is to be notified immediately so that appropriate action may be taken.

7 Operating Procedures

7.1 General Operating Procedures

7.1.1 Reserve Fuel / Battery Charge

All flights will be required to factor in reserve fuel/battery charge before takeoff for the return flights and/or emergencies that may arise during the mission. During operations, these reserves will be taken into account and withheld from the total flight time. For day operations, reserves for petroleum-fueled aircraft will be at least 30 minutes of flight time in case of emergencies. On electric powered aircraft, the flight batteries will under no circumstance drop below minimum battery capacity, see chart below. When the battery reaches 20-25% of remaining capacity, the aircraft will either return home, or fly to an alternate landing area. The 20-25% Cap threshold should be programmed into each UAS's battery failsafe. On DJI drones, this is the critical battery setting. The RPIC shall confirm this prior to operating the UAS. When applicable, Return to Home battery alert features shall be set at 25% for environmental temperatures equal to or greater than 41 degrees F and 35% for temperatures less than 41 degrees. On DJI drones, this is the low battery warning setting. Battery levels should be monitored closely during operations and communicated between MEC as necessary. Decisions will need to be made real time on when to begin landing procedures given the current battery levels and proposed flight paths.

When applicable, the RPIC shall not abort any Return to Home actions initiated by the aircraft, the only exception being in protection of people and property.

Cells	Full Charge Voltage	Minimum Voltage (Do Not Go Below)	Approx. Stop. (25%Cap.)	Approx. Storage Voltage (40-60% Cap.)
1	4.2 volts	3.0 volts	3.3 volts	3.9 volts
2	8.4 volts	6.0 volts	6.6 volts	7.7 volts
3	12.6 volts	9.0 volts	9.9 volts	11.6 volts
4	16.8 volts	12.0 volts	13.2 volts	15.4 volts
5	21.0 volts	15.0 volts	16.5 volts	19.3 volts
6	25.2 volts	18.0 volts	19.8 volts	23.1 volts

Note: Note: These voltages are for "resting" batteries (not under load) and are approximate. Actual in-use battery voltages will vary depending on the UAS/load.

7.2 Operations near personnel and Structures

No aircraft will takeoff or land closer than 25 feet from the outer edge of the travel lane on roadways with a posted speed limit of 45 miles per hour or greater. For all other roadways, no aircraft shall take off or land closer than 10 feet from the outer edge of a travel lane. In extremely rural areas, relaxation of these rules can be considered at the RPIC's discretion based on traffic and topography conditions that may warrant changes to safely take off and land the UA. Deviations to the rule should be documented as part of the post flight log procedures with justification, which would include no visible traffic within the area. Take off and landings between lanes of a divided highway are prohibited.

For operations taking off/landing near a travelled roadway, the RPIC should wait for a break in traffic that provides a safe distance based on current conditions between the nearest oncoming vehicle and the take-off/landing area in order to minimize risk of driver distraction.

UAS may only cross over a roadway without a closure, when the Remote Pilot and/or the Visual Observer can ensure the UAS would not fly over vehicles, bicyclists, or pedestrians underneath its path, nor create a visual distraction to the travelling public (cross at the highest AGL as practical, no less than 50' AGL minimum). The Remote Pilot shall plan the UAS Operation to avoid or minimize the need to perform a cross-over. All crossings over roadways shall do so in a path approximately perpendicular to the highway. The RPIC will complete the crossing when no on-coming vehicle is closer than 200 yards of the crossing or poses a risk that if the UA were to fail would cause impact with the vehicle. If the mission is being flown under a waiver, the waiver procedures and requirements govern and should be followed.

The aircraft will not operate within six feet of any fixed object. Fixed objects include buildings, utility poles, utility lines, signs, and trees among others. An aircraft can experience unexpected wind gusts near structures resulting in an impact and/or crash.

No aircraft will operate under the deck of an overpass bridge with traffic on a lower roadway without an approved traffic plan.

The aircraft will not operate sustained flights directly above a roadway. Data collection will always be from a "stand-off" position to the side of the roadway when vehicles are present. This rule is intended to prevent an aircraft from landing/impacting on the roadway in the event of a critical system failure. If flight directly above a roadway is required:

- Approval by the UAS Program Manager is required.
- Flight above the roadway will only take place when no vehicle(s) are directly below the aircraft; or within an approach distance that in the event of a critical failure the UA would impact the moving vehicle.

- A minimal of one VO is required for traffic monitoring.
- Lane closure may be necessary depending on the site characteristics.
- Alternative data collection technologies should be considered.

7.3 Mission Planning

7.3.1 Pre-Mission Coordination

All UAS flights require planning prior to scheduling or performing the missions. This includes at a minimum:

1. Logging the mission in NDOT's UAS Request Application
    a. Link to Form to submit a UAS Flight Request
2. Completing a site survey form (See Appendix C)
3. Creating a flight plan (See Appendix H)

All UAS flight operations will be required to operate as authorized by the FAA. Determine if the operation will be conducted under:

- Part 107
- COA
- Section 44807

NOTE: If your flight operation(s) require a COA, contact the NDOT UAS Program Office.

7.3.2 NOTAM's

Determine if the flight operation(s) requires a Notice to Airmen (NOTAM's) to be published. When dictated by appropriate regulations, all Notices to Airmen (NOTAMs) will be filed no less than 24 hours but no more than 72 hours prior to operations commencing by NDOT's UAS Program Manager or designee.

7.4 Flight Type

7.4.1 Flight Training

NDOT Districts and Divisions may permit NDOT UAS Remote Pilots to conduct training, and prospective NDOT Remote Pilots to train with experienced Remote Pilots, at a NDOT facility or other State designated location. The training may take place as long as the operating area can be safely secured from pedestrians and moving vehicles. The training must take place in class G airspace above Nebraska DOT Right of Way, with take-off and landings taking place from State ROW.

In Lincoln, the facility at 5001 South 14th has been identified as an approved UAS test site. Communication protocols are in place to notify the nearby property owners of any planned training flights, as the property directly north of the site house the Lancaster County Emergency Management office and Lancaster County Juvenile Detention center. Contact the UAS Program Office for more information on performing training missions at this location.

7.4.2 Initial UA Test/Tune Flights

Initial flights of a new UAS and tune flights require an increased level of oversight, planning, and Operational Risk Management. The increased risk to personnel and Aircraft requires highly qualified aircrew, specific preflight planning, and an increased awareness of the intended airspace to be utilized.

An initial test and tune flight are necessary for maiden flights or tuning custom UAS prior to releasing the UAS for normal flight operations. The following flight limitations shall be observed for test and tune flights:

- An FCF (Functional Check Flight) shall only be conducted by a qualified RPIC or maintenance personnel.
- All flight planning and safety considerations shall be completed and evaluated.
- A test flight should not be operated when the safety of the flight might be jeopardized by adverse weather.
- All FCFs will occur no less than 500 feet horizontally from non-participants.
- Night test flights shall not be conducted.

7.4.3 Functional Check Flights

Any UAS that has undergone maintenance or alterations that affect the UAS operation or flight characteristics, e.g. replacement of a flight critical component, must undergo a functional check flight (FCF) prior to conducting further operations. The FCF tests will be conducted by a qualified minimum MEC and be at least 500 feet horizontally from any other people.

7.4.4 Routine Operations

Routine operations will follow all Part 107 rules and regulations.

7.5 Pre-Flight

7.5.1 Preflight Action

Assuring strict adherence to the operation, the RPIC will make sure that all necessary items have been completed prior to launch. The RPIC needs to ensure all required operating documents are accurate and in hand prior to operations. Some of these items include the following items.

Prior to every launch, a thorough preflight inspection will be conducted by the RPIC to ensure the UAS is in an airworthy condition. The RPIC must utilize the aircraft specific preflight checklist to determine basic airworthiness. See Appendix I for a sample pre-flight checklist for a Mavic 2 Pro. All NDOT UAS will have their own checklists developed by the UA responsible party in coordination with the NDOT UAS Program Office.

7.5.2 Site Survey Review

The RPIC and appropriate MEC should review the site survey that was to be completed prior to scheduling the mission. Any deviations or additions should be documented in the appropriate sections and understood by the MEC. The site survey should be signed off on and becomes a record that is stored with the mission's documentation. Site surveys can be recalled in the future as a starting point for missions in the same location to alleviate re-work.

7.5.3 Weather Check

Prior to any UAS operation the RPIC will obtain weather reports and gather information from various resources such as surface analysis charts, weather radar, AIRMETs, SIGMETs and convective SIGMETs. If the weather forecasted is beyond the UAS's manufacture recommendations, then those operations in that area will be delayed until further notice.

Aircraft shall not be operated when outside air temperature is below the Minimum Operating Temperature Range as documented in the relevant user manual.

The RPIC will not fly the UAS above OEM recommended wind limitations. If the OEM does not provide wind limitations, then the UAS shall not be flown in winds greater than 20 Knots or winds above 15 knots with a gust spread greater than 7 knots. However, a UAS operation can be conducted above OEM and NDOT limitations if the operation is critical to the best interests of safety. Approval to fly in winds greater than the NDOT and/or OEM limits can be sought through the NDOT risk assessment. The NDOT risk assessment identifies winds above 20 knots require sign off approval.

7.5.4 Checklists: See Logbook

Before operational deployment, the RPIC must refer to all appropriate checklists. NDOT monitors and updates checklists as necessary to promote practical, useful, and efficient habits. NDOT periodically reviews checklists and makes modifications to promote cohesion and standardization. For standard missions, NDOT uses pre-deployment checklists, aircraft inspection checklists, communications checklists, and RPIC checklists. Refer to aircraft logbooks for individual checklists. For any non-standard mission, checklists will be developed based upon past experiences.

7.5.5 Risk Assessment

Prior to flight, the RPIC will complete a Risk Assessment Matrix and gather all pertinent information relating to the mission. In this context, a mission may consist of multiple flights. As an example, flying a mapping data collection mission may necessitate multiple battery changes to complete the mission. A Risk assessment is only required prior to the first launch unless the operational parameters drastically change during the sequence of flights (i.e. major weather changes, MEC changes, UAS swaps, etc.).

A risk assessment matrix will be completed prior the commencement of flight operations (See **Appendix D**). This form is to help reduce the likelihood of failures, incidents, and accidents by associating values of risk with operational hazards and proposing mitigation strategies. The risk assessment helps define the acceptable amount of risk for a given mission, and it reduces the likelihood of injury or the loss of the aircraft.

Projects requiring pre-approval are:

- Any project with an MRA score of “High Risk”
- Any project located within class B, C, or D airspace or Class E airspace that starts at ground level.
- Any project requiring an exception from any of the general rules listed in the Flight Planning Section.
- Any project requiring an FAA waiver or authorization.
- Any project requiring permission from a landowner.
- Any project that requires traffic control beyond warning signs. This includes any project that requires the placement of traffic cones on the roadway surface, speed reduction, or lane closure.

For projects that require pre-approval from the UAS Program Manager, all SMS documents and a traffic control plan (if required) must be sent as an email attachment to the NDOT UAS Program Office staff.

Risk assessment matrices should be kept on file for at least 5 years after the flight operation.

7.5.6 Flight Plan Review

The RPIC and additional MEC should review the documented flight plan and ensure the mission can be carried out as planned. If not, changes should be made accordingly and communicated.

7.5.7 Weight and Balance

The RPIC is responsible for the proper loading, payload security, weight, and weight distribution of the UA. The take-off and landing weights shall not exceed the maximum weights specified in the OEM User Manual.

7.5.8 Crew Briefing

The RPIC must conduct pre-mission coordination and pre-takeoff briefing as applicable prior to each launch. The briefing should include but is not limited to:

- Pre-Mission Coordination (See Section 7.8)
- Identify each flight crewmember and duty position assigned
- Roles and responsibilities
- Explain the operational intent or objectives of the flight
- Contents of the specific COA

- Operating conditions: weather or hazards associated with the flight (to include risk score)
- Altitudes to be flown
- Frequencies to be used
- Flight time, including reserve fuel requirement
- Contingency procedures to include lost link, diversions/deviations from the flight plan, and flight termination
- Hazards unique to the flight being flown

7.6 Flight

The launch and recovery of the UAS will be conducted such that it prevents the aircraft from doing damage to any surrounding structures if a failure occurs.

7.6.1 Radio Communication

During flight operations where radio communication is necessary, battery powered communication radios shall be charged and tested during the pre-deployment phase. All radios will be on the same channel during operations. If there are found to be unknown person(s) on the designated channel, a new channel will be assigned to avoid confusion.

Proper Radio Use:

- Listen before transmitting to verify you are not talking over anyone else
- Depress the talk button, wait for one second before speaking
- Use clear and concise communications
- Use standard ATC phraseology
- Read back instructions

7.6.2 Sterile Environment

To maximize the crew's situational awareness and maintain operational safety, NDOT incorporates a sterile environment around the Ground Control Station (GCS) during critical phases of flight. NDOT will strategically position the GCS in a low traffic area to avoid interference. Anyone within the sterile environment must be an official crewmember or cleared to be there by the RPIC. All personnel inside the sterile environment will comply with FAR 121.542 and FAR 135.100 during critical phases of flight. Critical phases of flight include all operations involving:

- Taxi (movement of an aircraft under its own power on the surface of an airport).
- Take-off and landing (launch or recovery).
- All other flight operations in which safety or mission accomplishment might be compromised by distractions.

No crewmember may perform any duties during a critical phase of flight not required for the safe operation of the aircraft which could:

- Distract any crewmember from the performance of his/her duties or

- Interfere in anyway which the proper conduct of those duties.

MEC will not engage in any activates that do not relate to the operation of the aircraft. The use of cell phones or other electronic devices is restricted to communications pertinent to the operational control of the unmanned aircraft and any required communications with ATC. Spectators or bystanders must not interfere with the flight operations in any manner. Any persons interfering with flight operations must be removed from the area immediately.

7.6.3 Avoidance Procedures

Adherence to 14 CFR Part 107.37, 91, §91.111, §91.113 and §91.115, is required.

UAS crewmembers will ensure there is a safe operating distance between manned aviation activities and the UA at all times. Any crewmember responsible for performing see-and-avoid requirements for the UA must have and maintain communications with the pilot flying.

If an encroachment seems imminent by non-participating parties, the RPIC may deviate from the flight plan to avoid collision. In extreme situations, the RPIC can declare an emergency and deviate from the authorization being flown under to avoid an accident. Once clear, the UAS will be landed immediately and flight operations will not resume until the area is clear.

8 Emergency Procedures

8.1 Failed Launch

A failed launch resulting in no/minor damage may occur during routine operations. The UA will be returned to service only after a thorough inspection has taken place and the CC has deemed it safe. If the failed launch results in major damage to the aircraft, then the aircraft will be required to return to the lab for further inspection. If only minor damage has occurred, (e.g. able to be repaired while in the field) then the CC will inspect before re-launching the aircraft. An inspection of all aircraft components must be accomplished. Inspections may include but not be limited to:

- Stripped servo gears
- Cracked servo cases
- Bent motor shafts
- Torn vibration isolators
- Motor mounts
- Airframe structural damage (composite delamination, tears, etc.)
- Propeller damage
- Wire connections
- Electrical harness and antennas

8.2 Loss of Propulsion

In the event of an engine failure, battery failure or any other means of disrupting propulsion during flight, "loss of propulsion" will be announced three times by the crew member who noticed the failure. Depending on the circumstances, the RPIC will have the EP or the AVO take control and execute the landing procedures while maintaining adequate clearance from obstacles and populated areas. The RPIC can declare an emergency if the situation permits. If the EP announces that the aircraft is out of visual range, the AVO will manually alter course to avoid obstacles and maintain safe clearance from populated areas while executing emergency landing procedures.

8.3 Lost Link Procedures

In the event of a lost link and the UAS AVO cannot regain link within the pre-set time (DJI defaults to immediate, some systems will need to be configured to set the time to respond) the MEC will monitor the UAS visually. If the UAS does not execute the lost link procedure or is BVLOS, the RPIC will follow the regulations or provisions under which they are operating.

The normal procedure is for the UAS to return to a specific location at a pre-set safe altitude and land automatically upon the loss of link with the GCS. Lost link events are not considered an emergency until the UAS does not execute its lost link protocol.

8.4 Lost Communications

When required, the UAS crew will have redundant communications with the ATC authority, which include the use of a 2-way base station radio, if within radio range, and cellular phones**.** In the event of a loss of communications with the ATC authority, the UA will hold its current altitude and position in a(n) orbit/hover for 1 minute. If communication is not reestablished within 45 seconds, the pilot will immediately return the UA for landing.

MEC will communicate with each other on a 2-way radio if not physically collocated. If communication is lost using the 2-way radios, the RPIC will use (or designate a member of the crew to use) a cellular phone to inform the MEC the UAS to hold for 1 minute while communications are re-established. If unable, the RPIC will command the UAS to proceed back to the home position for recovery.

8.5 Primary Navigation Failure

If the aircraft experiences a failure of the primary navigation system within visual line-of-sight (VLOS), the EP will assume command and land the aircraft if required to do so. In this scenario, turns and other maneuvers are to be minimized unless the EP is able to exercise positive control of the aircraft.

In the event that the aircraft experiences a primary navigation system failure while operating beyond visual line-of-sight (BVLOS), the recommended course of action should be to command the aircraft to execute lost-link procedures and minimize maneuvering to reduce the likelihood of additional navigational errors. If the navigation system failure is severe enough that the aircraft cannot navigate, the flight must be terminated in a safe manner that does not pose a hazard to other aircraft or people and property on the ground. Additionally, the RPIC will follow the regulations under which they are operating.

8.6 Traffic Conflict

The VO's role is to provide traffic de-confliction between the UAS and other air traffic. If a traffic conflict occurs, the procedure will be to reposition the UAS immediately to a location and altitude that mitigates the conflict. If it is not possible to maneuver out of the way, then a collision avoidance maneuver will be performed that best ensures adequate separation with the conflicting aircraft, following right-of-way rules defined in 14 CFR Part 91 and §107.37. This maneuver is typically an engine kill on a multirotor or ditch on a fixed-wing UAS.

8.7 Accident/Incident/Mishap Reporting

Immediately after an incident/accident the RPIC must first preserve life and limb, and then notify the NDOT UAS Program Manager of the incident/accident. After the incident/accident has been contained, an incident/accident form must be filed by the RPIC and include all MEC points of view.

8.8 Recovery of Aircraft following an incident or accident

The NDOT policy for recovery of an aircraft following incidents and accidents is as follows:

- If Emergency Medical Services are needed call 911
- **Do not touch or alter** the site until deemed appropriate by the RPIC.
- Reference NDOT's ERP (Emergency Response Plan) for further guidance.

- If property damage (other than the UAS) has occurred or someone is injured, inform NDOT UAS Program Manager immediately after preserving life and limb.
- Take pictures of the scene, aircraft, surrounding debris, and any other damage inflicted by the UA crash.
- Take GPS coordinates and log them into the flight log sheet for that specific mission.
- When transporting the aircraft and associated debris, leave the aircraft as intact as possible.
- Fill out NDOT's incident/accident form. Example of the incident/accident form can be found in Appendix F**.**
- Attach all photos to the incident/accident form.
- Report and fill out the accident/incident/mishap form to the FAA as required with the assistance of the NDOT UAS Program Office.
- **Do not talk** to outside persons about the event until the chain of command knows about the incident and informs you it is okay to do so.

9 Post-Flight Debrief

Upon conclusion of flight operations, a post-flight debrief must be conducted to inform the crewmembers of the results of the flight and any lessons learned. During this time, the RPIC will record all necessary documentation requirements and the CC will ensure completion of all post-flight tasks.

9.1 Crewmember Logbook Time Entries

Flight time for crewmembers will be recorded by the individual in their appropriate UAS logbooks. It is up to each crewmember to ensure their time is being tracked correctly within the system. It is recommended that a personal logbook be utilized to track the time individually as a second record.

