EMBRY-RIDDLE
Aeronautical University
WORLDWIDE

sUAS Consumer Guide

Operational Test Plan

Spring 2016

Overview

Within the next year, significant changes to how unmanned aircraft systems (UAS) are used and integrated into the National Airspace System (NAS) are anticipated, including wider application and operation under the Federal Aviation Administration (FAA)'s *small UAS (sUAS) certification and operation rules* (i.e., Part 107). With the increased accommodation for sUAS operation, subsequent oversight and tracking, and innovative development, the benefits and utility of these systems will continue to increase, including in the educational domain. Despite recent technological and regulatory advancement, concern for irresponsible operation of sUAS (55 pounds and under) continues to grow. The projection that more than 2.5 million such platforms are currently operating in the NAS, with potential growth of up to seven million by 2020, has far reaching implications for this evolving, $100+ million industry. However, by increasing awareness of rules, regulations, and best-practices through expanded public education, such as Embry-Riddle Aeronautical University (ERAU)'s UAS workshops and sponsored-research, as well as public service campaigns including *Know Before You Fly*, critical insight and guidance can reach this new segment of the aviation population.

Background

While the FAA has actively promoted safety and responsible operation, they cannot reach these new pilots alone; they need the full support of the aviation community. By providing educational information to inexperienced (novice) operators, we can help to increase awareness, while also connecting these fledgling pilots to critical resources and assistance to become responsible stakeholders in our shared community. ERAU-Worldwide hopes to reach a large and diverse audience through the development of an *sUAS Consumer Guide* to help promote thorough platform consideration and comparison prior to purchase and use. In support of this goal, we plan to examine 12 popular consumer multirotor sUAS platforms, reviewing key areas of critical importance to users. These investigation areas, essential to understanding suitability of platforms, include system performance, quality of construction, ease of operation, cost, accuracy of advertised capability, and user support. The *sUAS Consumer Guide* will be prepared to assist a wide variety of users, especially novices, to evaluate options for purchase, appropriate to their skill and experience levels, while introducing key metrics for future consumer sUAS comparison.

Purpose

This document contains the details of the ERAU-W *Operational Test Plan* to conduct flight test and evaluation operations using a sample of 12 multirotor sUAS, weighing 7.5 pounds or less and featuring varying levels of operator control, design complexity, and payload capability. Operational flight testing will be performed at two locations, indoors at the ERAU-Daytona Beach campus Field House and outdoors on private property. Outdoor operations are to be conducted in accordance with requirements of the Nevada Institute for Autonomous Systems (NIAS) UAS Test Site public certificate of waiver or authorization (COA), as well as Federal, State, and local UAS operational regulations.

Points of Contact

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Research Design and Methodology

A mixed-methods (sequential explanatory) research strategy will be used to examine a series of commercially-off-the-shelf (COTS) sUAS (instruments; see example in Figure 1) and ultimately identify suitability as a novice-use platform. Important performance values, such as speed, endurance, payload capacity, system configuration cost, and communication range, have been obtained through public sources, including the manufacturers (see Table 15 in Appendix). These values will be used to calculate average performance for all sUAS examined and combined with pricing and the number of applications supported to establish a series of performance scores (quantitative scoring). When a score is not available, it will be treated as a zero in the calculations. Team-members individually review the published details of each platform and will be operating, as suggested by the manufacturer; reviewing assembly (construction quality); comparing published performance to operational experience (availability and accuracy of reported values); and exploring the level of support available to an operator (user support). Each of these areas will be evaluated using a scoring rubric and then assigned an assessment rating (0 to 100%; quantitative scoring). The individual scores from the assessments (quantitative and qualitative) will be averaged to establish an overall rating score and ranking. The captured data has also been used to help identify additional strengths, weaknesses, and considerations associated with each platform.