9.2 UA Flight Log Entries

Logbook entries are documents that contain records of the flight. All information pertaining to the flight will be documented by the RPIC, or the MEC member assigned to do so, during the mission. A flight is defined by an aircraft launch and recovery. The RPIC shall complete a post-flight summary in the systems flight log (See Appendix E). The summary shall include, but not be limited to:

- Pilot name
- UAS being flown
- Mission type
- Date
- Flight time
- Take-off time
- All system batteries w/percent remaining logged
- Issue encountered
- Remarks
- COA (if applicable)
- Controlling agency (if applicable)
- Weather
- EP (if applicable)
- VO (if applicable)
- IP (if applicable)
- Location
- Airworthiness completion check

Current system logs are kept with each UAS at all times and part of the UA logbook. Nebraska Department of Transportation (NDOT) will maintain at least 5 years of flight logs on record. Pilots are responsible for submitting their flight logs to the UAS Program Office on the first business day of each month. The UAS Program Office will roll the monthly totals into the UAS log and return updated log sheet templates for to the pilot.

9.3 Aircraft Generated Flight Logs

UAS create electronic flight logs that are stored within the system. The electronic flight logs are subject to review and may be obtained and stored as part of NDOT’s UA inventory system.

10 Maintenance Reporting

10.1 Report Discrepancies

Logbook entries are critical for post-flight review. Reporting discrepancies is mandatory but should not be performed during critical phases of flight. This reporting is recommended during safe periods of flight such as straight and level flight, or while the aircraft is on the ground and has stopped moving. Discrepancies are reported in the comments section of the aircraft logbook and reported to the NDOT UAS Program Office (See Appendix J).

Appendix A **Definitions**

Accident

The National Transportation Safety Board (NTSB) defines an aircraft accident as “an occurrence associated with the operation of an aircraft that takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage. (See 49 CFR 830.) The FAA defines substantial damage as “damage or failure which adversely affects the structural strength, performance, or flight characteristics of the aircraft, and which would normally require major repair or replacement of the affected component. Engine failure or damage limited to an engine if only one engine fails or is damaged, bent fairings or cowling, dented skin, small punctured holes in the skin or fabric, ground damage to rotor or propeller blades, and damage to landing gear, wheels, tires, flaps, engine accessories, brakes, or wing tips are not considered substantial damage for the purpose of this order.” (http://www.faa.gov/air_traffic/publications/at_orders/media/AAI.pdf.)

FAA AC 107-2, 4.5 addresses accident reporting requirements. Reportable accidents are those that involve serious injury to a person, loss of consciousness, or property damage when the cost to repair or replace the property is greater than $500. This does not include damage to the sUA.

Air Traffic Control (ATC)

Air Traffic Control is the controlling agency of the airspace in the United States.

Air Vehicle Operator (AVO)

A pilot crew position in which aircraft control is conducted via the use of a Ground Control Station (GCS) such as a laptop computer with mission management software. May be the Remote Pilot-in-Command (RPIC) or anyone delegated the responsibilities by the RPIC.

Beyond Line of Sight (BLOS)

Operations flown beyond line of sight, to include beyond visual line of sight and beyond radio line of sight.

Beyond Visual Line of Sight (BVLOS)

Aircraft operations beyond the visual range of human observers.

Category

Is referred to as a group of UAS having the same type of characteristics. Fixed wing, Multi-rotor, and Single rotor are three categories of UAS found at NDOT.

Certificate of Authorization (COA)

A Certificate of Authorization from the Federal Aviation Association allows for Unmanned Aircraft to safely fly in the National Airspace.

Command and Control (C2)

C2 refers to a subset of systems and functions that allow for control of the UAS either directly or remotely. This term is commonly used to refer to the radio link that transmits data that is vital for the control and navigation of the unmanned aircraft.

Crew Chief (CC)
Lead person performing field-level maintenance associated with a flight.

Discrepancy

A defect or flaw of the UAS.

Estimated time of Expiration (ETE)
FAA Centers use ETEs as default NOTAMs expirations.

External Pilot (EP)
External Pilot may fly the aircraft manually, with a controller, during critical phases of flight or other periods of the mission as warranted. May be the Remote Pilot-in-Command (RPIC) or anyone delegated the responsibilities by the RPIC.

Extended Visual Line of Sight (EVLOS)
Operations in which the UA is beyond visual line of sight of the aircraft but within radio line of sight for C2 purposes.

Federal Aviation Administration (FAA)
The civil aviation authority of the United States.

Foreign Object Debris (FOD)

FOD is classified as an object or substance that is not associated with a particular vehicle or area that may cause damage if not removed from the environment in which it resides.

Global Positioning System (GPS)

GPS is an American space-based satellite navigation system that is capable of pinpointing a position on earth by referencing relative position to multiple satellites within the satellite constellation.

Ground Control Station (GCS)
Provides various features but primarily used as a command and control station for the Air Vehicle Operator.

Ground Crew (GC)
A group of individuals who are qualified to service the aircraft and prep for mission objectives.

Incident
According to the NTSB, an incident is an occurrence other than an accident that affects or could affect the safety of operations." (See 49 CFR 830.)

Instrument Flight Rules (IFR)
FAA's Instrument Flying Handbook defines IFR as: "Rules and regulations established by the FAA to govern flight under conditions in which flight by outside visual reference is not safe. IFR flight depends upon flying by reference to instruments in the flight deck, and navigation is accomplished by reference to electronic signals. It is also a term used

by pilots and controllers to indicate the type of flight plan an aircraft is flying, such as an IFR or VFR flight plan.

Mishap

An occurrence with an UA that does not qualify as an FAA reportable accident.

Mission Essential Crew (MEC)

The crew responsible for the operation of the UAS.

Notices to Airman (NOTAMs)

Written notification issued to pilots before a flight, advising special conditions that require local or national attention.

Payload

Equipment located on an aircraft to expand operational capability as to provide a certain service(s).

Payload Operator (PO)

Personal in charge of operating and maintaining the payload.

Pilot in Command (PIC)

While in flight, this person has ultimate responsibility of the operation and safety of all crewmembers. He/she is directly responsible for the operation of the aircraft and mission and is the final authority during operations.

Radio Frequency (RF)

A signal composed of radio waves that vary in frequency or are set to a specific frequency, measured in Hertz (HZ).

Remote Pilot in Command (RPIC)

An RPIC is the sole person responsible for the operation of a sUAS. The term derives from the manned aircraft version: Pilot in Command, or PIC.

Remote Pilot in Command Certificate

A certificate from the FAA required to act as RPIC under Part 107 flight operations.

Reserve Fuel

A quantity of fuel remaining in excess of that used for routine flight missions. Typically used at a point in time when the aircraft must end its mission and return home.

Security Manager

Individual responsible for all security matters in the lab.

Small Unmanned Aircraft Systems (sUAS)

Commonly used phrase used by the UAS industry to abbreviate small Unmanned Aircraft Systems. This classification is limited to aircraft in which the maximum operating gross weight is under 55 pounds.

Sterile Environment

An area designated around the GCS designed to limit any unnecessary distraction to the MEC.

Unmanned Aircraft (UA)
The aircraft component of a UAS.

Unmanned Aircraft Flight Instructor (FI)

A flight instructor that is qualified and internally certified to instruct in the function, operation, and flight characteristics of an unmanned aircraft.

Unmanned Aircraft Systems (UAS)
The entire system - the aircraft and payload, the GCS, link architecture, hardware, ground support crew and aircrew.

Unscheduled Maintenance
Unplanned maintenance, such as the repair of damage to the UA other than routine maintenance.

Visual Flight Rules (VFR)
VFR are a set of regulations under which a pilot operates an aircraft in weather conditions generally clear enough to allow the pilot to see where the aircraft is going. Specifically, the weather must be better than basic VFR weather minima. The pilot must be able to operate the aircraft with visual reference to the ground, and by visually avoiding obstructions and other aircraft.

Visual Observer (VO)
A qualified ground crewmember whose job is to watch the aircraft and the local airspace surrounding the UA. While acting as an observer this person cannot have another job during mission. The use of a VO satisfies visual flight rule requirements.

Appendix B **Acronyms**

ACFT – Aircraft

ACM – Air Crew Member

ACM-TP- Air Crew Member – Training Program

ADM - Aeronautical Decision Making

AGL - Above Ground Level

AIM - Aeronautical Information Manual

AMA – American Modelers Association

AOC – Advanced Operator Course

APART – Annual Proficiency and Readiness Test

ATC - Air Traffic Control

ATO – Air Traffic Organization

ATP – Aircrew Training Program

ATS – Air Traffic Service

AWOS - Automated Weather Observing System

AV – Air Vehicle

AVO – Additional Visual Observer

BVLOS – Beyond Visual Line of Sight

BOC – Basic Operator Course

C2 – Command and Control

CFR - Code of Federal Regulations

CG - Center of Gravity

COA – Certificate of Waiver or Authorization

CRM - Crew Resource Management

CTAF - Common Traffic Advisory Frequency

DME - Distance Measuring Equipment

EOC-IC - Emergency Operations Center – Incident Command

ETA - Estimated Time of Arrival

ETE - Estimated Time En route

FAA - Federal Aviation Administration

FBO - Fixed Base Operator

FCC – Federal Communication Commission

FSDO - Flight Standards District Office

GCS – Ground Control Station

GPS - Global Positioning Satellite

HAT - Height Above Take Off

ICAO - International Civil Aviation Organization

IATF – Individual Aircrew Training Folder

IFR – Instrument Flight Rules

IO – Instructor Operator

IOC – Instructor Operator Course

LAANC – Low Altitude Authorization and Notification Capabilities

LOA – Letter of Agreement

LOS – Line of Sight

METAR – Meteorological Terminal Aviation Routine Weather Report

MRA – Mission Risk Assessment

MO – Maintenance Operator

MOA - Military Operations Area

MSL - Mean Sea Level

NAS - National Airspace System

NM – Nautical Mile

NOTAM - Notice to Airmen

NTSB - National Transportation Safety Board

OEM- Original Equipment Manufacturer

OWO – Operational Work Order

PFE – Proficiency Flight Evaluation

PIC – Pilot in Command

PIREP - Pilot Weather Report

PO – Payload Operator

POC – Point of Contact

R&D – Research and Development

RPIC – Remote Pilot in Command

RF – Radio Frequency

RM – Risk Management

RTB – Return to Base

SIO- Senior Instructor Operator

SM – Statute Mile

SMS – Safety Management System

SRPIC – Secondary Remote Pilot in Command

TAF - Terminal Area Forecast

TAS – Traffic Advisory System

TAS – True Air Speed

TCAS – Traffic Alert and Collision Avoidance System

TOC – Table of Contents

UAS - Unmanned Aircraft Systems

UAS-MO – UAS Maintenance Operator

UAS-SO – UAS Safety Operator

USC – United States Code

UTC - Coordinated Universal Time (ZULU Time)

VFR - Visual Flight Rules

VMC – Visual Meteorological Conditions

VO – Visual Observer

VTOL - Vertical Take-off and landing

WX – Weather

Appendix C **NDOT Site Survey**

The State of Nebraska Department of Transportation	SITE SURVEY				
Location:	*Additional Details as needed in Appendix A: Maps & Illistrations*	**Completed By:**		**Date:**	

Section 1) Airspace

Item No.	Question:	Response
1	Is this operation being cunducted in other than class "G" airspace?	
2	Will operation at this site require an additional Certificate of Authorization COA?	
3	Will operations be conducted in restricted airspace?	
4	Is there an airport within 5NM of the flight area?, if yes:	
4.1	- Does it have an operational control tower within 5 NM?	
4.2	- Does it have an instrument approach within 3 NM?	
4.3	- Does it have a non-towered, no instrument approach, heliport within 2 NM?	
4.4	- If yes to any of the above, is there a signed letter of agreement with airport management?	
5	Are there any special use airspace areas near/within the operation area?	
6	Is the area in a DJI Geozone delineated area?	
7	Provide details including airport name, code, ATIS and CTAF frequencies, manager, and phone number for the nearest airport(s) regardless of distance to flight area.	REQUIRED
8	Are there any Temporary Flight Restrictions (TFRs) for the flight area?	
9	Are any active Notice to Airmen (NOTAMs) active in the flight area?	

Section 2) Terrain

Item No.	Question:	Response
1	Is there any terrain higher then the operating altitude?	
2	Are there any water or marsh hazards in the operating area?	
3	Are there any sand or dust hazards in the operating area?	
4	Are there any known environmental anomalies in this operating area?	
5	Are there any trees, heavy vegetation, or forest hazards in this operating area?	

Continue on Page 2

SITE SURVEY PAGE 2		
Section 3) Structures		
Item No.	**Question:**	**Response**
1	Are there any buildings higher than the operating altitude?	
2	Are there any towers higher than the operating altitude?	
3	Are there any bridges higher than the operating altitude?	
4	Are there any statues higher than the operating altitude?	
5	Are there any other natural / man-made structures higher than the operating altitude?	
Section 4) Populated Areas		
Item No.	**Question:**	**Response**
1	Are there populated areas within 5 NM?	
2	Are there sanctuaries near/within the operating area?	
3	Are there protected areas/land marks near/within the operating area?	
4	Are there fair grounds/large event areas near/within the operating area?	
Section 5) Other Survey Interests		
Item No.	**Question:**	**Response**
1	Are there any frequency issues?	
2	Will operation require communications with external source? e.g. tower, range control, etc.	
3	Have safe launch and recoverey sites (LRS's) been identified?	
4	Has ROW been evaluated in order to perform the mission per NDOT policy? If yes, provide details of right-of-way analysis in Comments.	REQUIRED
5	Have safe weather conditions been determined?	
6	Are there any other Hazards not covered above that should be identified?	
Continue on Page 3		

SITE SURVEY PAGE 3	
Comments Section: *For each question above that was answered with "YES" or "REQUIRED" an accurate Explanation will be required. Provide additional detail as needed in the Maps and Illistrations Section. (reference section and item number in left column)*	
Reference Item No.	**Answer/Explanation:**

Site Survey Approval Section:		
This Survey has been approved for use during NDOT operations in the identified area.		
Name:	Position:	Signature:

Site Survey Amendment Recommendation Section:	
Operation Teams will submit any changes and/or additions to the site survey in this section.	
Reference Item No.	**Change/Addition detail:**

Name:	Date:	Signature:

1- Airport and Airspace map:	
2- DJI Geozone map:	

3- Area of operation, ROW.	
4- Weather outlook as of: TBD	

5- Propeller Corrections Network Coverage:	

Appendix D **NDOT Mission Risk Assesement**

UAS MISSION RISK ASSESSMENT

The State of Nebraska
Department of Transportation

Mission Type:		**Date:**		**Time:**	
Mission Location:		**Assessment Completed By:**			

Part One: Weather

Risk Level	0	(+1)	(+2)	(+3) *Requires UAS PM Approval*
Winds	< 10 mph	11-15 mph	16-20 mph	> 20 mph or 7 mph over OEM
Ceiling	> 1,000 ft.	999-800 ft.	799-600 ft.	< 600 ft.
Visibility	> 6 Miles	5-6 Miles	4-5 Miles	< 4 Miles
Precipitation	None	Light	Moderate	Heavy
Temperature	45-90 °F	20-45°F/91-104°F	10-20°F/104-119°F	<10°F/>119°F

Part Two: Operator

Identify if operator is RPIC

Risk Level	0	(+1)	(+2)	(+3) *Requires UAS PM Approval*
Unmanned Experience	> 100 Hrs.	100-50 Hrs.	10-50 Hrs.	< 10 Hrs
Mission Type Experience	> 10 Hrs.	5-10 Hrs.	1-5 Hrs.	< 1 Hr.
UAS Platform Experience	> 20 Hrs.	10-20 Hrs.	5-10 Hrs.	< 5 Hrs.
Mission Type Currency	< 30 Days	30-60 Days	60-180 Days	> 180 Days
UAS Platform Currency	30-60 Days	60-180 Days	250-180 Days	> 250 days
Uninterupted Rest (last 24)	> 12 Hrs.	8-12 Hrs.	4-8 Hrs.	< 4 Hrs.

Part Three: Visual Observer

Identify if Visual Observer is RPIC

Risk Level	0	(+1)	(+2)	(+3) *Requires UAS PM Approval*
Total Experience	> 25 Hrs.	10-25 Hrs.	10-5 Hrs.	< 5 Hrs.
Mission Type Experience	> 10 Hrs.	5-10 Hrs.	1-5 Hrs.	< 1 Hr.
VO Currency	< 30 Days	30-60 Days	60-180 Days	> 180 Days
Uninterupted Rest (last 24)	> 12 Hrs.	8-12 Hrs.	4-8 Hrs.	< 4 Hrs.

Part Four: Mission Factors

Risk Level	0	(+1)	(+2)	(+3) *Requires UAS PM Approval*
Mission Terrain	Flat	Low Hills	High Hills	Mountains
Obstacle Altitude Risk	0-100 ft.	100-200 ft.	200-300 ft.	> 300 ft.
Structure Density	Rural	Suburb	Inner City	N/A
Non-Mission Personnel Proximity	> 500 ft.	250-500 ft.	50-250 ft.	0-50 ft.
Obstacles Other Then Object Being Inspected	> 500 ft.	100-400 ft.	50-100 ft.	0-50 ft.
Planning Time Allowed	15-30 Days	7-15 Days	1-7 Days	N/A

Flights being conducted: In-Doors/With No GPS/With No AV Video

CONTINUE ON BACK PAGE

UAS MISSION RISK ASSESSMENT BACK PAGE

Risk Assessment Calculations

Risk Assessment Base Line		
LOW RISK (RPIC)	MODERATE RISK (RPIC)	HIGH RISK (UAS PM)
≤16	17-30	31-56

Part 1: Weather	
Part 2: Operator	
Part 3: Observer	
Part 4: Mission Factors	
Total Risk Assessment Value	

Assessment Summery and Signature Authority

Once the mission's risk assessment has been calculated, ensure the appropriate approving authority is contacted. The RPIC will be responsible for ensuring this risk assessement is completed and signed.

Required Mission Approval Authority

RPIC ☐ RPIC ☐ PM ☐ Name: ________ Signature: ________

When UAS PM Appoval is required, a verbal notification will be recorded by the RPIC. Print the name of the Approving Authority above, then complete the RPIC section below:

Phone ☐ Text ☐ Email ☐

RPIC

Name: ________ Signature: ________ Date: ________

Appendix E **NDOT Sample System Log**

NEBRASKA DEPARTMENT OF TRANSPORTATION	UAS System Flight Log DJI Phantom 4 RTK (NDOT-UAS-P4RTK-1)			
Aircraft FAA ID	**Total Flights**	**Total Hours**	**Date in Service**	**Ownership**
Enter ID Here	**216**	**57.0**	**5-Sep-19**	**Address Here**

Mission Details	
Date:	Location (Lat/Long):
Mission Type:	Weather:
Controlling Agency:	COA:
Remarks:	

Flight Details

RPIC:	Flight #:	Take-Off Time:	Flight Time (hr):
VO(s):	Batt(s) Used:	ircraft Discrepancy Encountered?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
		SOP Deviation?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
Additional MEC (AVO, EP, FI, PO, CC):		Travel Lane Standoff Deviation?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
		Avoidance Proceedures Taken?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
Remarks:			Post Flight Airworthiness:
RPIC:	Flight #:	Take-Off Time:	Flight Time (hr):
VO(s):	Batt(s) Used:	ircraft Discrepancy Encountered?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
		SOP Deviation?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
Additional MEC (AVO, EP, FI, PO, CC):		Travel Lane Standoff Deviation?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
		Avoidance Proceedures Taken?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
Remarks:			Post Flight Airworthiness:
RPIC:	Flight #:	Take-Off Time:	Flight Time (hr):
VO(s):	Batt(s) Used:	ircraft Discrepancy Encountered?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
		SOP Deviation?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
Additional MEC (AVO, EP, FI, PO, CC):		Travel Lane Standoff Deviation?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
		Avoidance Proceedures Taken?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
Remarks:			Post Flight Airworthiness:
RPIC:	Flight #:	Take-Off Time:	Flight Time (hr):
VO(s):	Batt(s) Used:	ircraft Discrepancy Encountered?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
		SOP Deviation?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
Additional MEC (AVO, EP, FI, PO, CC):		Travel Lane Standoff Deviation?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
		Avoidance Proceedures Taken?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
Remarks:			Post Flight Airworthiness:
RPIC:	Flight #:	Take-Off Time:	Flight Time (hr):
VO(s):	Batt(s) Used:	ircraft Discrepancy Encountered?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
		SOP Deviation?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
Additional MEC (AVO, EP, FI, PO, CC):		Travel Lane Standoff Deviation?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
		Avoidance Proceedures Taken?: ☐ Yes ☐ No (Detail in Remarks if "Yes")	
Remarks:			Post Flight Airworthiness:

Flight Time Conversions			
0.1 - 6 min	0.1 hr	31 - 36 min	0.6 hr
7 - 12 min	0.2 hr	37 - 42 min	0.7 hr
13 - 18 min	0.3 hr	43 - 48 min	0.8 hr
19 - 24 min	0.4 hr	49 - 54 min	0.9 hr
25 - 30 min	0.5 hr	55 - 60 min	1.0 hr

Appendix F NDOT Mishap/Accident Report

If a mishap occurs it must be reported quickly and accurately. In addition, information and data must be collected to better understand what caused the mishap and account for all equipment. The following general format includes all information that should be collected and reported in the event that an UAS mishap:

1. Aircraft type __________________ Aircraft N # or serial # __________________

2. Date of mishap ________ (DD/MO/YR) Time_________(Local/Zulu)

4. Location of LRS and physical description: ____

5. Location of mishap (if different than LRS):____

6.Type of flight (commercial/training/maintenance/other)_________________________________

7.Customer name ____________________________ Mission type_________________________

8. General data:

REMOTE PIC: ____

MO:____

Observer:__________ ______________________________

Launch Time:______________________________________

Mishap Time:______________________________________

Temperature:_____ Wind Speed:____ Wind Direction:_____ Precipitation:____ Clouds:______

(Other):____

9. Circumstances:

a. Mishap occurred during: Launch ____ Landing ____ Flight ____ Other (state) ___________

b. Mishap caused injury: Yes ____ No ____ List name and extent of injury in comment section

c. Private property damage: Yes ____ No ____ describe in comment section

d. Public property damage: Yes ____ No ____ describe in comment section

e. Mishap caused damage to system: Yes ____ No ____ describe in comment section

e. Flight mode at time of mishap: ____________________

f. Commanded altitude or throttle setting:_______________

g. Aircraft altitude above ground: ____________Feet

h. Air Vehicle heading: _______ Degrees magnetic

i. Was there a loss of: Link_____GPS ______Video_______________

j. Was the video and metadata recorded: Yes ____ No ____ explain in comment section

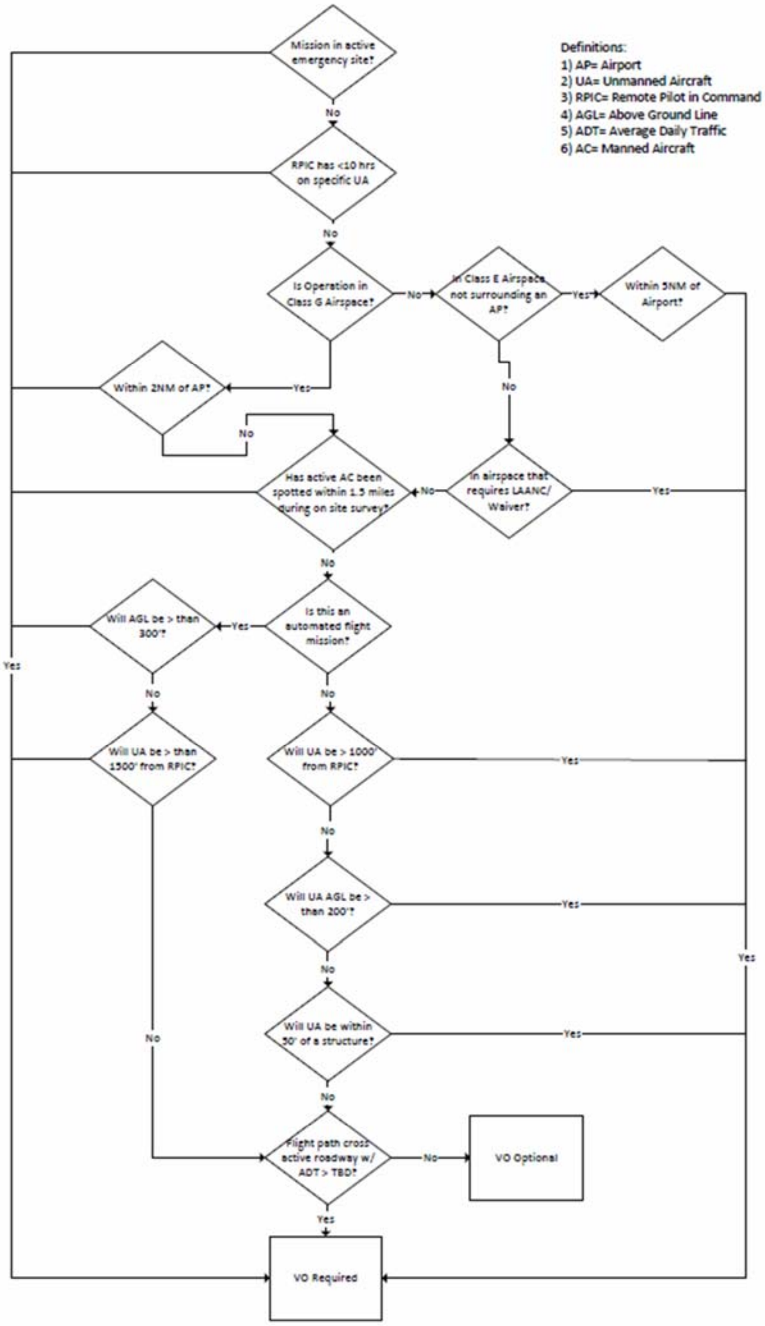
k. Were civil authorities notified: Yes ____ No ____ If yes explain in comment section

l. Has the customer been notified (who when):____________________________

10. Comments (Summary of mishap, damages, injuries, actions take (during mishap & after mishap)) :Use additional sheets as necessary.

____
____
____

Appendix G **NDOT Visual Observer Decision Tree**



VO Requirements Flow Chart

NOTES:

1. This flow chart is to help the RPIC determine if a VO is required for his/her operation. However, even if this chart determines the RPIC does not need a VO, he/she should always elect to have one if they feel it is in the best interest of safety

2. This flow chart does not supersede an FAA waiver provision. If the operation is conducted under a waiver that contains a VO provision, this document flow chart should not be utilized.

Appendix H **NDOT UAS Flight Plan**

NDOT-UAS Flight Plan

Year-Month-Date_ Mission Descriptor:

Purpose:

(comments- provide a detailed purpose statement of why this mission is taking place)

Location:

(comments- provide a detailed location description of the intended flight area).

Project Contacts:

(comments- Add all project contact information as necessary. This may include central staff who requested, district staff who need to be aware or onsite during activity, and any other external agency/entities as needed)

Name	Role	Phone #	Email Address	Comments

Objectives:

(comments- Provide a detailed list of the mission's objectives. The purpose statement is likely a higher level, the objectives are the conditions that the UAS team will meet in order to satisfy the mission. These will also be linked directly to the plan below in order to ensure the objectives are met)

ADD OBJECTIVE HERE

1. Objective #1:

Plan:

(comments- Detailed plan, including the platform that will be used to meet each objective above. This will also include the detailed specifications on GSD, flight planning application, Ground control methods, etc. This should be more technical and completed by the UAS Manager, Operation lead and/or pilots having input and understanding)

ADD PLAN HERE

1.

Personnel:

(comments- Provide names of all MEC, detailing each individual's role in the mission)

Deployment Plan:

(comments- Detailed plan for the actual deployment, including meeting time/leave time from central office, travel time, arrival time, planned operation time, etc.)

ADD DEPLOYMENT PLAN HERE

1.

Equipment Checklist:
(comments- modify and/or add to the checklist of all items, UAS and other, that need to be part of this mission)

- ☐ UAS Operations Binder
- ☐ Part 107 Certificate
- ☐ Mavic 2 Pro System & Binder
  - ☐ iPad Mount (MavMount)
- ☐ Phantom 4 RTK System & Binder
  - ☐ Base Station Tripod
- ☐ Matrice 210 RTK System & Binder
  - ☐ Base Station
  - ☐ Base Station Tripod
  - ☐ Z30 Payload
  - ☐ X7 Payload
  - ☐ XT2 Payload
- ☐ 2 Sets (10) AeroPoints
- ☐ Ground Target Paint Template
- ☐ Landing Pad (s)
- ☐ Traffic Cones
- ☐ Clipboard w/ Checklists
  - ☐ Flight Plan
  - ☐ Site Survey
  - ☐ Risk Assessment
  - ☐ Pre-Flight (included in platform binder)
  - ☐ Email with "approval" to fly in this area
- ☐ Appropriate PPE
  - ☐ NDOT hardhats/ballcaps
  - ☐ High visibility vests
  - ☐ Medical masks
  - ☐ Hand sanitizer
- ☐ iPad & Charger
- ☐ Two-way Radios & Chargers
- ☐ Aviation Radio & Charger
- ☐ Wind Meter
- ☐ External Hard Drive
- ☐ Laptop
- ☐ Tool Bag
- ☐ Table
- ☐ Chair

Appendix I NDOT Sample Pre-Flight Checklist for Mavic 2 Pro

**Pre-flight Checklist (Mavic 2 Pro)

Tuesday, July 30, 2019 3:13 PM

Aircraft

☐ 1. Unfold arms and check for solid seating.
☐ 2. Check body and arms of aircraft for damage.
☐ 3. Check that motors spin freely by hand and smell for burned components.
☐ 4. Install or verify SD card is in place.
☐ 5. Check battery condition.
   a. If bulged, dented or deemed unsafe, discard and replace.
☐ 6. Check power level on battery.
   a. Define threshold to replace before mission can go.
☐ 7. Remove gimbal cover.
☐ 8. Check gimbal and camera for damage, ensuring gimbal moves freely by hand.
☐ 9. Check propellers and install.
   a. If nicked, cracked, missing tangs or deemed unsafe, discard and replace.
☐ 10. Place aircraft (nose out orientation) on approved landing pad.
   a. Landing pad should be placed on level ground, clear of surrounding/overhead obstacles.
☐ 11. DO NOT power on aircraft until RC checks are complete.

Remote Control

☐ 1. Check battery level of remote control.
   a. Define what adequate is for mission?
☐ 2. Check battery level of mobile device (if applicable).
☐ 3. Power on remote controller and mobile device (if applicable).
☐ 4. Exit/log out of any flight controller apps not being used for mission to avoid conflicts.
☐ 5. Open DJIGo4 app on mobile device (if applicable).
   a. Login to your account and/or verify that it is your account.
☐ 6. Validate remote controller is connected to device.
☐ 7. Open antennae on remote and set appropriate position.
☐ 8. Check that controller is set to p-mode.

Aircraft Configuration (Using the DJIGo4 App)

☐ 1. Power on the aircraft.
☐ 2. Validate remote and DJIGo4 app are connected to aircraft.
   a. If not connected, perform manual link procedure.
☐ 3. Review DJIGo4 checklist for any errors/warnings.
☐ 4. Compass Calibration (if necessary):
   a. If necessary due warnings perform calibration.
   b. If you are 250 miles east/west from last flight perform calibration.
   c. If not true to above, DO NOT calibrate (best practice from RMUS training).
   d. DO NOT calibrate compass indoors when doing maintenance, not necessary.
   e. DO NOT calibrate compass near large metallic and/or magnetic objects.
☐ 5. IMU Calibration:
   a. If necessary, follow on-screen prompts to complete.
☐ 6. Set return to home elevation to appropriate level.
☐ 7. Set return to home location.
☐ 8. Set maximum flight altitude to appropriate level.
☐ 9. Set maximum flight distance to appropriate level
   a. See Pre-mission Initiation for OEM C2 signal distance.

☐10. Ensure stick mode is set to Mode 2.
☐11. Ensure a minimum of 8 satellites are connected.
☐12. Set low battery warning at 30%.
    a. Keep mission in mind, if this isn't enough to return home adjust accordingly.
☐13. Set critical battery warning at 15% (recommendation from RMUS; although udot sets at 20%).
☐14. Ensure desired data storage is selected and formatted (internal or SD card).
☐15. If using a flight controller app other than DJIGo4:
    a. Close the DJIGo4 app and open desired flight controller app.
    b. Validate flight controller app is connected to aircraft.
    c. Sync accounts (if applicable). Example: Sync DJIGo4 account to Kittyhawk.

Pre-Mission Initiation

☐1. Communications Check
    a. Ensure primary and secondary forms of communication are on and functioning properly.
☐2. Reconfirm safe weather conditions and flight area.
    a. Maximum wind speed of 18-23 mph.
    b. Operating Temperature Ranges:
        i. Aircraft: 14˚F - 104˚F
        ii. Remote: 32˚F - 104˚F
        iii. CrystalSky: -4˚F - 104˚F
    c. Battery Charging Temperature Ranges:
        i. M2P Battery: 41˚F - 104˚F
        ii. WB37 Battery: 59˚F - 104˚F
☐3. OEM C2 Signal Distance (FCC):
    a. Maximum: 10000 m / 32808 ft / 6.2 mi
    b. 80% (no obstructions): 8000 m / 26246 ft / 4.9 mi
    c. 50% (obstructions): 5000 m / 16404 ft / 3.1 mi
☐4. Ensure UA maintains proper distance from the edge of travel lane and roadway crossing height.
    a. Roadway ≥45 mph: 25' standoff distance
    b. Roadway <45 mph: 10' standoff distance
    c. Cross over Roadway only if:
        i. UA is ≥50' AGL
        ii. No oncoming vehicle closer than 200 yards
☐5. Ensure spectator safety
    a. No more than 10 spectators unless crewmember (other than RPIC, ER, AVO or VO) is designated as a spectator monitor to ensure a sterile cockpit.
☐6. Have a brief discussion with all crewmembers to reconfirm mission objectives and flightpath.
☐7. Take off and perform basic controls check at an approximate altitude of 10'.

Appendix J **NDOT UAS Discrepancy Form**

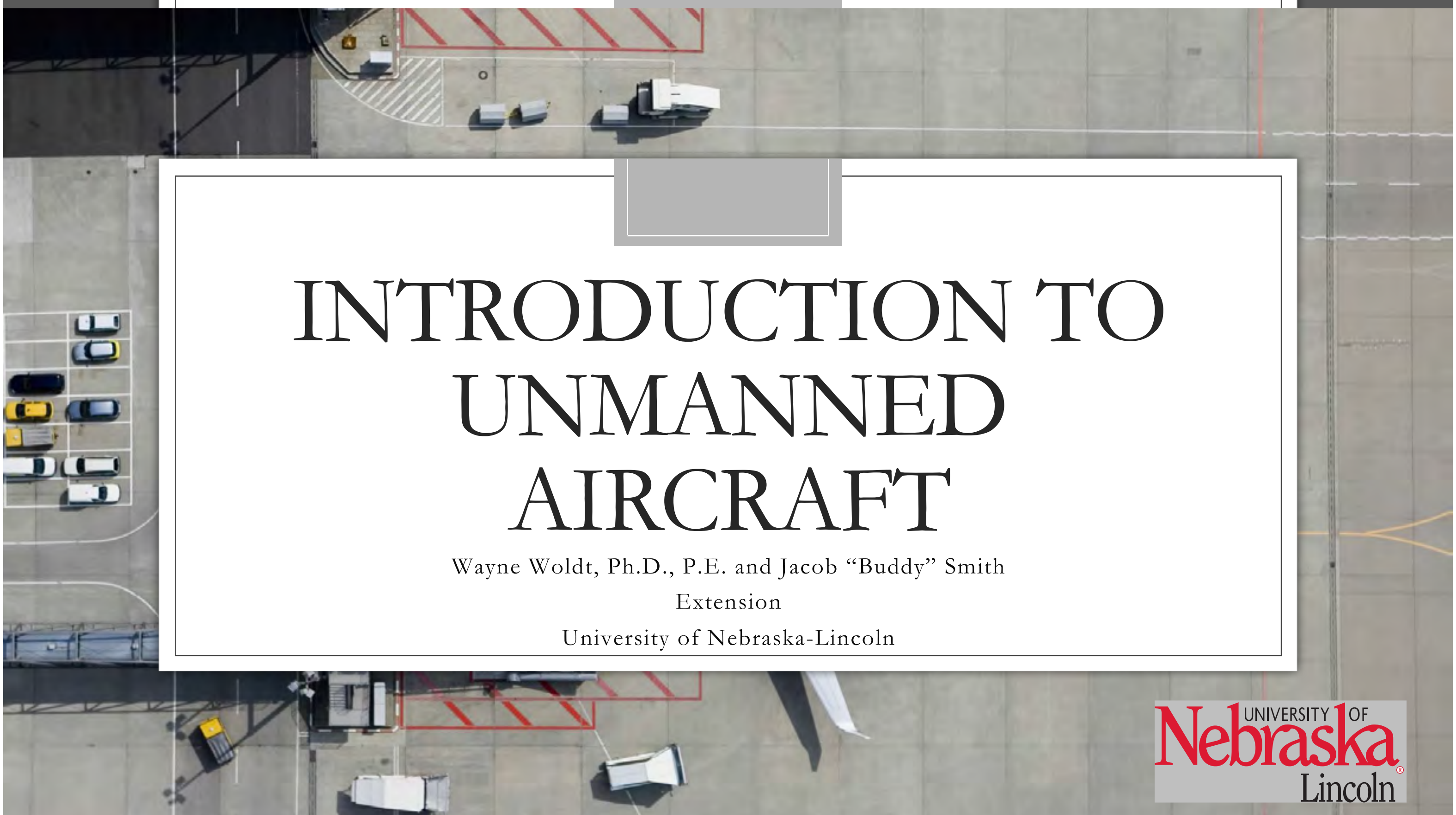
Add header

NEBRASKA
DEPARTMENT OF TRANSPORTATION

UAS Discrepancy Reporting Form

Aircraft Details	
NDOT ID:	Total Flights:
FAA ID:	Total Hours:
Flight Details	
Date:	Location (Lat/Long):
Time:	Mission Type:
RPIC:	VO(s):
Additional MEC (AVO, EP, FI, PO, CC):	
Discrepancy Details	
Description:	
Field Repair Required?	
Shop Repair Required?	
Airworthiness:	

August 2019



INTRODUCTION TO UNMANNED AIRCRAFT

Wayne Woldt, Ph.D., P.E. and Jacob “Buddy” Smith
Extension
University of Nebraska-Lincoln

Part of Unmanned Aircraft Systems Training for Nebraska Department of Transportation

Commercial UAS Pilot Training Curriculum

Day 1

45 min.	Introduction and Course Overview (Wayne & Buddy – Lesson 1)
120 min.	UAS Rating Privileges and Limitations (Buddy – Lesson 2)
15 min.	Break
90 min.	UAS Flight Operations (Buddy – Lesson 2)
60 min.	Lunch on your own
120 min.	Airspace Classification (Wayne – Lesson 3)
15 min.	Break
60 min.	Airspace Classification (part 2) (Wayne – Lesson 3)
Self-Study	

Day 2

90 min.	Aviation Weather (Buddy – Lesson 6)
15 min.	Break
90 min.	Aviation Weather Sources (Buddy – Lesson 6)
60 min.	Lunch on your own
60 min.	sUAS Loading and Determining Performance (Wayne – Lesson 7)
15 min.	Break
60 min.	sUAS Loading and Determining Performance (part 2) (Wayne – Lesson 7)
120 min.	Emergencies and Emergency Procedures (Buddy – Lesson 8)
Self-Study	

Day 3

60 min.	Radio communication procedures (Wayne – Lesson 5)
60 min.	CRM & ADM (Buddy – Lesson 9)
15 min.	Break
60 min.	CRM & ADM (part 2) (Buddy – Lesson 9)
60 min.	Lunch on your own
60 min.	Physiological Effects of Drugs, Alcohol and Hypoxia Break (Buddy – Lesson 9)
90 min.	Airport Operations (Buddy – Lesson 4)
60 min.	Maintenance and Preflight Inspection (Buddy – Lesson 10)
Self-Study	

Take Exam.