Figure 1. Example consumer multirotor sUAS, Yuneec Typhoon 4K

Research Statement

This mixed-methods study was designed to examine and identify the suitability of a series of consumer sUAS as initial platforms for novice operators. A sequential explanatory mixed methods design was employed, with quantitative and qualitative data collected in series, analyzed independently, and then merged for final analysis. For this study, the rationale supporting collection and analysis of both quantitative and qualitative data was the need to compare individual measures representing platform capability (quantitative) with subjective, assessed quality (qualitative) ratings to determine an overall level of platform suitability to an end user, a novice sUAS operator.

sUAS Qualitative Assessment Criteria

The qualitative (subjective) assessment criteria for each sUAS is focused around four primary elements; *construction quality, operational ease, availability and accuracy of reported values, and user support*. The details for these criteria items are found in Table 1.

Table 1. sUAS Assessment Criteria

Construction Quality	**High (76-100)**	**Medium (51-75)**	**Low (1-50)**	**None (0)**
The workmanship evident in the construction and assembly of the systems and its OEM components. This evaluation consists of examining durability of construction materials, ease of maintenance and calibration, and precision of assembly. Third-party components are not accessed in this evaluation.	High degree of quality is evident. Construction materials are highly durable and able to withstand unexpected stresses of repeated operation. System has been designed to support inspection, overhaul, repair, preservation, replacement of parts, and preventive maintenance (e.g., component replacement). Components are fitted together with no movement or gaps, except where required.	Medium degree of quality is evident. Construction materials are somewhat durable and able to withstand expected stresses of operation. System has been designed to accommodate some maintenance (major component replacement). Components are fitted together with slight movement or gaps, except where required.	Low degree of quality is evident. Construction materials are not very durable and may not withstand stresses of repeated operation. System has been designed to accommodate little to no maintenance and components are not replaceable. Components are fitted together with significant movement or gaps, except where required.	No quality of construction is evident in the design and manufacturing of the system.
Operational Ease	**High (76-100)**	**Medium (51-75)**	**Low (1-50)**	**None (0)**
The ability of the system to be operated by a wide range of operators from inexperienced first-time operators, to experienced and trained manned pilots. This evaluation consists of examining the intuitiveness of operators controls and their placement, ability to vary response to suite proficiency, and integration of easy to operate automatic features in the operator interface.	The design of the control interface exhibits significant thought towards supporting a wide range of operators with responsiveness of the system configurable to match the ability of the operator. Important information or controls are easy to reach and use. Efficiency and safety controls are provided, such as heading and/or altitude hold, return to home, and automatic landing.	The design of the control interface exhibits some thought towards supporting a wide user (operator) base with responsiveness of the system being adjustable. Important information or controls are somewhat easy to reach and use. Limited efficiency and safety controls are provided, but may require complex operation or configuration to enable.	The design of the control interface has been developed for a single experience level and provides very little to no customization. Important information is not present and/or controls are not easy to reach or use. No efficiency and safety controls are provided.	This system provides no user control for operation

Availability and Accuracy of Reported Values	High (76-100)	Medium (51-75)	Low (1-50)	None (0)
The availability and accuracy of performance values (metrics) specified by the vendors or third-parties, which are used to analyze and justify selection or use of a platform and perform detailed flight planning and safety analysis. This evaluation consists of examining critical performance values identified in associated marketing or support literature (e.g., maximum speed, endurance, payload capacity, camera quality, and communication range) and comparing to results observed throughout repeated operation.	The information provided for the system is complete and accurate. The system operated in accordance with published parameters and in some cases, better than advertised.	The information provided for the system is partially complete and accurate. The system operated closely to published parameters.	The information provided for the system is incomplete and inaccurate. The system did not operate as advertised.	No information was available for the system, comparison was not possible.
User Support	**High (76-100)**	**Medium (51-75)**	**Low (1-50)**	**None (0)**
The level of support available to an operator. This evaluation consists of examining the amount and quality of media, documents, specifications, training, and user communities (e.g., forums).	The level of support is very high, with detailed operational and maintenance guidance provided. There is a dedicated website, featuring documentation downloads, user groups for collaborative discussions and queries, and dedicated service personnel to address inquiries.	The level of support facilitates finding answers to inquiries through a FAQ, presentation of system specification values, with some operational and maintenance guidance provided. There is a dedicated website, that provides operator access to some relevant information and/or guidance.	The level of support facilitates finding answers to inquiries through a FAQ, presentation of system specification values, with some operational and maintenance guidance provided. There is a dedicated website, that provides operator access to basic system specifications.	No support is available to operators, the system is only advertised through resellers with availability of information subject to considerable change.

Operational Plan

This section contains the details associated with conducting the proposed operational plan. In support of this plan, the available resources, past experiences, and risk have been identified and analyzed to define appropriate courses of actions, as they relate to potential scenarios. The plan is organized as follows:

- Objective and goals
- Resources
- Operational responsibilities, assignments, and schedule
- Operational criteria
- Operational environments
- Test procedures
- Safety and risk assessment
- Emergency response procedures
- Non-Punitive reporting mechanism

Objective and Goals

The objective of this operation is to capture quantitative and qualitative data relating to performance and inspection of 12 consumer multirotor sUAS to determine suitability as novice-use systems. The goals are to capture required metrics, assess suitability in accordance with outlined criteria, generate observations relating to actual sUAS operation, develop further questions for follow on research, and expand the operational experience of participants. The performance of the specified testing activities are expected to foster and grow sUAS operational and research experience of ERAU UAS students and faculty, in a collaborative team setting. The knowledge, skills, and abilities gained in the design and performance of this plan; related research inquiry, exploration, and analysis; operational planning; and observed operation are anticipated to support future sUAS pursuits of the University and study participants.

Resources

A series of resources will be required to successfully complete the activities outlined in this operational plan. This section contains the details of these resources and how they will be used.

Facilities and Tools

Several ERAU facilities will be used, in addition to University owned assets, in support of this operational plan. The availability of these resources will be critical to the success of the operational testing. The following represent specific facilities and tools necessary to this effort:

- ERAU-Worldwide Headquarters
    - Storage – sUAS, associated paperwork, and data will be secured and stored at this location
    - Infrastructure – WiFi internet access will be used to facilitate communication, planning, briefing, and platform firmware/software updates
    - Conference rooms – meetings may be conducted using available rooms
    - Business tools – PCs, printers, scanners, and other business tools will be used in support of this effort
- ERAU-Daytona Beach Campus
    - Field House – this facility will be used to conduct indoor operations, a student employee will be required to facilitate use
    - Infrastructure – WiFi internet access will be used to facilitate communication, planning, briefing, and platform firmware/software updates
    - Conference/class rooms – meetings may be conducted using available space

Participants

ERAU-Daytona Beach and Worldwide campus students enrolled in UAS-related programs (e.g., BS in UAS Science, MS in Unmanned Systems, and MS in Aeronautics-UAS) will work directly with UAS faculty and staff from both campuses. The faculty will serve as subject matter experts, providing examination and operational oversight, guidance, and flight control (outdoors). The students will conduct flight operations, where applicable, based on demonstrated and assessed knowledge and skill. Several ERAU staff members will also participate and observe operations, assisting in the capture of multimedia materials (pictures and video). A representative of NIAS may also be present to provide support as a Visual Observer under the NIAS COA in the outdoor setting (private property). Several outside parties may also be present to observe operations, at the discretion of the sUAS Testing Points of Contact (Dr. Brent Terwilliger and David Thirtyacre). Any approved non-crewmember participants will be located in pre-defined observation areas, while flight operations are being conducted.

Prior to the commencement of flight operations, all parties will have successfully completed an sUAS operations examination and flight proficiency demonstration conducted by ERAU-W. These tools will be used to confirm appropriate level of knowledge and operational skill of the crewmembers. Any potential crewmember who fails the examination and operational proficiency will not be permitted to control the sUAS. However, they will still be permitted to provide operational support, such as non-participant visual observation and data recording, equipment transport, and perimeter/site security.