INTRODUCTION TO UNMANNED AIRCRAFT

Wayne Woldt, Ph.D., P.E. and Jacob "Buddy" Smith
Extension
University of Nebraska-Lincoln

University of Nebraska Lincoln

Getting Started

- **Goal of this training program**
  - Pass the 107 knowledge exam and bring you to "proficient remote pilot" status
  - Inform continued development of NDOT UAS policy
- **Introductions**
  - Self introduction and what you are hoping to accomplish with UAS
- **Outline of training program**
  - Preparation for knowledge exam (2 days)
  - Basic Multi-rotor (0.5 day)
  - Take Part 107 exam to earn your remote pilot certificate (0.5 day)
  - Advance Multi-rotor (2 days)
  - Aerial Mapping (flight 0.75 day) (data processing 0.75 day)
  - Simulated deployment (2 days)
  - On site transition training (24 deployments)
- **Begin Lesson 1**

Lesson 1: Language of Drones

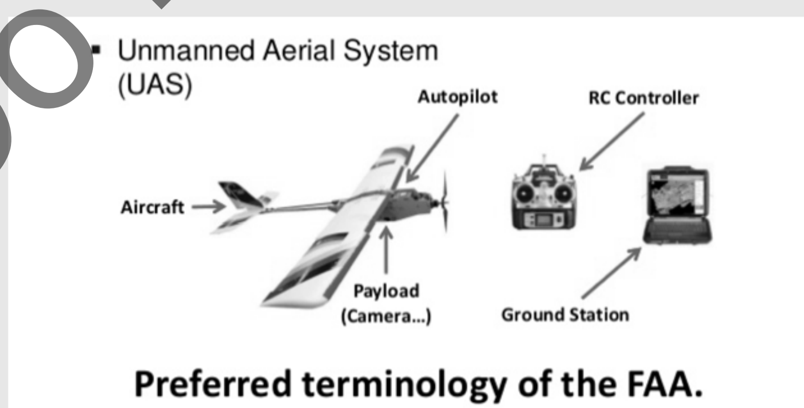
- Goal of Part 107 training
  - Pass the FAA Part 107 Knowledge Exam!
  - FAA is Federal Aviation Administration
  - Flight Standards District Office (FSDO) for Nebraska is in Lincoln
- Terms and Abbreviations
- Types of UAS
- UAS Components
- Common Uses

Terms and abbreviations

- Alphabet soup!
- Let's look at pages 1-2 through 1-4 of the book

Types of UAS

Components of UAS



Common uses

- Real estate
- Farmers
- Search and rescue
- Game wardens
- Scientists
- Inspection of assets
- Security and law enforcement
- News coverage
- Film makers
- Departments of Transportation

UNMANNED AIRCRAFT REGULATIONS

Jacob "Buddy" Smith, CFI
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Summary of Topics

- Airman Information Manual
- Federal Aviation Regulations
- Waivers
- State, County, Local Aviation Regulations and Legislation
- Privacy
- Advisory Circulars
- NOTAMS

Airman Information Manual

- Pilot and Air Traffic Controller "Bible"
- Updates every 2 years
- Online: FAA.Gov
- Printed and sold

Federal Aviation Regulations (FAR's)

- Title 14 CFR
  - 101.41 Model Aircraft
  - 107 Commercial sUAS
    - General
    - Operating Rules
    - Certification

Model Aircraft (14 CFR 101.41)

- Hobby or Recreational Use
- Community-Based Safety Guidelines (AMA)
- 55 lbs or less
- No interference with manned aircraft
- Airport 5-mile rule

Part 107 (14 CFR 107…..) Definitions

- Control Station
- Small unmanned aircraft-55 lbs
- Small unmanned aircraft system
- Unmanned aircraft
- Visual Observer

Inspection, Testing, and Compliance

- Pilot Certificate
- Relevant records
- Test or Inspect

Accident Reporting

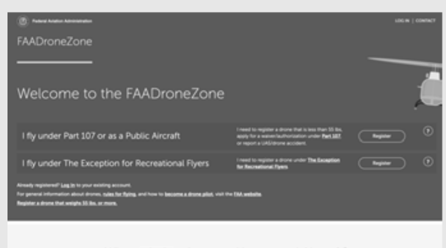
- PIC-10 Calendar Days
  - Serious injury or knocked unconscious
  - Property damage in excess of $500
    - Does not include value of the damaged sUAS or payload
  - NTSB-Notify immediately, report within 10 days
    - Serious injury or death
    - Gross takeoff weight = or > 300 lbs

Manipulate controls of sUAS:

- Remote Pilot Certificate with a small UAS Rating
- Under the supervision of a certificated remote pilot with the ability to immediately take over control

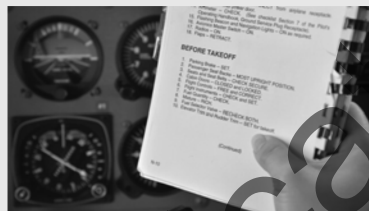
Registration

- Regardless of purpose (commercial or hobby)
- Over .55 lbs.



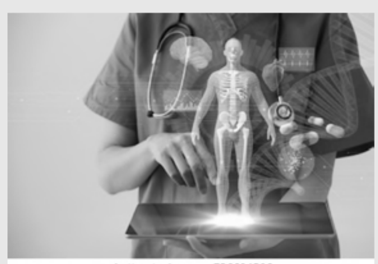
Condition for Safe Flight

- PIC must check/inspect to insure it is safe to fly before every flight
- Checklist



Medical Self Certification

- Cannot have (or reason to believe they have) a physical or mental condition that would interfere with the safe operation of the sUAS
  - PIC
  - Manipulator of the controls
  - Visual observer
  - Direct participant



Remote PIC Responsibilities

- Does not pose any hazard to people, aircraft, or property if control is lost
- Operation complies with all applicable regulations
- Must have the ability to control or direct (control) to ensure compliance with the regulations

In-flight Emergency

- During an emergency, the remote PIC can deviate from any rule as needed to deal with the emergency
  - Upon request, must send a report to the administrator of the FAA

Hazardous Operation

- No person may operate a sUAS carelessly or recklessly that could endanger people or property
- Objects can't be dropped in a way that endangers people or property

Operation from a moving vehicle or aircraft

- Never from a moving aircraft
- Not from a moving land or water vehicle unless:
  - In a sparsely populated area
  - The aircraft is not transporting property for compensation or hire

Drugs and Alcohol

- Cannot act as PIC, Manipulator of the Controls, or Visual Observer if:
  - Alcohol consumed within 8 hours
  - Under the influence of alcohol
  - Using drugs that may impair the safe use of the aircraft
  - Have blood or breath alcohol concentration of .04
    - Implies law enforcement can request a sobriety test and breathalyzer/blood test

Daylight Operation

- Cannot fly at night without a waiver
- Can fly during civil twilight (30 minutes prior to official sunrise, 30 minutes after official sunset)
  - sUAS must be fitted with anti-collision lights visible to at least 3 statute miles

Operational Distance Limitations

- Visual Line Of Sight (VLOS)
- Remote Pilot In Command, person manipulating the controls, or visual observer must be able to:
  - Determine the location of the sUAS
  - Determine its attitude, altitude and direction of flight
  - Ensure it is not endangering persons or property
  - Monitor the airspace for other traffic or hazards
- This situational awareness must be maintained through line-of-sight vision unaided by any device other than corrective lenses

Multiple sUAS

- No person can be remote PIC or visual observer for more than one sUAS at a time

Carriage of Hazardous Materials

- sUAS are prohibited from transporting hazardous materials
- Lithium batteries used to power the sUAS or subsystems are exempt

Right-of-Way Rules

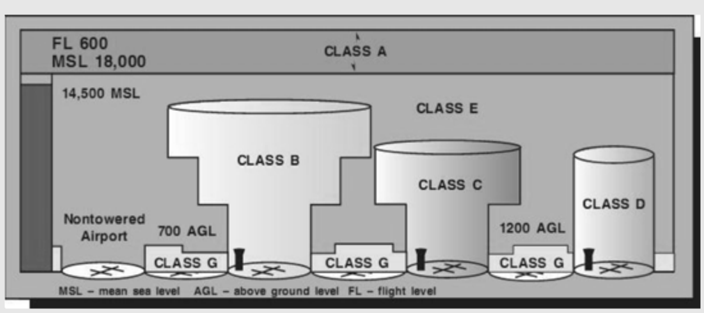
- sUAS must give way to any and all other aircraft
- May never operate a sUAS so close to another aircraft that it creates a potential for collision
- Must give way to other sUAS's

Operation Over Human Beings

- sUAS are not permitted to be flown over human beings unless:
  - Directly participating in the operation (Visual Observer)
  - Under a covered structure
  - In a stationary vehicle which would protect from a falling sUAS

FAA Airspace Restrictions

- Operations in Class B, C, D and surface-based ClassE airspace are allowed with the required ATC permission
- Normally restricted to Class G airspace



Other Airspace Restrictions

- Near Airports, Heliports, Seaplane Bases and their Traffic Patterns
- In Prohibited and Restricted Areas without permission of the owner of the airspace
- NOTAM'ed Airspace
- TFR's (Temporary Flight Restrictions)

FAA Airspace Restrictions

Remote PIC Preflight Responsibilities

- Evaluate the surface and air operating environments to include assessment for potential risks to persons and property
- Check local weather conditions
- Determine airspace restrictions and acquire waivers and permissions as required
- Research applicable NOTAMs
- Assess location of persons or property on the surface
- Determine and plan for any ground hazards
- Brief all participating crew members on operating conditions, emergency and contingency procedures, roles and responsibilities, and hazards
- Test and ensure all control links between the ground control station and the sUAS are working properly
- Ensure enough power is on the aircraft for the intended length of the operation
- Be satisfied any attached objects will not negatively affect flight characteristics or controllability of the aircraft and are securely connected to prevent falling inflight

Operating Limitations

- Maximum groundspeed of 100 mph (87 knots)
- Maximum altitude of 400 feet above ground level (AGL) or, if higher than 400 feet AGL, remain within 400 feet of a structure
- Minimum flight visibility of 3 statute miles
- Remain 500 feet below and 2000 feet horizontally clear of any clouds

Certification: Alcohol and Drug Offenses

- If convicted of any Federal or State drug dealing statute, or if convicted of violating regulations related to drugs and alcohol, or you refuse to submit to or provide results of an alcohol test requested by law enforcement or the FAA
  - Subject to denial of a Remote Pilot Certificate application
  - Subject to suspension or revocation

Remote pilot In Command Qualification/Certification

- Demonstrate aeronautical knowledge by either:
  - Passing an initial aeronautical knowledge test at an FAA-approved knowledge testing center
  - Hold a part 61 pilot certificate other than student pilot, complete a flight review within the previous 24 months, and complete a UAS online training course provided by the FAA
- Be vetted by the Transportation Security Administration
- Be at least 16 years old
- Be able to read, speak, and understand English
- Not know or have reason to know you have a physical or mental condition that would interfere with sUAS operations
- Apply online (IACRA) with your passing airman knowledge test report
- Temporary Certificate is valid for up to 120 days

Aeronautical Knowledge Testing

- Must complete recurrency training every 24 months in the form of an Aeronautical Knowledge Test
- Must submit proper identification which must include a photograph, your signature, date of birth, and permanent mailing address
- Minimum passing grade is 70%
- No cheating!!! If you do, you will be prohibited from applying or taking a test for one year, and be subject to suspension or revocation
- Retesting: Must wait 14 calendar days

Change of Name or Address

- Name Change:
  - Apply to FAA with your certificate and a copy of the legal authorizing document
- Change of Address:
  - Inform the FAA within 30 days using mail or designated website

Waivers

- Granted on a case-by-case basis
- Performance based standards are applied to determine if a waiver will be granted
- Promptly respond to requests for additional information or clarification-Exceed 30days and application will be closed

State, County, and Local Aviation Regulations and Legislation

- In general, only the FAA or other Federal Agency can tell you <u>where</u> to fly
- Other government bodies can enact laws or rules governing <u>what</u> you do with your sUAS
- The FAA has the authority to supercede any state or local rules, regulations, or ordinances
- The FAA does not regulate privacy in terms of sUAS use
- Be courteous and use good judgement

Chart Supplements

- Information on Sectional Charts is limited
- Chart Supplements provide detailed information on airports including
  - Noise abatement procedures
  - Frequencies
  - Telephone numbers
  - Obstructions
  - Services
  - Special local area procedures

Advisory Circulars

- FAR's are brief and concise and written in "legal language"
- Advisory Circulars explain a regulation or procedure in detail so that it can be understood by the flying public
- Numbered to correspond to the regulations
- Found on the FAA.Gov home page

Notices to Airmen (NOTAMS)

- Information that might affect the safety of a flight
  - Airport or runway closure
  - TFR
  - Communication frequency changes
- Available from Flight Service Station (FSS) briefer or online
- Most full-scale pilots get them through computer or tablet application (Electronic Flight Bags)
- Released every 28 days

UAS Flight Operations

- Concept of Operations
  - Pages 183 - 186
- Operational Planning
  - Pages 183 – 186
- Will circle back around to these – very important but not critical to exam

TEST AND REVIEW

AIRSPACE AND NAVIGATION

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Charts and Parts

- Aeronautical Charts
- Geographical Coordinates
- Time Reference
- Distance Measure
- Magnetic Variation
- Wind Drift
- Groundspeed vs. Airspeed
- Chart reading
- Airspace
- Special Use Airspace
- ADIZ
- Wildlife Refuge

Aeronautical Charts

- This is a very important lesson
- Probably one of the more important topics, long with regulations
- National Airspace System (NAS) is a complex, 3-D, web of different types of airspace.
- Very important to understand, in order to operate safely
- Aeronautical Charts are best source of information
- Also need to check Notices to Airmen

Aeronautical Charts

- Sectional is most frequently used "map of the sky"
- Let's take a look at the Omaha sectional (also - www.skyvector.com)
- Scale is 8 nautical miles per inch and published every 6 months
- Look for roads, freeways, power lines, railroads, lakes, contours, cities
- Different types of airports
- Boundaries of controlled airspace

Aeronautical Charts

◦ Chart supplement

◦ Issued every 56 days – higher frequency than sectionals

◦ Let's access and take a look at the North Central chart supplement

◦ https://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/dafd/

◦ Let's look at Crete,   Columbus,   Lincoln

◦ Although not an aeronautical chart, Google Earth is very important (be careful)

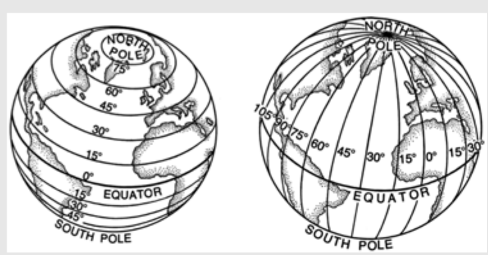
Geographical Coordinates

◦ Latitude and Longitude

◦ Lines of latitude

◦ Lines of longitude

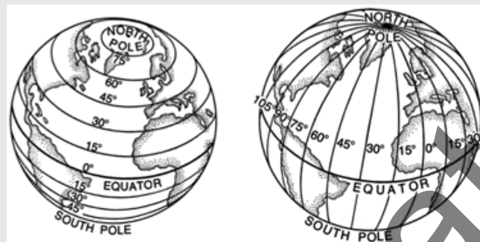
◦ Coordinates of Holland, NE?



Geographical Coordinates

- Latitude and Longitude
- Lines of latitude
- Lines of longitude
- Coordinates of Holland, NE?

  40 degrees 36 minutes north, 96 degrees 35 minutes west



Time Reference

- Definition of time in aviation references the prime meridian
- Referenced as Universal Time Coordinated (UTC), also as Zulu time (Z)
- Currently (Daylight time) computed as "local time" + 5 hours

  3:00 pm local is 8:00 pm Zulu
- Using military time from 0:00 to 24:00 Zulu

  3:00 pm local is 15:00, and 20:00 Zulu, or 20:00Z

Time Reference

Distance Measure

- Statute miles and nautical miles
- Nautical miles quite common in aviation
- Knots – commonly used for windspeed (nautical miles per hour)
  The surface windspeed is 23 knots, gusting to 28.
- However, visibility is reported in statute miles
  The current visibility is 5 miles.
- Conversion is 1.15 statute miles per nautical mile

Magnetic Variation

◦ Use of compass references are very common in aviation

◦ Magnetic north is not at same location as true north

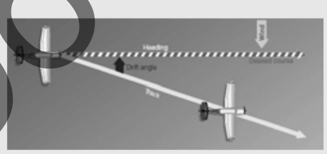
◦ Isogonic lines on a map convey the difference

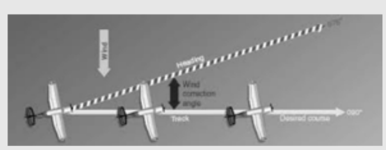
◦ Let's locate the isogonic lines on the Omaha sectional
    What year were they updated?

◦ When isogonic lines are "east" subtract from true to get magnetic
    If I am at Ainsworth airport and want to point my compass true north, what magnetic heading should I point the compass?

Wind Drift

◦ Typically important on longer ranger piloted missions





◦ Such as Beyond Visual Line of Sight. (Beyond VLOS)

◦ However, will have considerations in our missions

Groundspeed and Airspeed

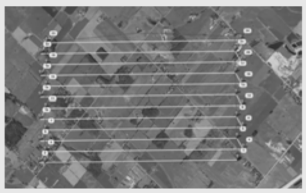
- Groundspeed is velocity across ground
- Airspeed is velocity in air mass
- Not necessarily the same, unless calm wind
- Remember, winds generally reported in knots
  with sUAS systems commonly using statute velocity (mph)
- Also, true airspeed increases 2% per 1000' MSL
  why does all this matter?

Groundspeed and Airspeed

- Does wind speed generally increase or decrease with increasing altitude?

Groundspeed and Airspeed

- Does wind speed generally increase or decrease with increasing altitude?
- Suppose surface wind out of north at 11 knots
- Winds aloft at 400 feet are from west (270) at 22 knots
- What is preferred direction to orient flight path?



or

- What is impact of gusting winds?

Chart reading

- What is the Maximum Elevation Figure (MEF) for Lincoln, NE area? Units?
- Most flight controllers provide altitude information relative to takeoff point
- Helpful to have elevation of land surface information in area of flight
- Radio and TV towers - Elevation above MSL (elevation above ground level)
  Careful for guy wires
- Watch for parachute jumping areas, wind turbines, cables across rivers, etc.