The following represent the minimum qualifications recommended to clear operators for indoor sUAS operations and under the NIAS COA (under direct operational supervision of the approved Pilot-in-command):

- All operations
  - Candidate operators will review applicable manufacturer and educational materials describing rules governing conduct and operations; aeronautical decision making and safety practices; and multirotor theory of operation
  - Candidate operators will successfully complete a written test covering previously identified materials AND specific details of assigned sUAS (see Tables 2 and 3 for assignments), achieving a minimum score of 70-percent
  - Candidate operators will successfully exhibit proficient control of an sUAS multirotor operation, while ensuring implementation of safety practices
  - Physical Requirements: 20/20 corrected vision and no medical conditions that would otherwise rule out operational suitability
- Outdoor-specific
  - Pilot-in-command (PIC) will be approved by certificate of waiver or authorization (COA) holder, NIAS
  - Visual Observer (VO) will be approved by COA holder, NIAS
  - The Pilot-in-command will determine roles and responsibilities of crewmembers (operators, visual observers, and others as determined by the pilot-in-command as needed) and participants under their supervision

Faculty – ERAU has a well established record of safety management in aviation operations, including design and conduct of sUAS operations, in both indoor and outdoor settings, using simulation tools and actual sUAS. ERAU-Daytona Beach campus has conducted sUAS operations, including use of tethered and unrestrained fixed-wing and multirotor configurations in support of their UAS curriculum and research, under a Section 333 Grant of Exemption (including civil-use nationwide blanket COA). ERAU-W campus has conducted sUAS operations using tethered and unrestrained multirotor configurations indoors, within a large netted enclosure, and recently outdoors under the NIAS public COA.


Figure 2. ERAU UAS faculty operating sUAS in outdoor (tethered) and indoor (simulated and enclosed) settings

The following ERAU UAS faculty will be leading and conducting the operational flight testing:

- David Thirtyacre, Director of Unmanned Flight Operations and NIAS approved COA Pilot-in-command, ERAU-W
- Stefan Kleinke, Program Chair of the BS in Unmanned Systems Applications and NIAS approved COA Visual Observer, ERAU-W
- Dr. Brent Terwilliger, Program Chair of the MS in Unmanned Systems, ERAU-W
- Dr. David Ison, Research Chair of the College of Aeronautics, ERAU-W
- Scott Burgess, Program Chair of the BS in Aeronautics (featuring UAS minor), ERAU-W
- Dr. Joe Cerreta, Assistant Professor, ERAU-DB

The following ERAU UAS faculty and administrators provided support for this project:

- Dr. Brad Sims, Chief Academic Officer, ERAU-W
- Dr. Kenneth Witcher, Dean of the College of Aeronautics, ERAU-W
- Dr. Dan Macchiarella, Dean of the College of Aviation, ERAU-DB
- Dr. Michael Wiggins, Department Chair of Aeronautical Science, ERAU-DB
- Dr. Dennis Vincenzi, Department Chair of Undergraduate Studies, ERAU-W
- Dr. Ian McAndrew, Department Chair of Graduate Studies, ERAU-W
- Dr. Patrick Ford, Assistant Professor of Aeronautics, ERAU-W
- Dr. John Robbins, Program Coordinator of the BS in UAS Science, ERAU-DB

Students – the following ERAU UAS-related program students will be conducting the research and some of the operational flight testing (under faculty oversight):

- Christian Wilder, MSUS, ERAU-W
- Brett Chereskin, MSUS, ERAU-W; and ERAU-DB Army ROTC faculty member
- Jonathan Westberry, MSA-UAS, ERAU-W
- Stacy Martorella, MSUS, ERAU-W
- Cody Dangler, BSUASS, ERAU-DB
- Jacob Aytes, BSUASS, ERAU-DB
- Jordan Lamar, BSUASS, ERAU-DB
- Nicholas Kannard, BSUASS, ERAU-DB
- Thomas Ludwick, BSUASS, ERAU-DB
- K'Andrew France-Beckford, BSUASS, ERAU-DB

The following students provided research and development support for design of this *Operational Test Plan* and sUAS platform data:

- Matt Pignataro, MSUS, ERAU-W
- Jill Brown, Master of Systems Engineering, ERAU-W
- James K. Bonner, MSA-UAS, ERAU-W
- Ryan Langlois, BSA-UAS and MSUS, ERAU-W
- Nicholas Damron, BS in Technical Management, ERAU-W
- Mathew Edeker, BSUASS, ERAU-DB
- John Middleton, BSUASS, ERAU-DB
- Rollin LeMand, BSUASS, ERAU-DB
- Kalina Gonzales, BSUASS, ERAU-DB

Staff - the following ERAU staff members will be providing support for the project:

- Jordan Weis, UAS Flight Training Standards Manager and Chief UAS Pilot, ERAU-DB
- Shannon Stenberg, Assoc. College Administrator, College of Aeronautics, ERAU-W
- Molly Justice, Director of Communications, University Marketing, ERAU
- Trish Kabus, Creative Director, ERAU-W
- Paulo Jiminez, Media Producer, ERAU-W
- Greg Igel, Instructional Design and Development, ERAU-W
- Stephen Anest, Instructional Design and Development, ERAU-W
- Tim Davis, Instructional Design and Development, ERAU-W

Other – NIAS may provide a representative to support Visual Observer duties for outdoor operations conducted under the NIAS COA (see Figure 3); otherwise, Stefan Kleinke will serve as NIAS COA Visual Observer.

Figure 3. ERAU-W UAS faculty operating sUAS outdoors under NIAS COA

sUAS and Tools

The following represent the sUAS purchased by ERAU-W or donated by manufacturers and resellers.

- 3DR Solo (donated by 3D Robotics)
- DJI Inspire 1 (purchased by ERAU-W)
- DJI Phantom 3 (Standard; purchased by ERAU-W)
- Parrot Bebop 2 (purchased by ERAU-W)
- Elanview Cicada (use donated by Hobbico)
- Helimax Form500 (use donated by Hobbico)
- Yuneec Typhoon 4K (use donated by Yuneec)
- Syma X8C Venture (purchased by ERAU-W)
- Dromida Venture (use donated by Hobbico)
- Dromida Kodo (use donated by Hobbico)
- Hubsan X4 Pro (use donated by Hobbico)
- Xiro XPlorer G (use donated by Hobbico)

Each of the systems weighing greater than .55 pounds will be registered with the FAA prior to conducting operational testing, in accordance with Federal and NIAS requirements for operation under the NIAS COA. Each system features, at a minimum, a transmitter, platform, two batteries (primary and spare), charger, and spare propellers. Some systems also feature a camera sensor, video and data communication equipment, and/or transport storage. Protective eyewear, tether, and anchor have also been acquired to support further operational safety. Additionally, personal tools, such as laptop PCs, tablets, cameras, diagnostic equipment, and repair tools, will be used in support of this effort.

Operational Documentation

A series of operational documents and logs will be compiled for each sUAS to confirm manufacturer recommendations, operational limitations and constraints, and record operational details of the system, such as maintenance and operational hours on the airframe. This information will be contained in a binder, unique to each aircraft, with identifying information, such as serial numbers of platform, transmitter, and batteries, recorded, when available. These binders will accompany the sUAS and be stored, along with any other associated records, such as receipts and FAA registration paperwork, at ERAU-W headquarters.

The following represent the manufacturer manuals and factsheets of the sUAS to be used for this effort. Where applicable, appropriate notes relating to specific operational constraints or requirements are noted.

- 3DR Solo
  - Manual: https://3dr.com/wp-content/uploads/2016/03/v9_02_25_16.pdf
  - NOTE: Do not fly indoors (requires active GPS) and ensure 20ft horizontal separation
- DJI Inspire 1
  - Manual: https://dl.djicdn.com/downloads/inspire_1/en/Inspire_1_User_Manual_en_v2.0_1218.pdf
- DJI Phantom 3 (Standard)
  - Manual: https://dl.djicdn.com/downloads/phantom_3_standard/en/Phantom_3_Standard_User_Manual_v1.4_en_0112.pdf