Chart reading

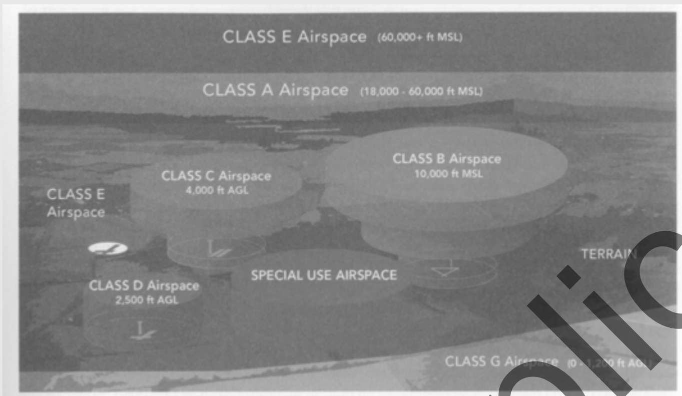
- Airport and Navigation Aid Identification
- Lincoln - LNK -- KLNK
- Central City – 07K – 07K (no K prefix)
- Lincoln VORTAC – LNK
- Columbus VOR – OLU

Airspace

- Controlled vs. Uncontrolled Airspace
- Controlled airspace is where aircraft of ALL types may be subject to air traffic control.
- Controlled airspace is referred to as Class A, B, C, D, or E
- In uncontrolled airspace, aircraft are not subject to air traffic control, but are required to follow all regulations.
- Uncontrolled airspace is referred to as Class G

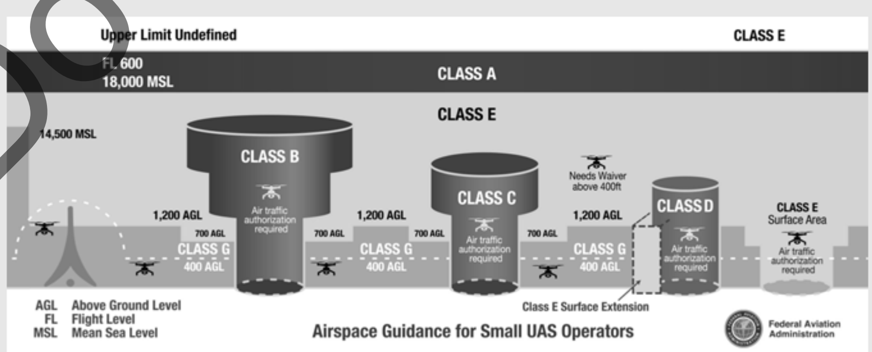
Airspace

- Airspace defined Class A, B, C, D, E or G



Airspace

- Airspace defined Class A, B, C, D, E or G



Airspace

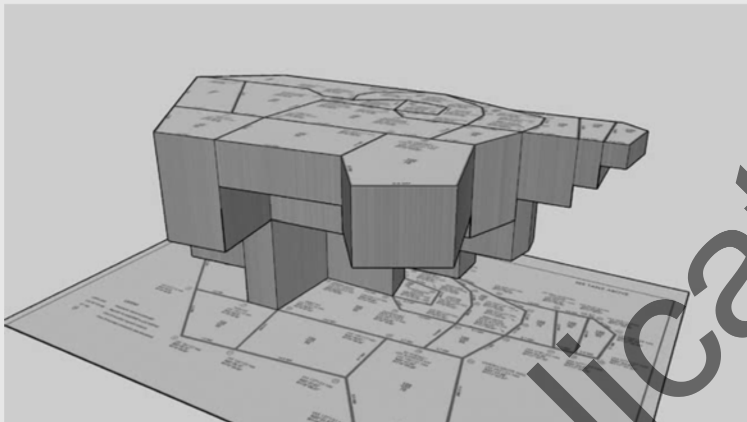
- Let's look at airspace when moving from KBIE to KCEK
  - Beatrice to Crete
- Let's look at airspace when moving from KOLU to KOFK
  - Columbus to Norfolk
- Let's look at airspace when moving from KBIE to KLNK
  - Beatrice to Lincoln

?? How about Class G to 14,500 ft MSL ??

Airspace

- Class A airspace
  - 18,000 MSL and above to FL600
  - Large piloted aircraft – IFR – large piloted aircraft
- Class B airspace
  - Think "B" for Big!
  - No class B on the Omaha sectional - so let's look at Appendix D
  - Complicated airspace – Solid heavy BLUE lines
  - Study and even work with local pilots to learn the airspace before flying
  - Some Class B airports don't allow student pilots (Page 3-8)
  - Mode "C" veil?

Airspace



Airspace

Airspace

- Class C airspace
  - Think “Circles”
  - Magenta circles
  - Inner core usually 5nm radius
  - Outer ring usually 10nm radius
  - Ceiling generally 4000’ AGL
  - Outer generally ring begins at 1500’ AGL
  - Need ATC permission to fly in Class C airspace
  - Many Class C areas do not operate 24 hours a day
    - Sectional conveys airspace change when tower closed
  - Let’s look at Lincoln (KLNK) airspace

Airspace

- Class D airspace
  - Airport with tower, but not Class B or Class C (Grand Island)
  - Boundary depicted as blue dashed line
  - Ceiling of core is generally at 2500’ AGL
  - Core generally has a radius of 5 statute miles (about 4.4nm)
  - If there are extensions in blue dash, then still Class D airspace
  - When control tower closed – airspace reverts to Class E to surface
  - Permission is required to operate sUAS in Class D airspace
  - Let’s look at Sioux City (KSUX) airport

Airspace

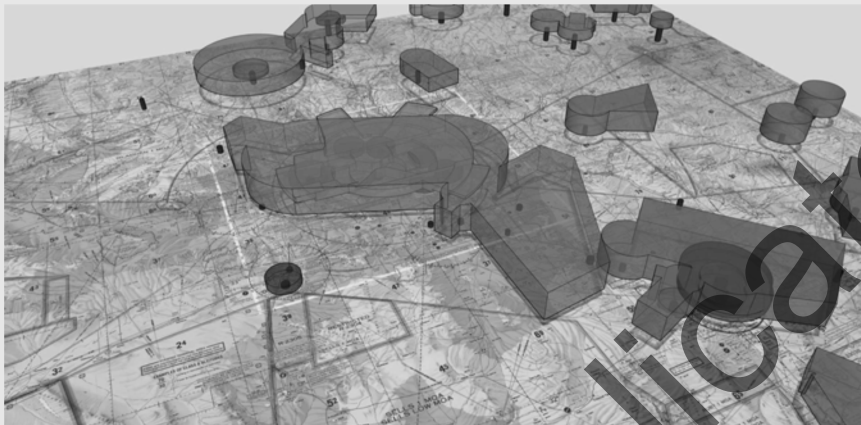
- Class E airspace
  - This is most of the controlled airspace over the US, below 18,000 MSL
  - Mostly starts at 700’ and 1200’ AGL, depending on proximity to airport
  - However, possible for Class E to surface
  - Magenta dashed lines indicate Class E to surface
  - Let’s look at Columbus (KOLU) airport
  - Notice Class E to surface within dashed magenta line
  - Must have ATC permission to operate in this controlled airspace

  - Let’s look at Grand Island (KGRI) airport
  - Let’s talk about this airspace with combined Class D and Class E to surface

Airspace

- Class G airspace
  - Class G is “Go for it”
  - Most Class G lies beneath Class E floors at 700’ and 1200’
  - Careful for temporary control towers. (ie, Alliance for solar eclipse)
  - Most sUAS flight operations will take place in Class G airspace
  - No ATC permission required to operate in Class G airspace
  - However, all applicable FAA regulations are in effect for Class G airspace

Airspace



Air Map

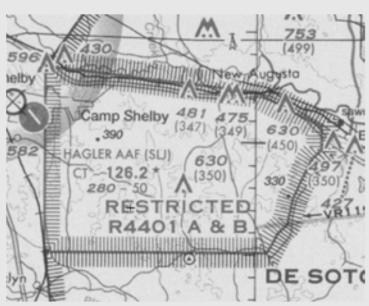
- Device based awareness of airspace and sUAS situational awareness
- www.airmap.com
- Take a look at iPad implementation
- Now take a look at Low Altitude Authorization and Notification Capability
- https://support.airmap.com/hc/en-us/categories/360000609111-LAANC-Low-Altitude-Authorization-Notification-Capability-

Special Use Airspace

- Prohibited areas – VERY high sensitivity area
- Virtually no way to get permission to fly a UAS in prohibited area

Special Use Airspace

- Restricted areas – controlled by military and may involve firing ranges, etc.
- Must get permission to fly a UAS in restricted area



Special Use Airspace

- Temporary Flight Restriction (TFR) – political and sporting events, fire fighting
- Do not fly a UAS in a TFR area without explicit permission
  Will most likely need to be part of event to get permission
- Contact flight briefer if concerned about TFR (1-800-WXBRIEF)
- Be careful of "popup" TFRs

Special Use Airspace

- Warning areas and alert areas – military related areas of operation
- Warning areas are similar to restricted areas, but offshore in international waters
- Alert areas involve high volume of training activity – think T-38 jet trainers
  No ATC clearance required, but extreme vigilance (or avoidance) is required

Special Use Airspace

- Military Operations Areas (MOAs)– military related areas of operation
- Magenta hatching
- Altitude and hours of operation on sectional
- Always confirm times of operation with FSS via briefer
- Don't need permission – but military aircraft operate without restriction
- Confirm understanding of flight operations if flying in vicinity of MOA
- Let's look at Omaha sectional – look for MOAs

Special Use Airspace

- Air Defense Identification Zone (ADIZ)
  - Stay away!
- Wildlife Refuge
  - Stay at least 2,000 feet above terrain to minimize effect on wildlife
  - Not required, but recommended
- National Parks
  - UAS not permitted to fly in National Parks without permission

Notice to Airmen (NOTAM)

- https://pilotweb.nas.faa.gov/PilotWeb/
- Always check the NOTAMS for airports in the area of flight operations
- Electronic Flight Bag software such as AVARE can provide NOTAMS

Summary

- Navigation concepts
- Sectional and airspace
- Chart supplement
- AirMap
- NOTAMS

Words of wisdom

There are old pilots.

And there are bold pilots.

But, there are NO old, bold pilots.

Topics

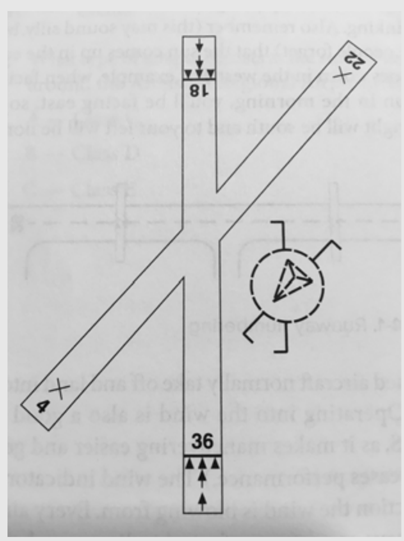
- General Info
- Sectional interpretation
- Chart Supplement info
- Towered vs Non-towered
- Pavement markings and signage
- Non-towered operations
- Towered operations
- Off-airport operations

Airports-Questions

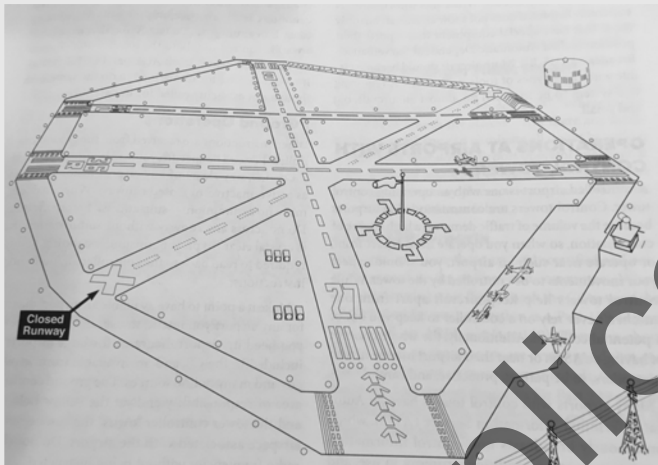
- What kind? Towered or non-towered
- Runway in use?
- Weather and winds
- Procedures
- Lights and markings
- Services

Runway Numbering

- Name/Number corresponds to magnetic direction of alignment within 10 degrees
- Aircraft takeoff and land into the wind
- Wind direction is always interpreted as an azimuth "from" which they are blowing

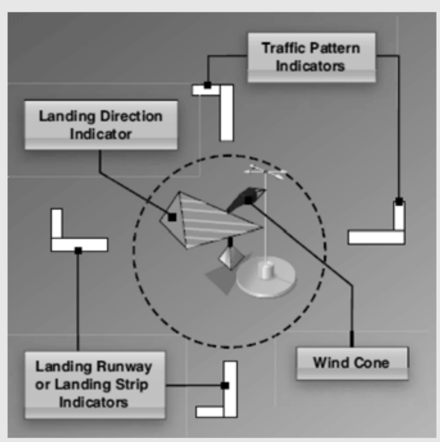


Runway Markings

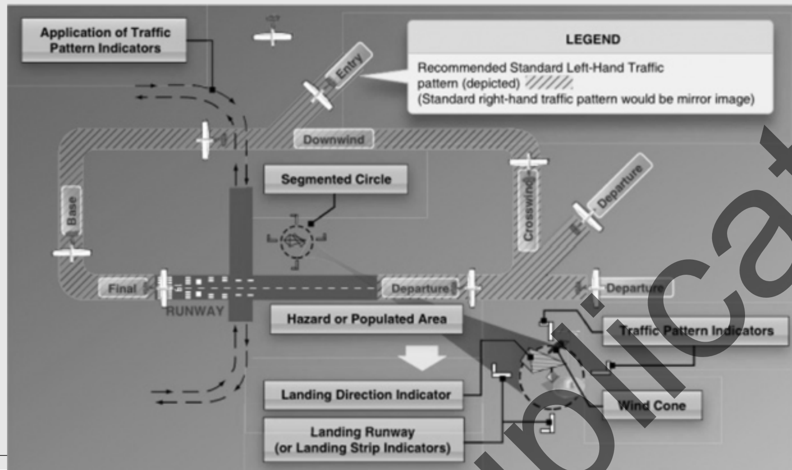


4-9. Airport runway and taxiway markings

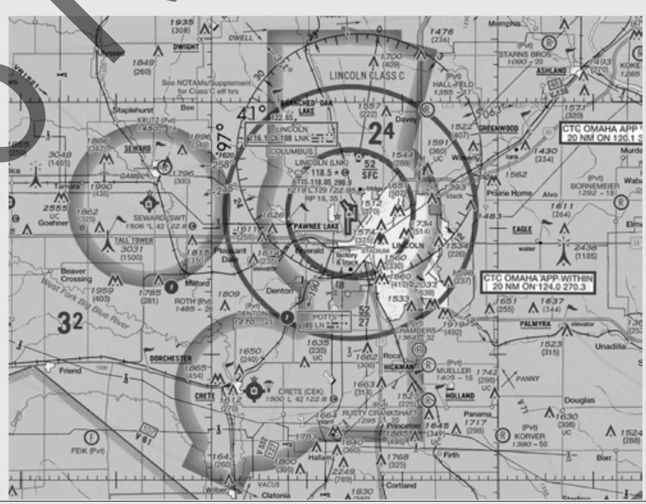
Wind and Pattern indicators



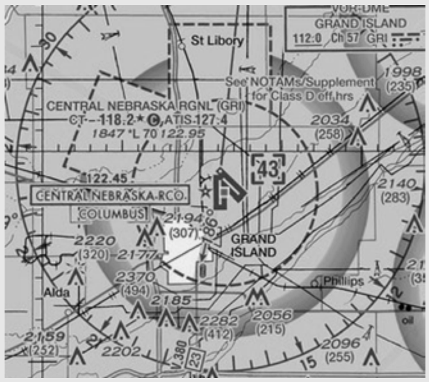
Traffic Patterns and Terminology



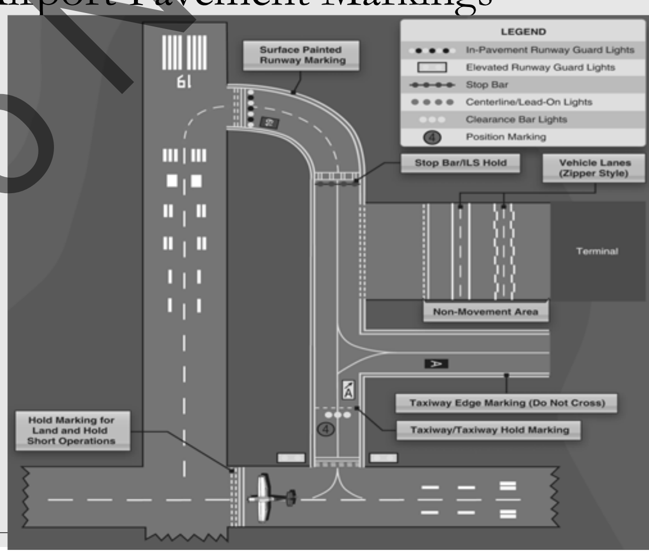
Airport Types and Depictions



Towered vs Non-towered



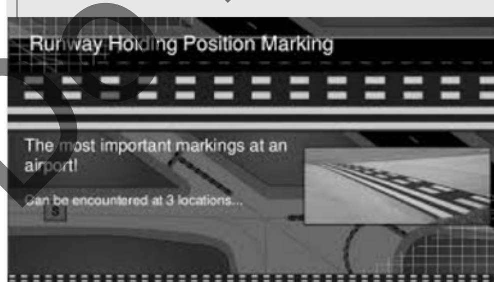
Airport Pavement Markings



Airport Signage

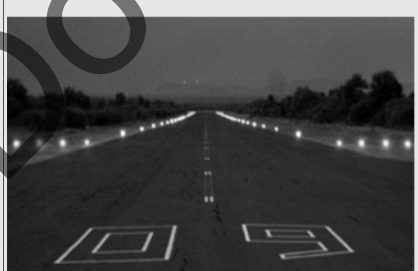
Type of Sign	Action or Purpose	Type of Sign	Action or Purpose
4-22	**Taxiway/Runway Hold Position:** Hold short of runway on taxiway		**Runway Safety Area/Obstacle Free Zone Boundary:** Exit boundary of runway protected areas
26-8	**Runway/Runway Hold Position:** Hold short of intersecting runway		**ILS Critical Area Boundary:** Exit boundary of ILS critical area
8-APCH	**Runway Approach Hold Position:** Hold short of aircraft on approach	J→	**Taxiway Direction:** Defines direction & designation of intersecting taxiway(s)
ILS	**ILS Critical Area Hold Position:** Hold short of ILS approach critical area	↙L	**Runway Exit:** Defines direction & designation of exit taxiway from runway
⊖	**No Entry:** Identifies paved areas where aircraft entry is prohibited	22↑	**Outbound Destination:** Defines directions to takeoff runways
B	**Taxiway Location:** Identifies taxiway on which aircraft is located	↖MIL	**Inbound Destination:** Defines directions for arriving aircraft
22	**Runway Location:** Identifies runway on which aircraft is located		**Taxiway Ending Marker:** Indicates taxiway does not continue
4	**Runway Distance Remaining:** Provides remaining runway length in 1,000 feet increments	↙A G L→	**Direction Sign Array:** Identifies location in conjunction with multiple intersecting taxiways

RWY/TWY Movement vs Non-movement



Closed Runways

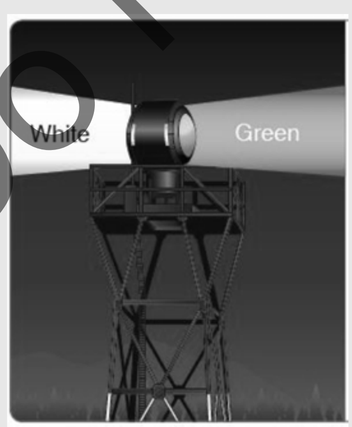
RWY/TWY Lights



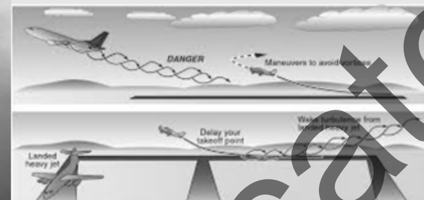
Pilot Controlled Lighting

- Controlled by activating the microphone on radio in clicks
- Number of clicks indicates desired intensity
- Typically on CTAF frequency

Rotating Beacon



Wake Turbulence



Non-Towered Airport Operations

- Study sectional and Chart Supplement
- Check the weather
- Monitor the CTAF frequency for traffic
- Announce intentions in the blind to make other pilots aware of your location
- Be aware of surface-based Class E

Towered Airport Operations

- Waiver required
- Communicate as directed by the waiver
- Check ATIS
- Follow ATC instructions if directed to contact them
- Use airport and taxiway diagrams. When in doubt---ASK!
- If airport is LAANC supported, process may be greatly simplified
- Use Airmap or Kittyhawk

Off-Airport Operations

- Approach—Google Earth Recon
- Launch/Recovery areas
- Obstacles
- Airspace awareness
- People
- Proximity to private property
- Be courteous to the locals
- Arrive with a plan but be ready to adapt

RADIO COMMUNICATION PROCEDURES

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UNIVERSITY OF Nebraska Lincoln

All Talk

- Frequencies
- Radio Procedures
- Non-towered Airports
- Towered Airports
- Radar Services
- ADS-B
- Phraseology

All Talk (actually – all listen)

- Frequencies
- Radio Procedures
- Non-towered Airports
- Towered Airports
- Radar Services
- ADS-B
- Phraseology

Frequencies

- Disclaimer: Use of handheld aviation radios require FCC license. Do not transmit on your aviation radio. Use it to gather information and monitor communications. No current protocol for use by unmanned aircraft operators.
- Aircraft radios use VHF range, which is limited to line-of-sight.
  - Altitude becomes an important factor
- Aviation frequencies
  - Let's look at pages 5-1 and 5-2
- Will be looking for Tower or Common Traffic Advisory Frequency (CTAF)

Frequencies

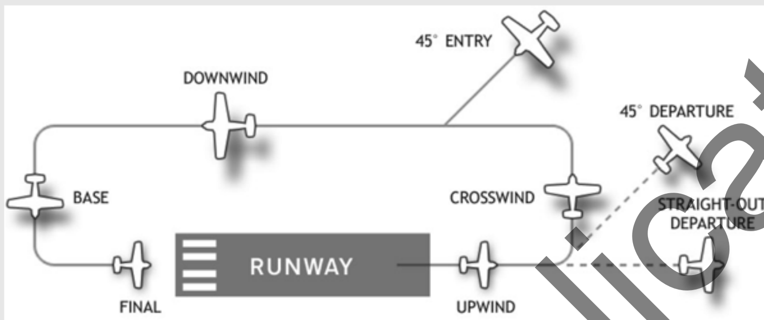
- Let's look at Omaha sectional
- Take a look at Crete airport (KCEK)
- Now, take a look at Central City airport (07K)
- Now, take a look at York airport (KJYR)
- Now, take a look at Columbus airport (KOLU)
- Now, take a look at Lincoln airport (KLNK)

Radio Procedures

- If you don't have computer access to current weather conditions
- Check if you can receive the nearby airport weather (ATIS, AWOS, ASOS)
- Perhaps check as you drive by an airport in the area
  - Aviation radio does not work well inside cab of vehicle
- Emergency frequency 121.5 should be remembered and monitored if radio allows for standby monitoring

Non-Tower Airports

◦ Traffic pattern



Non-Tower Airports

◦ Use CTAF frequency on aviation radio to monitor nearby airport activity

◦ Understanding aviation phraseology will be helpful

◦ Generally there is a sequence as aircraft approaches or departs airport
  ◦ 10 miles out – announce approach and intentions
  ◦ 5 miles out – announce approach and intentions
  ◦ 2 miles out – announce plan to enter downwind leg for runway ??
  ◦ On downwind – announce on downwind and intention to land, or touch and go, or?
  ◦ Entering base – announce entering left (or right) base for runway ??
  ◦ Entering final – announce entering final for runway ??
  ◦ Exiting runway – announce clear of runway ??