- Parrot Bebop 2
  - Manual: https://parrotcontact.parrot.com/website/user-guides/download-user-guides.php?pdf=bebop-2/Bebop-2_User-guide_UK.pdf
- Elanview Cicada
  - Manual: http://www.pnj-cam.com/img/cms/Manuel-CICADA-PLUS_EN.pdf
- Helimax Form500
  - Manual: http://manuals.hobbico.com/hmx/hmxe0863-manual.pdf
- Yuneec Typhoon 4K
  - Manual: https://www.yuneec.com/download/manuals/q500_4k_user_manual.pdf
  - NOTE: Indoor operation requires disabling GPS and operating under Angle Mode
- Syma X8C Venture
  - Manual: http://hitoys.org/symatoys/20150213/2015021314391289.pdf
- Dromida Vista
  - Manual: http://manuals.hobbico.com/did/dide02-manual.pdf
- Dromida Kodo
  - Manual: http://manuals.hobbico.com/did/dide0005-quickstart-manual.pdf
- Hubsan X4 Pro
  - Manual: http://manuals.hobbico.com/hbn/x4-pro-manual.pdf
- Xiro XPlorer G
  - Manual: http://storow.xirodrone.com/file-English%20User%20Manual.pdf

Figure 4. ERAU-W UAS faculty operating sUAS within ERAU-W netted enclosure

Figure 5. ERAU-W operation of Dromida Ominus sUAS within ERAU-W netted enclosure

Operational Responsibilities, Schedule, and Assignments

Testing and evaluation operations are to be held over a two-day period, from April 23 to 24, 2016. Table 2 depicts the planned operations test schedule, with groups (grp) 1 and 2 conducting simultaneous operations indoors at the ERAU-Daytona Beach Field House and group 3 conducting individual operations outdoors on the personal property of a ERAU alumnus. Each group will be led and operate under the supervision of an assigned ERAU-W UAS faculty member.

Table 2. sUAS Flight Operations Testing Schedule

Key
Flight (Outdoors)
Flight (Indoors)
Max End (Inside)
PRE-FLIGHT TEST
BRIEFING
TEST ENDS
NO TESTING

	Day 1 Indoors Grp 1 (Terwilliger)	Day 1 Indoors Grp 2 (Ison)	Day 1 Outdoors Grp 3 (Thirtyacre)	Day 2 Indoors Grp 1 (Terwilliger)	Day 2 Indoors Grp 2 (Ison)	Day 2 Outdoors Grp 3 (Thirtyacre)
8:00 AM	PRE-FLIGHT TEST	PRE-FLIGHT TEST	PRE-FLIGHT TEST	BRIEFING	BRIEFING	BRIEFING
8:30 AM	PRE-FLIGHT TEST	PRE-FLIGHT TEST	PRE-FLIGHT TEST	Phantom 3 (RL-TL)	X8C (SM-RLe)	Inspire (SB-BC)
9:00 AM	BRIEFING	BRIEFING	BRIEFING	Phantom 3 (RLe-JW)	X4 Pro (RL-SM)	Inspire (SB-BC)
9:30 AM	Typhoon (RL-JW)	Form500 (SM-TL)	Phantom 3 (SK-JC)	Kodo (JW-RLe)	X8W (TL-KG)	Solo (SK-JC)
10:00 AM	Typhoon (CW-CD)	Inspire (RL-JA)	Phantom 3 (SK-JC)	Kodo (KG-SM)	Vista (CW-CD)	Solo (SK-JC)
10:30 AM	Bebop 2 (CD-JW)	Inspire (JW-CW)	Kodo (SB-BC)	Xplorer (CW-SM)	Vista (JA-KG)	Cicada (SB-BC)
11:00 AM	Bebop 2 (RL-CW)	Cicada (SM-TL)	Kodo (SB-BC)	Xplorer (KG-RL)	X4 Pro (CW-RLe)	Cicada (SB-BC)
11:30 AM	Bebop 2 (CW)	Cicada (JA-CD)	Vista (SK-JC)	Xplorer (RL)	X4 Pro (RLe)	Bebop 2 (SK-JC)
12:00 PM	Typhoon (CD)	For 500 (JW-JA)	Vista (SK-JC)	TEST ENDS	X8C (KG)	Bebop 2 (SK-JC)
12:30 PM	LUNCH	LUNCH	LUNCH		TEST ENDS	LUNCH
1:00 PM	LUNCH	LUNCH	LUNCH			LUNCH
1:30 PM	Cicada (TL)	Inspire (JA)	X8C (SB-BC)			Form500 (SB-BC)
2:00 PM	Phantom 3 (JW)	Form500 (JA)	X8C (SB-BC)			Form500 (SB-BC)
2:30 PM	Kodo (SM)	Vista (CD)	X4 Pro (SK-JC)			Typhoon (SK-JC)
3:00 PM	TEST ENDS	TEST ENDS	X4 Pro (SK-JC)			Typhoon (SK-JC)
3:30 PM			Xplorer (SB-BC)			TEST ENDS
4:00 PM			Xplorer (SB-BC)			
4:30 PM			TEST ENDS			
Time (hrs)	**7.5**	**7.5**	**9**	**4.5**	**5**	**8**