Towered Airports

◦ Class D airspace

Monitor tower frequency for information

◦ Class C airspace

More complicated

Monitoring tower will only provide part of the story

There is also Approach Control and Departure Control

◦ Let's look at Lincoln (KLNK)

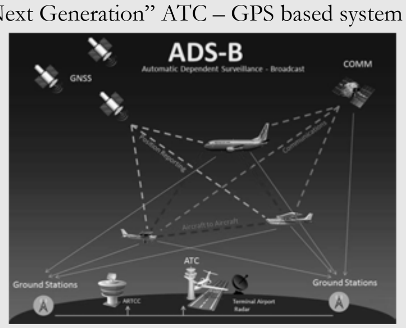
◦ Let's look at Omaha (KOMA)

Radar Services and ADS-B

◦ sUAS probably too small to be detected by ATC radar

◦ Automatic Dependent Surveillance – Broadcast (ADS-B)

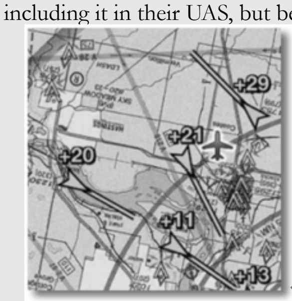
Part of "Next Generation" ATC – GPS based system



Radar Services and ADS-B

◦ Two elements – "ADS-B out", and "ADS-B in"

- All piloted aircraft operating in Class A, B, C, D airspace must have "ADS- B out" as of January 1, 2020
- ALL aircraft can have "ADS-B in", but not mandatory
- (DJI will be including it in their UAS, but be careful



Phraseology

◦ Aeronautical Information Manual (AIM) is source for phraseology

◦ Let's take a look at page 5-7

◦ Letters and numbers

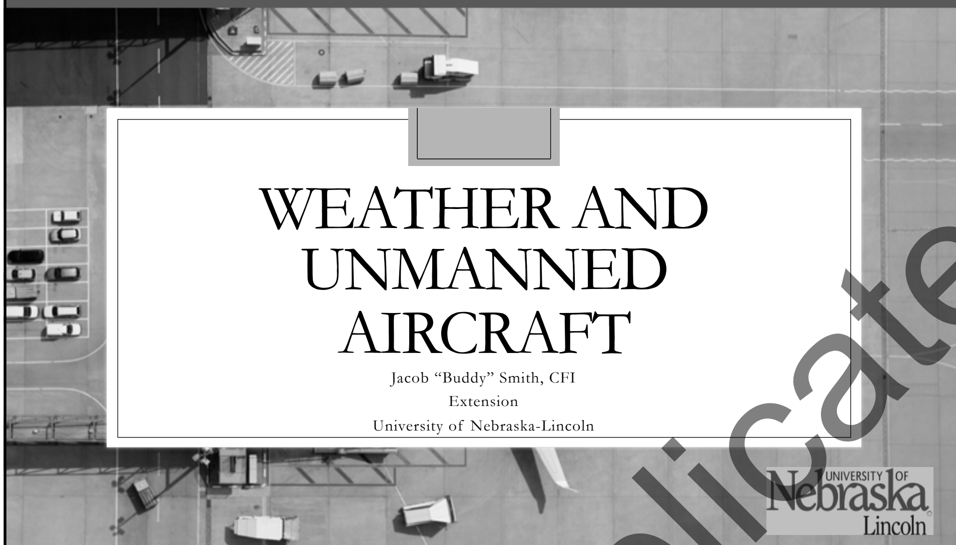
◦ Unable and Immediately

Words of Wisdom

- There's no such thing as too much altitude, to much runway, or too much fuel

Words of Wisdom

- There's no such thing as too much altitude, to much runway, or too much fuel
  (unless your airplane is on fire)



WEATHER AND UNMANNED AIRCRAFT

Jacob "Buddy" Smith, CFI
Extension
University of Nebraska-Lincoln

Topics

- Physics
- Predicting threats to sUAS
- Digital weather sources
- Textual weather sources
- Electronic Flight Bags (EFB)

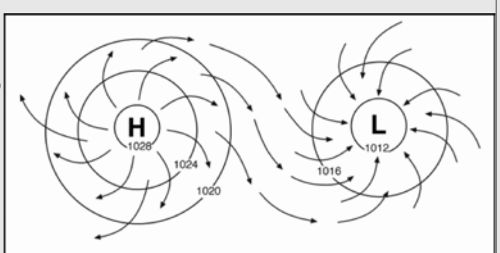
Weather caused by variations in:

- Pressure
- Density
- Temperature
- Moisture content

- Short answer: Differential heating of the earth

Circulation Around Pressure Centers

- High—Clockwise
- Low—Counter Clockwise
- High—Push down (dome)
- Low--Suck up (funnel)
- Winds–High to low with Coriolis
- Speed = Isobars packed closely



A high pressure and a low pressure center with wind directions (northern hemisphere). Circles are isobars with pressure in mb.

Moisture Content of Air

- Temperature dependent
- 100% = Visible moisture (clouds, fog, precip)
- Dewpoint—Temperature air becomes saturated
- Temp/Dewpoint spread (2C/5F degrees)

Stability of Air

- Air is unstable if it cools more rapidly than the standard 2 degrees/1000 feet
  - Adiabatic Lapse Rate
- Cool over warm = unstable
- Warm over cool – stable
  - Temperature inversion (poor visibility)

Cloud Base Prediction Formula

Temperature/Dewpoint spread
$$\frac{\text{Temperature/Dewpoint spread}}{4.4} \times 1000$$

Temp = 72

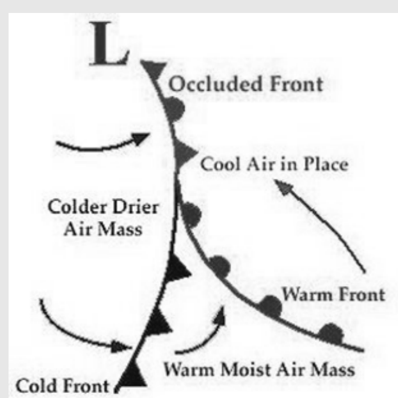
Dewpoint = 65

72-65=7

7/4=1.75 x 1000 = 1750 Feet

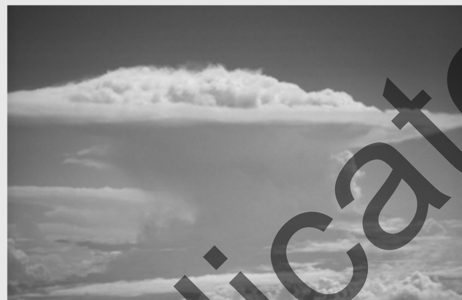
Fronts: Air masses with different properties meet

- Warm and cold are relative
- Cold air
  - Dense
  - Heavy
  - Pushes warm air up = stuff happens



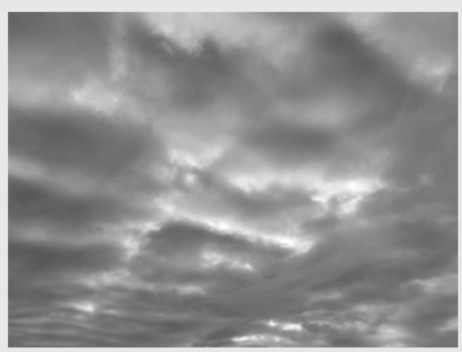
Cold Front Generalizations

- Visibility good behind
- Flight conditions bumpy
- Windy
- Showery
- Unstable air = cumulus clouds
- Small geographic area
- Clear icing



Warm Front Generalizations

- Visibility poor (trapped pollutants)
- Flight conditions smooth
- Stable air (no thermals)
- Precip: Drizzle or continuous rain
- Stratus or layered clouds
- Spread out horizontally over large geographic area
- Icing: Rime (rough, milky)

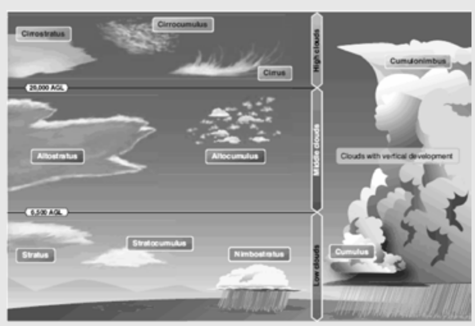


Occluded Front Generalizations

- Fast-moving cold front overtakes a warm front lifting warm air away from the surface
- Contains the worst features of both warm and cold fronts
- Turbulent flying conditions
- Showers and/or continuous precipitation
- Poor visibility
- Broad geographic extent

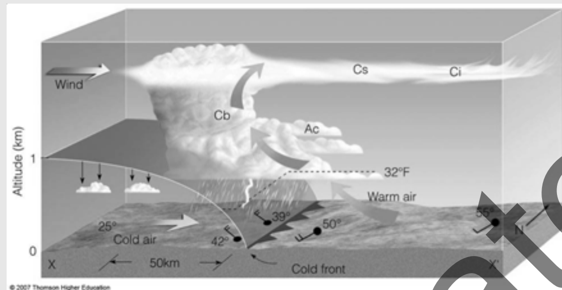
Cloud Families

- 4 families (Altitude)
  - Low
  - Medium--Alto
  - High--Cirro
  - Vertically developed
- Cumulus—puffy, unstable
- Stratus—Flat, smooth, stable
- Cirrus—very high , wispy
- Nimbus—precipitation filled
- Virga—falling precipitation evaporating before it reaches the ground



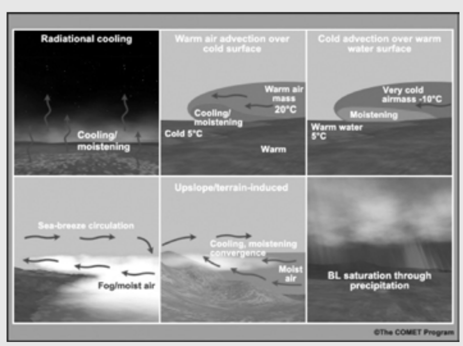
Thunderstorms

- 3 Components
  - Water vapor
  - Unstable lapse rate
  - Lifting force
- Dangers
  - Updrafts/downdrafts
  - Lightening
  - Wind shear (microbursts)
  - Strong surface winds (shear near objects)



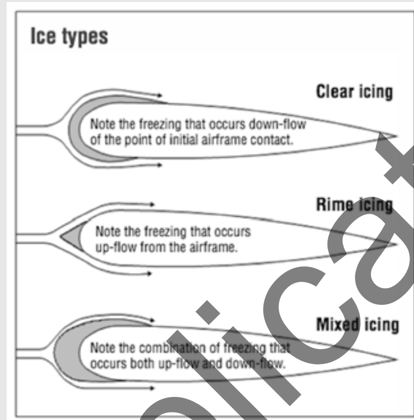
Fog

- Radiation fog (Clear skies = Radiate heat)
- Advection fog (moist air moves to cold)
- Upslope fog (air moves to higher terrain)
- Condensation nuclei



Icing

- 3 Components necessary
  - Air is at or below freezing
  - Visible moisture
  - Clear, rime, mixed
  - Don't forget frost



Cold Weather Operations

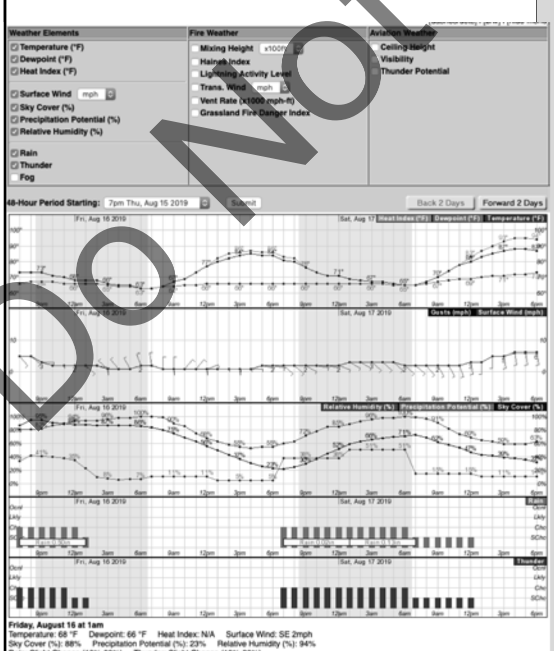
- Components exposed to extreme temperatures
- Battery performance
- Gloves/transmitter mitten

Weather Information

- 2 Categories
  - Observations
    - METARS
    - AWOS/ASOS/ATIS
  - Forecasts
    - TAF's
    - FA's (Area forecasts)
- Local weathercasts
- Digital internet web pages and mobile applications
- Textual weather products

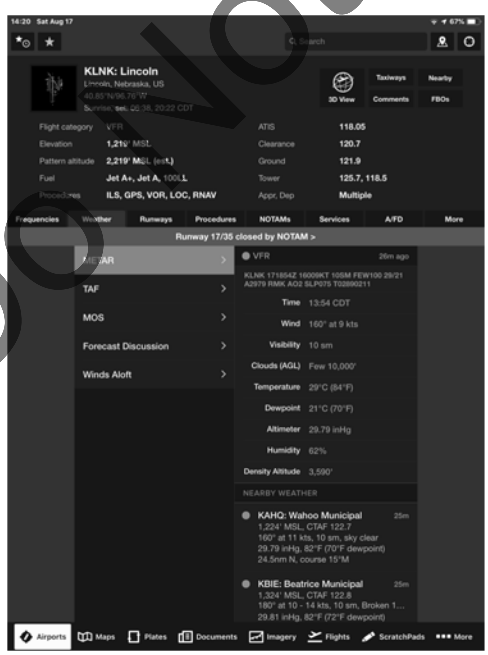
Digital Weather Sources AWC—aviationweather.gov

Digital Weather Sources
National Weather Service
digital.weather.gov

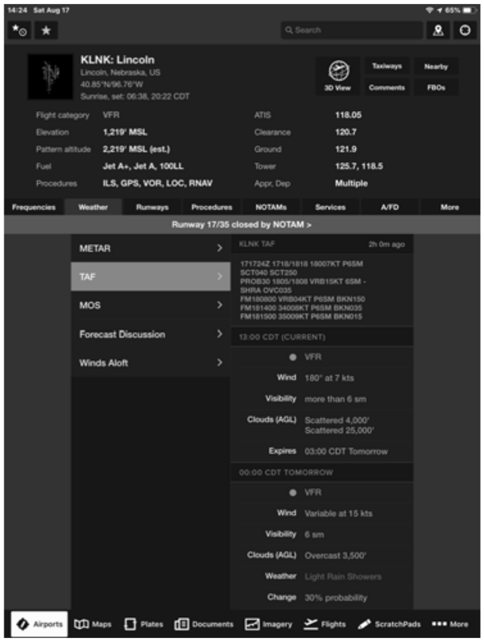


DIGITAL WEATHER SOURCES: HOURLY FORECAST GRAPHS

Digital Weather Sources: Electronic Flight Bags

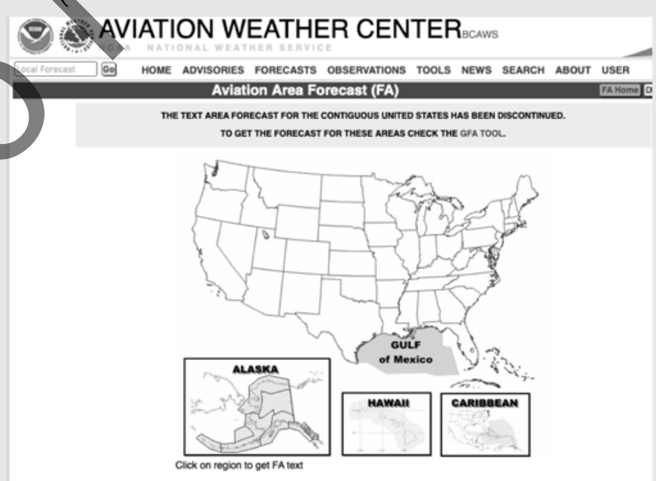


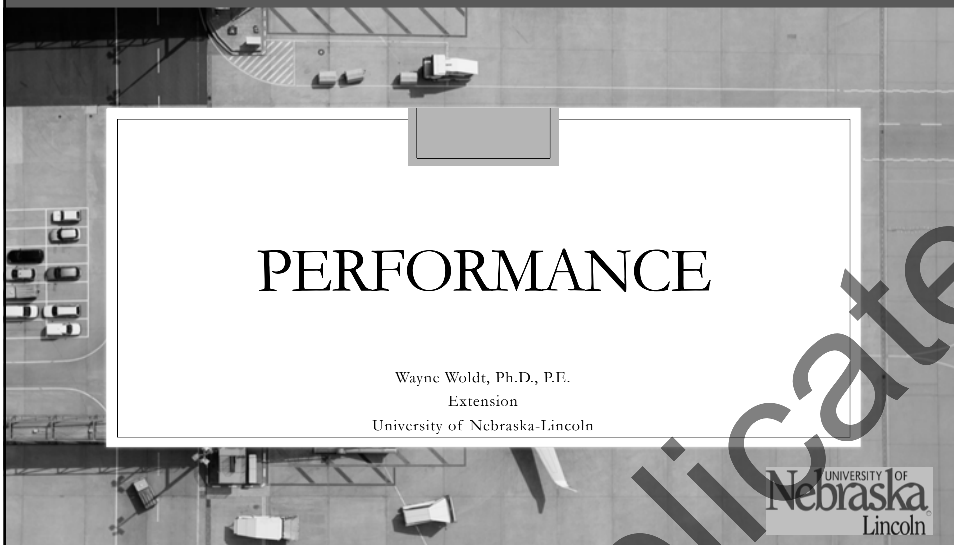
TEXTUAL WEATHER SOURCES METAR'S



TEXTUAL WEATHER SOURCES TAF'S

Textual Weather Sources
FA's (Area Forecasts





PERFORMANCE

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What Goes Up, Must Come Down

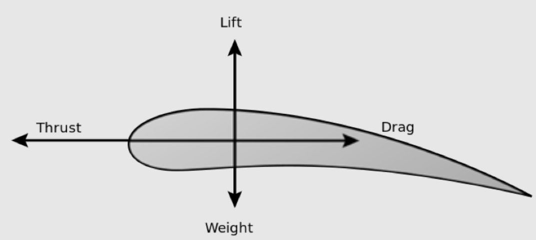
- Aerodynamics
- Weight and Balance
- W&B Calculations
- Performance
- Density Altitude
- Takeoff and Climb
- Endurance
- Landing Distance
- Vortex Ring State
- Ground Effect
- Trim

Aerodynamics

- Not only required for certification, but leads to better pilot
- What makes an airplane fly?