Group 1 will operate sUAS indoors, in accordance with ERAU UAS operational policies, and under the supervision of faculty member Dr. Brent Terwilliger. *Group 2* will operate sUAS indoors, in accordance with ERAU UAS operational policies, and under the supervision of faculty member Dr. David Ison. *Group 3* will operate sUAS outdoors, in accordance with Federal, State, and local laws, NIAS COA provisions, and ERAU UAS operational policies, and under the supervision of NIAS approved Pilot-in-command David Thirtyacre and an assigned Visual Observer. On day 1 or before, all parties will have successfully completed an sUAS operations examination and flight proficiency demonstration to confirm appropriate level of knowledge and operational skill. Each indoor sUAS operator will be required to review the operational details and requirements of assigned sUAS, as identified in Table 3.

Table 3. Indoor sUAS Operational Testing Assignments

Key	Terwilliger	Ison	Westberry	Langlois	Wilder	Martorella	LeMand	Gonzales	Aytes	Dangler	Ludwick	COUNT
OVERSIGHT	Solo (no indoor testing)											
PRIME (OP)		INSPIRE	INSPIRE	INSPIRE	INSPIRE				INSPIRE			5
BACKUP (OP)	PHANTOM		PHANTOM	PHANTOM			PHANTOM				PHANTOM	5
BACKUP/ENG		CICADA				CICADA			CICADA	CICADA	CICADA	5
NO ASSIGNMENT	BEBOP		BEBOP	BEBOP	BEBOP					BEBOP		5
N/A		FORM500	FORM500			FORM500			FORM500		FORM500	5
	TYPHOON		TYPHOON	TYPHOON	TYPHOON					TYPHOON		5
		X8C				X8C	X8C	X8C			X8C	5
		Vista			Vista			Vista	Vista	Vista		5
	KODO		KODO			KODO	KODO	KODO				5
		X4		X4	X4	X4	X4					5
	XPLORER			XPLORER	XPLORER	XPLORER		XPLORER				5
	5	6	6	6	6	6	4	4	4	4	4	

At least two primary operators, a backup and a backup/engine (eng) test operator, have been assigned to each platform to increase the potential pool of successful operational candidates. Each scheduled flight operation will feature use of this pair (primary and backup operators); one to control the aircraft (operator) and the other to serve as a visual observer and data recorder. Prior to the commencement of any sUAS flight testing, an operational briefing will be held. An effort will also be made to ensure each platform is flown at least twice, indoors.

Each outdoor sUAS operator will be required to review the operational details and requirements of assigned sUAS, as identified in Table 4.

Table 4. Outdoor sUAS Operational Testing Assignments[1]

Key
OVERSIGHT
PRIME (OP)
BACKUP (OP)
NO ASSIGNMENT

Thirtyacre (PIC)	NIAS (VO)	Kleinke	Burgess	Cerreta	Chereskin	COUNT
SOLO		SOLO		SOLO		3
INSPIRE			INSPIRE		INSPIRE	3
PHANTOM		PHANTOM		PHANTOM		3
CICADA			CICADA		CICADA	3
BEBOP		BEBOP		BEBOP		3
FORM 500			FORM 500		FORM 500	3
TYPHOON		TYPHOON		TYPHOON		3
X8C			X8C		X8C	3
VISTA		VISTA		VISTA		3
KODO			KODO		KODO	3
X4		X4		X4		3
XPLORER			XPLORER		XPLORER	3
12	0	6	6	6	6	

At least two primary operators (experienced pilot), a backup and a backup/engine (eng) test operator, have been assigned to each platform. Each scheduled flight operation will feature use of this pair (primary and backup operators); one to control the aircraft (operator) and the other to serve as a visual observer and data recorder. Prior to the commencement of any sUAS flight testing, an operational briefing will be held. An effort will also be made to ensure each platform is flown at least twice, outdoors. In addition, the Pilot-in-command (PIC) will provide operational oversight, with Visual Observer (VO) providing observation and further data recording.