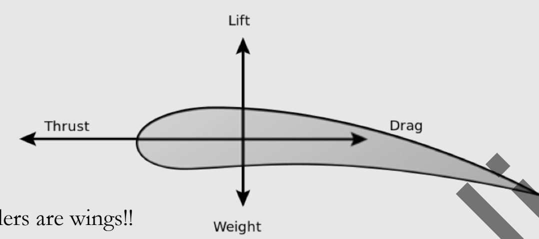
Aerodynamics

- Not only required for certification, but leads to better pilot
- What makes an airplane fly?



Aerodynamics

- Not only required for certification, but leads to better pilot
- What makes an airplane fly?



- Propellers are wings!!

Aerodynamics

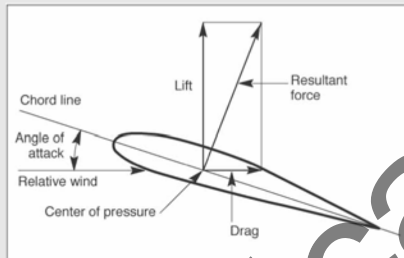
- When a wing is moving, air pressure is reduced on top of wing

https://www.youtube.com/watch?v=UqBmdZ-BNig

- And air is pushed down by bottom of wing

Aerodynamics

- Lift can be controlled by the angle of the wing
- Termed "Angle of Attack"

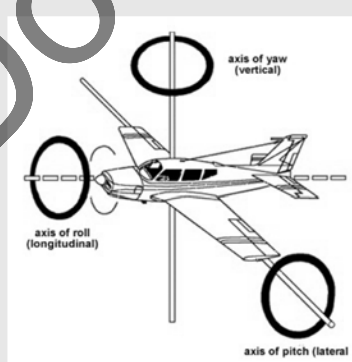


Stall!

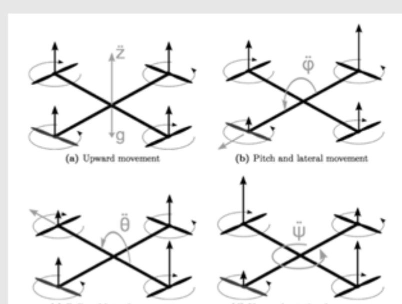
- Also controlled by speed of wing through air
- Remember, propellers are wings

Aerodynamics and Flight

Three axes of rotation (and control)



Multi-rotor

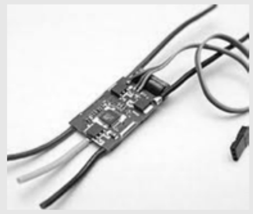


gyro!

Aerodynamics and Flight

◦ Propulsion system for multi-rotor

Battery



Electronic Speed Controller (ESC)

Outrunner Motor

Rotating Wing

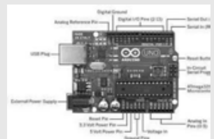
Aerodynamics and Flight

◦ Handheld controller

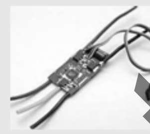
◦ Let's look at page 100 of sUAS Guide

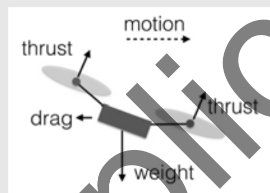
Aerodynamics and Flight

◦ Handheld controller has radio communication with onboard mini-controller



Onboard controller





Aerodynamics and Flight

◦ Handheld controller has radio communication with onboard receiver

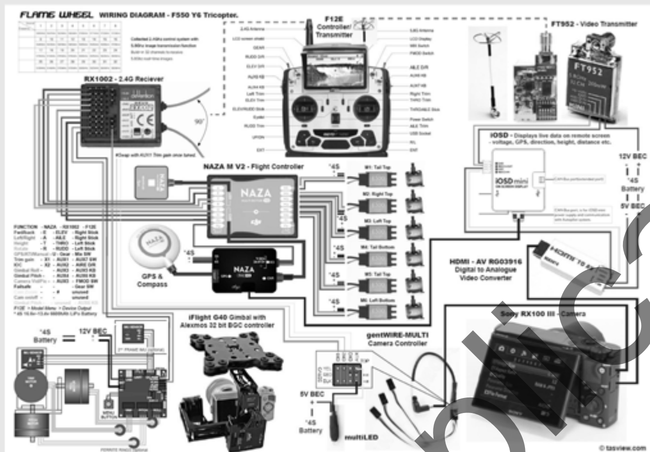
Receiver

Servo

Landing Gear

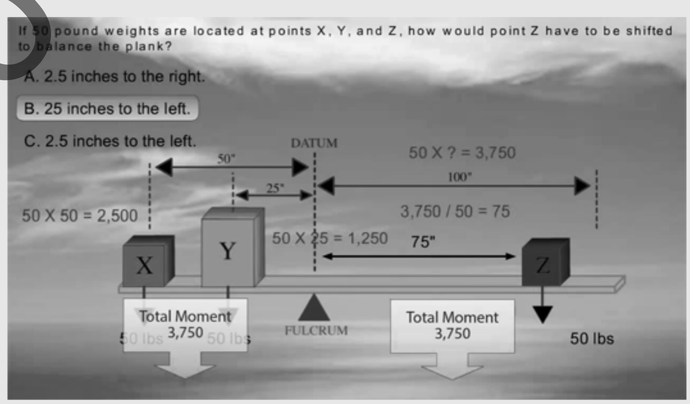
Aerodynamics and Flight

◦ Putting it all together



Weight and Balance

◦ Very important for stability of aircraft and efficiency of flight



Weight and Balance

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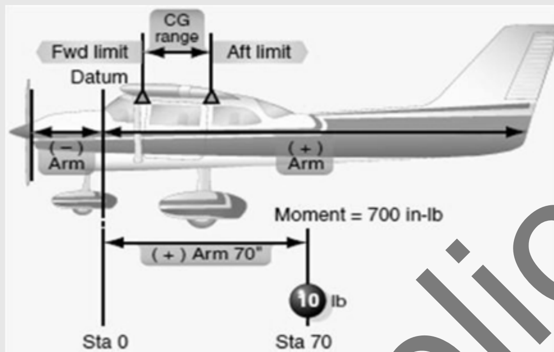

Weight and Balance

◦ Very important for stability of aircraft and efficiency of flight

W&B Calculations

- Establish a reference "Datum"
- Determine weight and moment arm for each component
- Weight x Moment Arm = Moment
- Add all individual moments = Total Moment
- Add all individual weights = Total Weight
- Center of Gravity = Total Moment / Total Weight
- All forces act through the center of gravity (within allowable envelope!)

W&B Calculations

- Establish a reference "Datum"
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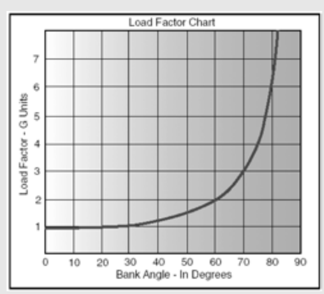


Performance

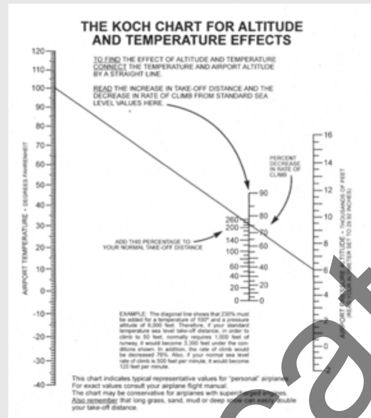
- Piloted aircraft have many "standards"
- Up to remote PIC to determine performance metrics to be expected!

  https://ecalc.ch/xcoptercalc.php

Density Altitude

- Aircraft fly by pushing air molecules around
- At higher altitude, there are less air molecules to push around
  therefore LESS performance!!
- Density altitude is the altitude at which the aircraft thinks it is flying
  - Altitude > Higher altitude = reduced performance
  - Temperature > Higher temperature = reduced performance
  - Atmospheric pressure > Lower pressure = reduced performance
  - Humidity > More humidity = reduced performance (H2O is lighter than N2 and O2)
- Airport weather reporting often gives density altitude

Takeoff and Climb



- Impact of density altitude
- Let's look at page 7-7 (remember propellers are wings!)
- Pressure altitude = (29.92 – atmospheric pressure) x 1000 + field altitude
  - (29.92 - 29.45) x 1,000 + 5,000 = 5,470 feet

Endurance

- Modern controls are good at monitoring battery condition
- Don't discharge below 20% capacity
- How do gusty conditions impact endurance?
  - Why?

Landing Distance

◦ Typical flight pattern for fixed wing

Vortex Ring State

◦ Occurs when there are components of air "upflow" through propellers

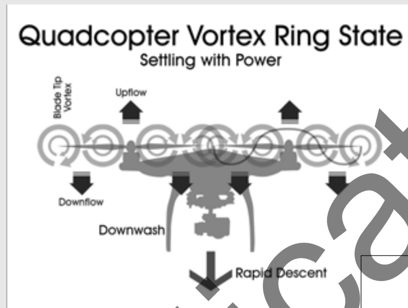
◦ Adverse effect on controllability
  Rapid descent
  Instability
  UAS can fall out of sky

◦ How to avoid – combination of
  Forward speed and descent

◦ If VRS occurs, then recovery
  increasing rate of descent (reduce power)
  increase forward speed

Vortex Ring State

- Occurs when there are components of air "upflow" through propellers
- Adverse effect on controllability
  - Rapid descent
  - Instability
  - UAS can fall out of sky
- How to avoid – combination of
  - Forward speed and descent
- If VRS occurs, then recovery
  - increasing rate of descent (reduce power)
  - increase forward speed



Ground Effect

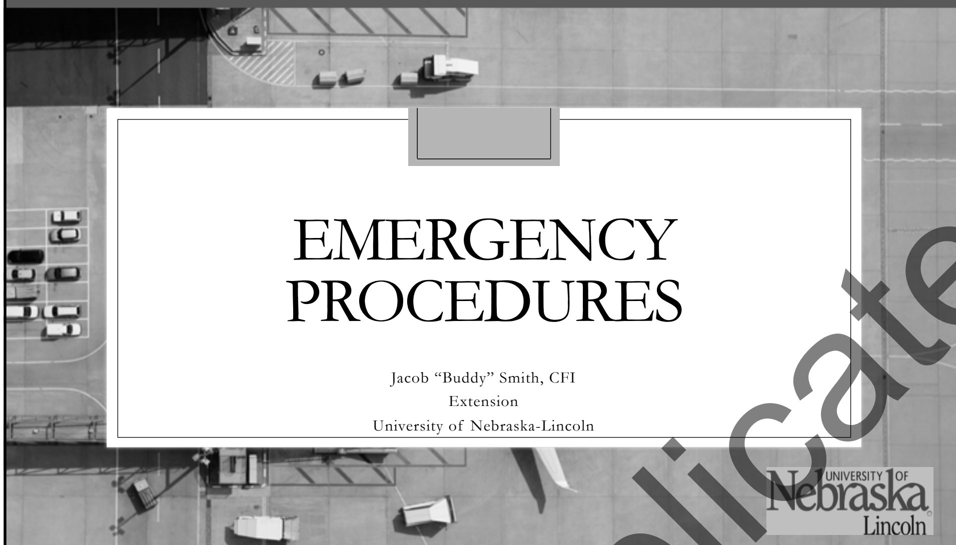
- Drag induced by interaction between ground surface and
  - wing / wing vortices (for winged aircraft)
  - down draft (for multi-rotor)
- Implications for takeoff
  - firm takeoff –> don't "dilly – dally" around
- Implications for landing
  - be prepared for ground effect --> especially in strong winds

Trim

- Fine adjustments for stability
- Small trim tabs on the hand controller by sticks

Words of wisdom

- Airspeed, Altitude or Brains. You only need two.



EMERGENCY PROCEDURES

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Emergency Procedures

- Good pilots possess just the right amount of optimism and pessimism (realist)
- Think through emergencies on ground before they happen in the air
- What could possibly go wrong?
- What am I going to do if…..? (manned)
- Full-scale aviation: "emergency procedures checklists are written in blood"

Emergency Procedures — **Cessna 172R Checklist**

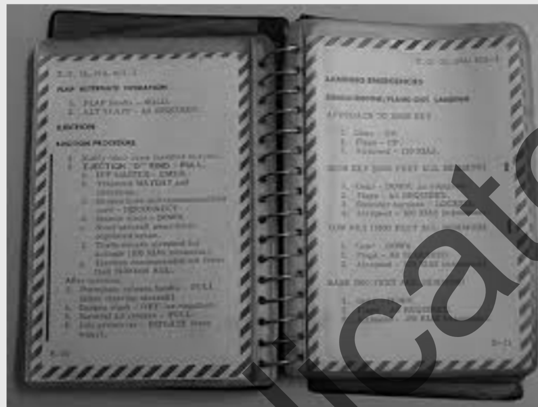
Challenge	Response
ENGINE FAILURE DURING TAKEOFF ROLL	
Throttle	IDLE
Brakes	APPLY
Wing Flaps	RETRACT
Mixture	IDLE CUT-OFF
Fuel Shutoff Valve	PULL OFF
Magneto Switch	OFF
Master Switch	OFF
ENGINE FAILURE IMMEDIATELY AFTER TAKEOFF	
Airspeed	(flaps up) 65 KIAS
Mixture	IDLE CUT-OFF
Fuel Shutoff Valve	PULL OFF
Magnetos	OFF
Wing Flaps	AS REQUIRED
Master Switch	OFF
ENGINE FAILURE IN FLIGHT	
Trim for Best Glide	65 KIAS
Pick Suitable Landing Site	
Fly Toward Landing Site	
Fuel Selector	BOTH
Fuel Shutoff Valve	IN
Mixture	AS REQUIRED
Fuel Pump	ON
Magnetos	ON / BOTH
IF NO RESTART OR AN OFF AIRPORT LANDING IS NECESSARY:	

Challenge	Response
ENGINE FIRE IN FLIGHT	
Mixture	IDLE CUT-OFF
Fuel Shutoff Valve	OFF / PULL OUT
Fuel Pump	OFF
Vents Heat / Air	CLOSED
(except wing root vents)	
Airspeed	100 KIAS
(If fire is not extinguished, increase glide speed to find an airspeed which will provide an incombustible mixture.)	
Forced Landing	EXECUTE
SEE ENGINE FAILURE IN FLIGHT: NO RESTART CHECKLIST	
ELECTRICAL FIRE IN FLIGHT	
Master Switch	OFF
All Other Switches Except Ignition	OFF
Vents Heat / Air	CLOSED
Fire Extinguisher	ACTIVATE
WARNING: AFTER DISCHARGING FIRE EXTINGUISHER WITHIN CLOSED CABIN, VENTILATE CABIN	
IF FIRE APPEARS OUT AND ELECTRICAL POWER IS NECESSARY FOR CONTINUANCE OF FLIGHT	
Master Switch	ON
Circuit Breakers	check for faulty circuit, do not reset
Radio / Electrical Switches	ON
(One at a time, with delay after each until short circuit is localized.)	
Vents Heat / Air	OPEN
(When it is ascertained that fire is completely extinguished.)	

Rules to memorize!!!

- Aviate
- Navigate
- Communicate

- In that order of priority



Rules to memorize

1. Maintain aircraft control
2. Analyze the situation and take appropriate actions
3. Land as soon as practical

Terminology

VISUAL

BLIND

EYES DOWN

Important Concepts

STERILE COCKPIT

CREW RESOURCE MANAGEMENT

Ground Emergencies

- Lipo Battery Fires
  - Never charge unattended
  - Bulges in wrapping or swelling
  - Smoking or hissing
  - Extinguisher, sand
- Won't Turn Off
  - Cycle start/stop sequence
  - Off switch
  - Battery drain
- Unexpected visitors
  - 2-person crew really helps—Hand off PIC
  - Be courteous, Remember Aviate, Navigate, Communicate

Inflight Emergencies (IFE's)

- Know your aircraft—existing emergency checklists
- Research and create your own
- Fly-Away
  - Attempt to regain control
  - Autonomous to manual
  - Press RTH button
- Engine Failure
  - Component failure rates???
  - Recon landing sites in advance
  - Unexpected?---Precautionary landing
  - More engines the better
  - Fixed wing---Glider

Inflight Emergencies

- Structural Failure (usually props)
- Fire Inflight
  - Land as soon as practical
  - Extinguish
  - Dirt/sand
- Lost Link
  - Home point is critical
  - Try re-establish contact
    - Move/check antenna
    - Obstructions
- When to go “Manual”
  - GCS failure
  - Loss of GPS
  - Flight plan hiccup

Disorientation

- Stop
- Make small control input and assess
- Do follow-up control input
- Repeat until orientation regained
- Resume flight or RTH

Emergencies Involving ATC

- Controlled airspace fly-away
  - Notify ATC ASAP
- Declaring an emergency
  - Myths about paperwork
- Emergency Communications
  - VHF 121.5
  - Emergency Locator Transmitter (ELT)
  - "Mayday"

Surprises

- Troubleshoot on the ground
- Tether if fear of fly-away
- People: Respect, Courtesy, Abort flight if necessary

HUMAN FACTORS

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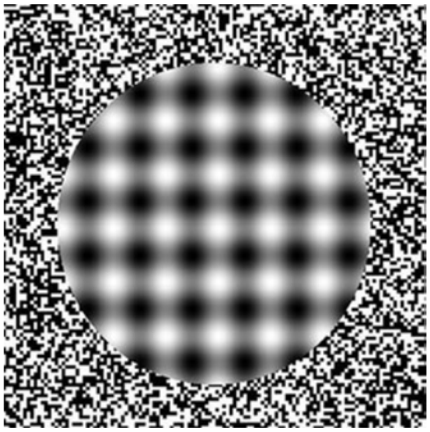
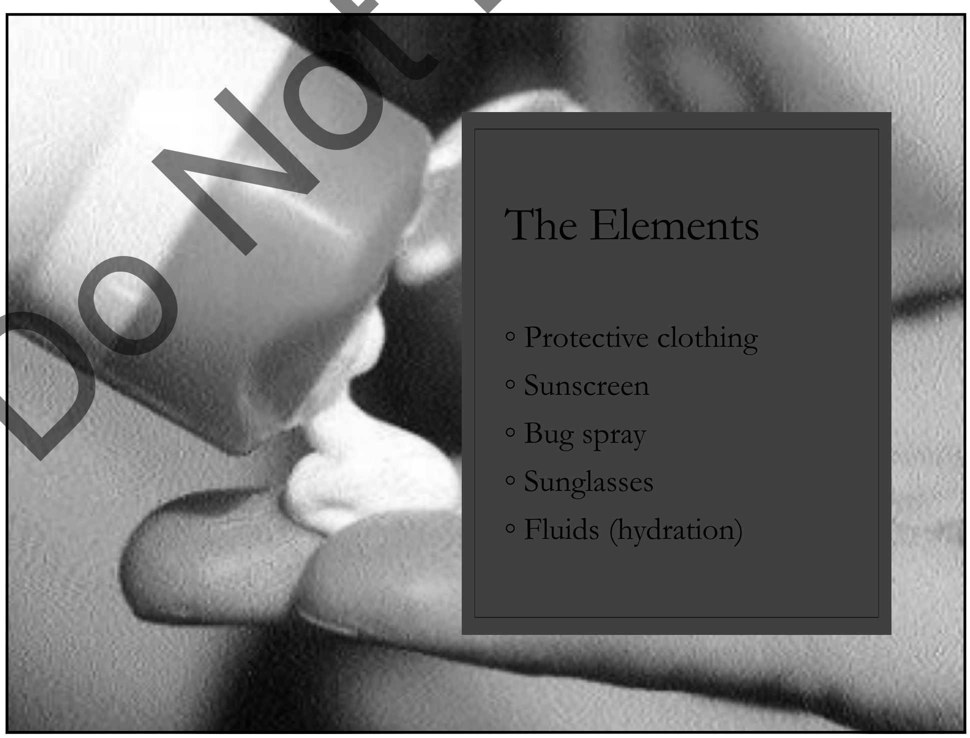
Basics

- Self assessment is for everyone on the crew (PIC, VO)
- PIC can ground any member of the crew
- Drugs/Alcohol
  - 8 hours bottle to throttle
  - .04 BAC
  - Failure to submit or provide: Refusal, Revocation, Suspension



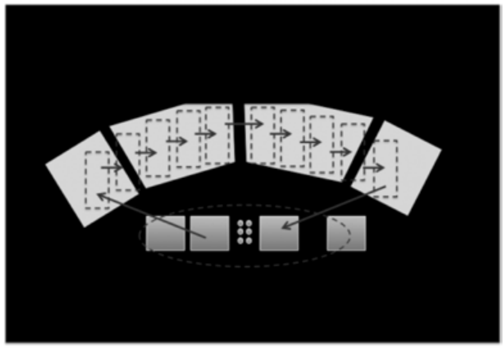
Visual Illusions

- Autokinesis—Look off-center
- Featureless terrain illusion (no depth perception)
- Atmospheric illusion (fog/haze), Aircraft appears further away
- Ground lighting illusion (lights/stars)
- Disorientation, exacerbated by distance
- Spatial disorientation—Temporary confusion resulting from misleading information being sent to the brain



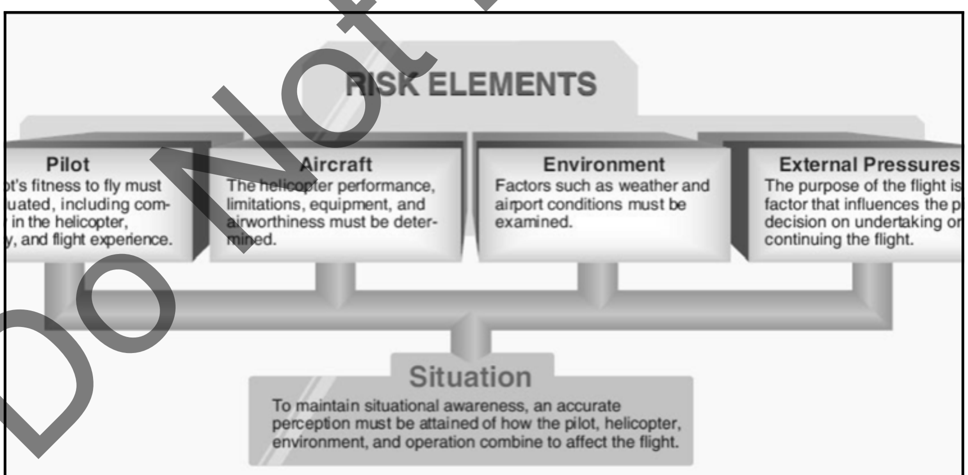
The Elements

- Protective clothing
- Sunscreen
- Bug spray
- Sunglasses
- Fluids (hydration)



Scanning

- 10 degree sectors, up and down
- Night: Only see objects slightly out of direct line-of-sight
- Stationary objects in your field-of-view—collision danger



5 DECISION MAKING SUBJECTS OR RISK ELEMENTS

Hazardous Attitude	Antidote
Anti-authority: Don't tell me.	Follow the rules. They are usually right.
Impulsivity: Do something quicky.	Not so fast. Think first.
Invulnerability: It won't happen to me.	It could happen to me.
Macho: I can do it.	Taking chances is foolish.
Resignation: What's the use?	I'm not helpless. I can make a difference.

5 HAZARDOUS ATTITUDES

DECIDE MODEL

Detect the fact that a change has occurred.
Estimate the need to counter or react to the change.
Choose a desirable outcome for the success of the flight.
Identify actions which could successfully control the change.
Do the necessary action to adapt to the change.
Evaluate the effect of the action.

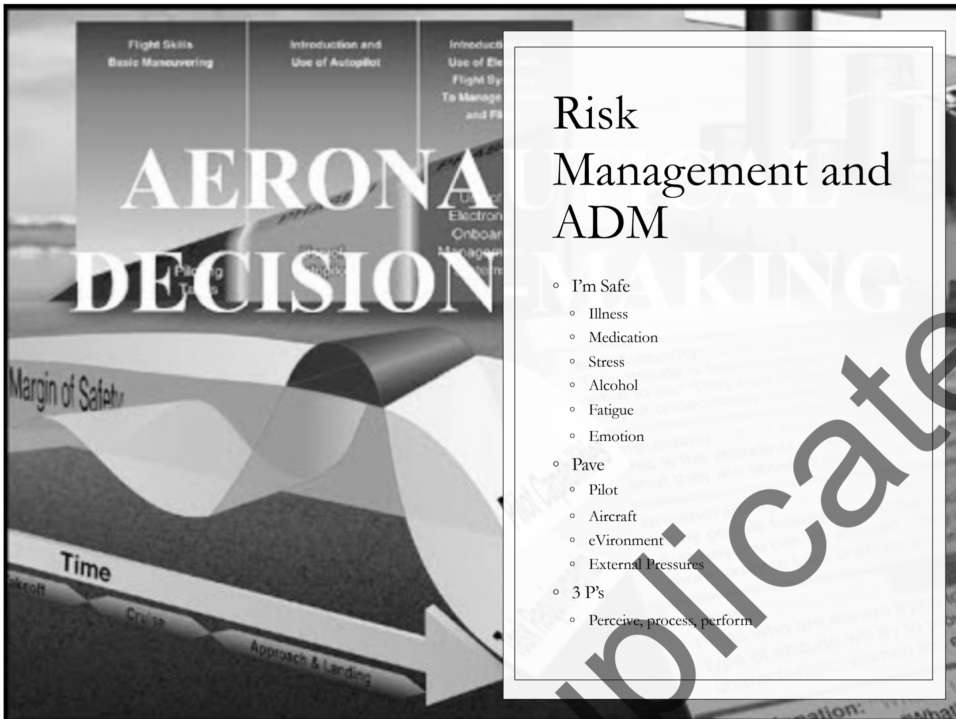
DECIDE MODEL

Get-Home-It is and Completion Bias

- Get-home-itis
  - "Driven people"
  - External pressures
  - Is this me?
  - What am I prone to do?
  - Make rational not emotional decisions
- Completion Bias
  - "I've gotten this far, I have to finish"
  - Desire for closure
  - Change in environment or situation—set limits

Training

- Process of substituting a new reaction for normal or typical responses
- Counterintuitive
- Psychomotor responses must be refreshed



Risk Management and ADM

- I'm Safe
  - Illness
  - Medication
  - Stress
  - Alcohol
  - Fatigue
  - Emotion
- Pave
  - Pilot
  - Aircraft
  - eVironment
  - External Pressures
- 3 P's
  - Perceive, process, perform

MAINTENANCE AND INSPECTION PROCEDURES

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Preflight Checklist Mavic Pro

Before leaving for location:

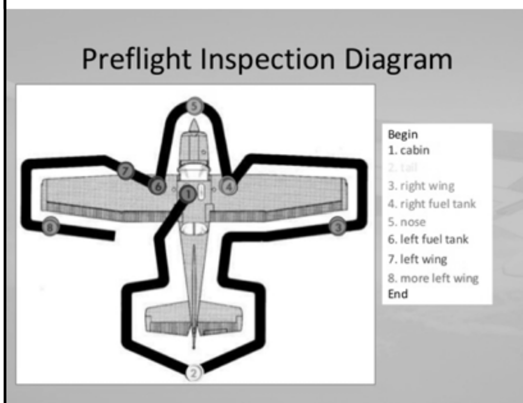
1. Determine goal of flight mission
2. Obtain any waivers or authorizations if needed for flight location
3. Check weather conditions of flight location
4. Check NOTAMS for flight location
5. Check battery levels (Mavic, controller, phone)
6. Confirm MicroSD is in Mavic and formatted
7. Check for any firmware updates

At location:

1. Unfold Mavic arms
2. Check propeller blades condition (If nicked, cracked or deemed unsafe, replace before flight)
3. Check battery condition (If bulged, dented or deemed unsafe, discard & replace before flight)
4. Remove Lens cover
5. Remove Gimbal clamp
6. Attach ND Filter if needed
7. Place Mavic on Launch site (Level ground, clear of any overhead obstacles)
8. Connect phone to controller
9. Open DJI app
10. Power on controller
11. Power on Mavic
12. Set phone to do not disturb & airplane mode
13. Set camera settings
14. Look for "Ready to Go" message on controller
15. Confirm GPS & Compass are connected
16. Confirm return to home is set
17. Clear area for takeoff
18. Power on motors
19. Take off

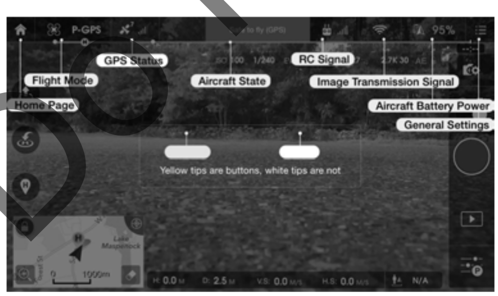
Inspection Checklists

- RPIC is responsible for determining that the aircraft is safe for flight
  - Checklists for sUAS are rare
  - Make your own
  - "Borrow" from others
  - Adapt them as you gain experience



Preflight

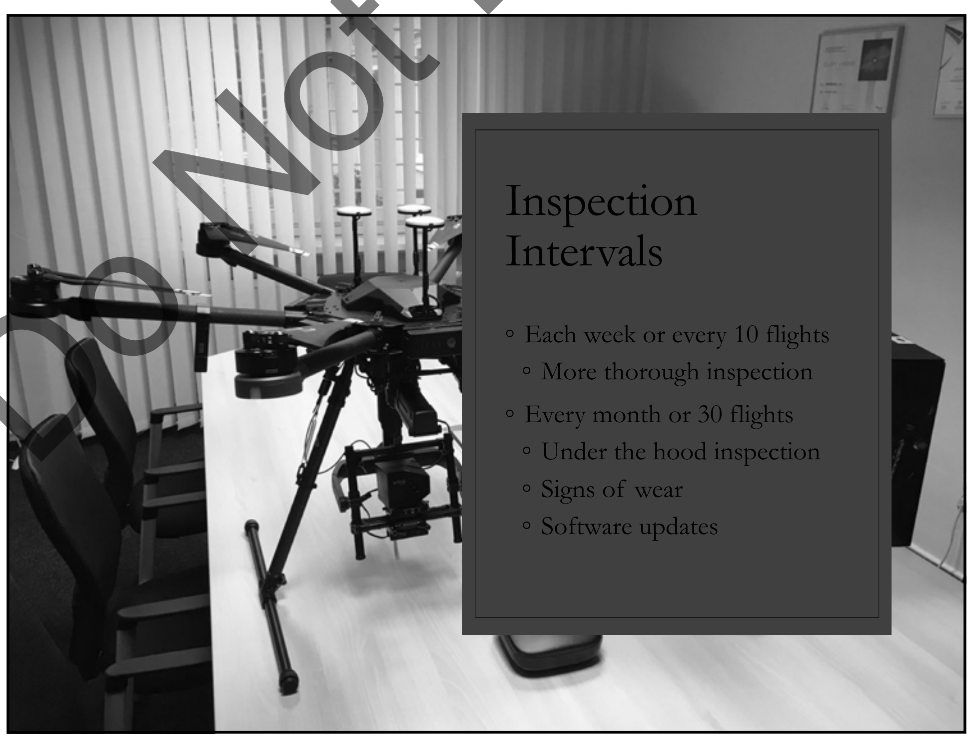
- Propellers
- Motors (smell)
- Booms
- Gimbal
- Payload
- Connections
- Bolts and screws
- Batteries
- Ground Control Station
- Antennas
- Crew briefed



Power On

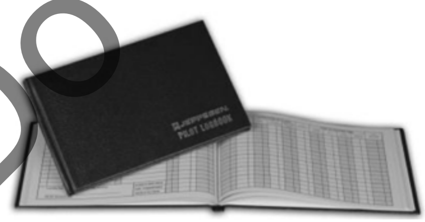
- Control checks
- Home Point
- Systems faults
- Gimbal checks
- Sensor checks
- Mission loading and confirmation
- Final crew and area clearance


Postflight
Basically like the preflight
Battery removal
Data/media cards
Propellers
Motors
Leads/connections
Transport prep


Inspection Intervals
Each week or every 10 flights
More thorough inspection
Every month or 30 flights
Under the hood inspection
Signs of wear
Software updates

Battery Maintenance

- Break-in gently (50% first few cycles)
- Storage: 40%, 3.8 volts/cell
- Don't charge cold or hot
- Never charge unattended
- 20% minimum, 3.6 volts/cell (50 vs 300 cycles)
- Freezing—Complete failure
- Won't consistently hold 80% charge—Replace
- 150-200 cycles—Watch more closely



Flight, Maintenance, and Battery log's

- Paper or electronic
- Pilot logbooks enable you to prove experience, currency, and recency
- Maintenance and Battery Logbooks
  - Track replacement cycles
  - Note discrepancies and repairs
  - Determine service limits
  - Show documentation to FAA

Advanced Multi-rotor Training
UN-AIRE Laboratory
University of Nebraska-Lincoln
Maneuvers

Basic maneuvers:

Here we go ______ ______ ______

Preflight
Starting systems
Vertical takeoff to 4’
Vertical landing
Vertical takeoff to 4’
Move left 4’
Move right 8’
Move left 4’
Move forward 4’
Move aft 8’
Move forward 4’
Vertical landing

Go we here ______ ______ ______

Vertical takeoff to 4’
Yaw aircraft 180 degrees clockwise (looking down)
Vertical landing
Vertical takeoff to 4’
Move left 4’
Move right 8’
Move left 4’
Move forward 4’
Move aft 8’
Move forward 4’
Vertical landing

Let’s hang out ______ ______ ______

Exercise to learn hovering
Vertical takeoff to 4’
Yaw aircraft 180 degrees clockwise
Descend to 2’
Hover for 15 seconds
Descend to 1’
Hover for 15 seconds
Vertical landing

This is fun ______ ______ ______

Landings while aircraft is some distance away

Take off vertical to 10'

Fly 20' away and land vertically

Intermediate maneuvers:

Are you square ______ ______ ______

Fly a square with UAS pointing **forward**

Vertical takeoff with nose pointing north to 10' AGL

Yaw 90 degrees CW, and fly 10' east, stop and yaw 90 degrees CCW

Fly 10' north, stop and yaw 90 degrees CCW

Fly 10' west, stop and yaw 90 degrees CCW

Fly 10' south, stop and yaw 90 degrees CCW

Yaw 90 degrees CCW and land vertically.

Square are you ______ ______ ______

Repeat square in opposite direction with yaws in opposite direction.

Arch time ______ ______ ______

Fly an arch with UAS pointing forward

Vertical takeoff nose pointing north to 5' and yaw 90 degrees clockwise

Fly to east level for 5' and then gradually increase height to 10' while continuing to fly

Descend to 5' while continuing to fly

Continue flying to east for 10' and stop

Yaw 180 degrees CCW and return to takeoff flying at 5'

Yaw 90 degrees CW and land with aircraft nose pointing away.

Arch time (with hover) ______ ______ ______

Fly an arch with UAS pointing forward

Vertical takeoff nose pointing north to 5' and yaw 90 degrees clockwise

Fly to east level for 10' and then gradually increase height to 10' while continuing to fly

Once at peak of arch, stop and hover for 10 seconds, then continue maneuver

Descend to 5' while continuing to fly

Continue flying to east for 10' and stop

Yaw 180 degrees CCW and return to takeoff flying at 5'

Yaw 90 degrees CW and land with aircraft nose pointing away.

Circle with nose facing same direction (ie, north) ______ ______ ______

Vertical takeoff to 10'

Fly circle of 15' radius with nose facing north through circle

Vertical landing

Repeat, only in clockwise direction

Inspection time ______ ______ ______

Vertical takeoff to 10'
Fly to vertical wall and stop 12'' away from wall, with nose to wall, hover for 10 seconds
Descend vertically 5', maintaining distance and orientation
Hover for 10 seconds
Ascend vertically 5', maintaining distance and orientation
Reverse fly away from wall 5'
Yaw correct degrees to fly direct home, nose first
Yaw until nose is pointed away, and land

Advanced maneuvers:

Inspection time 2 ______ ______ ______

Fly to object to be inspected
Approach to within 24" of object
Fly circle around object, keeping nose of aircraft pointed toward object
Reverse fly away from object 5'
Yaw correct degrees to fly direct home, nose first
Yaw until nose is pointed away, and land

Minimum Operating Climb Altitude (MOCA) ______ ______ ______

Purpose: Establish the minimum height plus ten feet that the aircraft should climb to so that it will not strike an object during the abort of a flying maneuver.

Maneuver: With the camera set in its level position, the Student Pilot will climb straight up after take-off until the aircraft is even with any obstacles within the area of operations. The pilot will do this by looking at the screen and seeing the top of obstacle and the horizon behind it. The pilot will then yaw the aircraft 360 degrees to ensure that he/she has identified the tallest obstacle. The screen will then indicate how high the highest obstacle is above ground level. The Student Pilot will then add 10 feet to this height to obtain the MOCA.

Accuracy Landing ______ ______ ______

Purpose: Pilots will need to demonstrate that they can perform a controlled descent and landing within a one square foot area.

Maneuver: The Instructor will identify a location on the ground that the Student Pilot must land the aircraft. The Student Pilot should do a controlled descent to approximately 10 feet above the target and slowly descent using the camera facing straight down. At approximately 2 feet above the target the Student Pilot should hold; make any final adjustments; raise the camera; then land the aircraft.

Point of Interest ______ ______ ______

Purpose: The Student pilot should know how to apply the Point of Interest maneuver. This maneuver is used a lot for focusing on a area of interest.

Maneuver: The Student Pilot will pick a building and perform the DJI Point of Interest maneuver. Aircraft will circle the building two complete rotations and then go the opposite direction at least two rotations.

Standoff Distance ______ ______ ______

Purpose: The Student pilot will gain confidence flying near buildings and maneuvering the drone sideways along the building structure.

Maneuver: The Student Pilot will fly to the edge of the roof and hover at 6 feet above the edge. The Student Pilot will adjust the camera to a 45 degree angle and then back off the roof until the edge of the roof is in the center of the screen. The Student Pilot then will snap the camera perpendicular to the ground and descend until they can peek in the glass windows. The Student Pilot will then transition left and right observing what is inside the building by looking through the glass windows. The Student Pilot will more than likely have to adjust the exposure wheel to see beyond the reflection in the glass.

Reveal Climb ______ ______ ______

Purpose: The Student Pilot will practice hand to eye coordination and applying multiple control inputs simultaneously.

Maneuver: The Student Pilot will fly to “eye level hold” position on an object approximately 4 feet off the ground and 30 feet away. Pilot will perform a 6 foot per second climb for 60 feet (10 seconds) tilting camera down at 10 degrees per second. Camera tilt action should end at the same time the drone reaches its 60 foot climb.

Emergency preparations:

Emergency blind landing ______ ______ ______

Vertical takeoff to 30’
Fly forward to position where landing will be behind barricade
Vertical landing behind barricade with VO assistance

Long Distance Orientation ______ ______ ______

Purpose: Have the Student Pilot get comfortable with orientating the aircraft during long distant drone operations.

Maneuver: With the Student Pilot turned around, the Instructor will fly above MOCA away from departure point and orientate the aircraft away from a direct path returning to the departure point. The Student Pilot will then turn around, take the controller and orientate the aircraft so it is facing directly away from the departure point without using the First Person Screen, the Student Pilot will return the aircraft to the home point without using the DJI Return to Home command.

<u>Blind return and landing</u> _______ _______ _______

Vertical takeoff to 10'
Hand off controller to instructor and turn away from flight area
Instructor to fly UAS to random location with random yaw
VO talks pilot back to TO point with in person