Operational Criteria

The following represents the recommended criteria for conducting the proposed sUAS operations:

- *ERAU Safety Culture* – ensuring safety is critical to successful operation, ERAU supports everyone in voicing any concerns without fear of retribution
    - If anyone is uncomfortable with any phase of operations, they may stop the procedure until all concerns are heard and addressed with suitable mitigation
    - Upon observation of any questionable practices or violation of law and/or policies, participants are encouraged to report details of the occurrence to one or more ERAU representatives, without punitive repercussion
- *Operator Qualifications* - each operator will complete a pre-flight safety examination and sUAS operational demonstration[2]
    - Comprehension of appropriate rules governing conduct and operations
    - Aeronautical decision making
    - Multirotor theory of operation
    - Exhibition of control and proficiency
    - Comprehension of safety practices

[1] ***Note:*** Stefan Kleinke has been approved by NIAS to serve as a Visual Observer for UAS operatiosn conducted under their COA. If an NIAS representative is not available, Stefan Kleinke will provide support for this role and another ERAU representative will be added as a backup operator.

[2] Only the COA PIC must be an FAA certified airman

- *Safety Briefing* - all participants will participate in an operational briefing
    - Roles and responsibilities of all involved parties, including crew members
    - Operational objective and test plans (steps), specific to the operational locale (indoors or outdoors)
    - Known issues, risks, and contingency plans
    - Details of the environment, sUAS configuration, and other factors that can affect operations (e.g., availability of on-site medical support; maintenance for diagnosis and repair; power charging; and facilities)
- *Safety Equipment* - appropriate safety equipment and apparel will be required for operators, visual observers, and any other crewmembers
    - Eye protection
    - Closed toe shoes (e.g., boots)
    - Full length pants (e.g., cargo or khaki pants)
    - Sleeved shirts (no tank tops)
    - Tether and anchor (for sUAS greater than 2.5 pounds, indoors)
- *Inspection* - a pre-flight inspection of the environment and sUAS will be conducted
    - Check weather forecast for area
    - Confirm visibility and weather is acceptable for planned flight operations (e.g., visual flight rules [VFR] in visual meteorological conditions [VNC])
    - Note direction and speed of wind and plan appropriate contingencies (e.g., identification of alternative landing/recovery sites)
    - Confirm planned operational area is clear of traffic and debris; establish a sufficient perimeter to ensure maintenance of safety
    - Identify and determine risk of obstacles, terrain, and hazards present in the area, such as buildings, power lines, and foliage
    - Identify planned recovery location and an alternate location, as a contingency; confirm with all crewmembers
    - Ensure non-crewmember participants are located sufficient distance from startup, launch, operational, and recovery locations
    - Confirm appropriate permission for planned operation has been obtained; e.g., FAA (including ATC coordination, if necessary), landowner, property management, insurance provider, and any individuals that might be affected by the flight (privacy)
    - If possible, a spectrum analyzer will be used to identify potential presence of conflicting signals or interference in the operational area
    - Airworthiness and appropriate control response of each platform, including confirmed full charge of at least two batteries (primary and spare)
- *Testing* – operations will be designed to satisfy research objective and goals, while ensuring safety is maintained
    - At least two tests per platform will be attempted for each environment (indoors and outdoors) to measure operational effectiveness and qualitative measures (e.g., ease of operation, quality of construction, and accuracy of published quantitative performance data)
    - The total flight time of a platform, operated both indoors and outdoors, will be recorded and analyzed to derive a mean operational endurance value
    - A hover endurance test will be attempted, with the sUAS restrained (tethered and anchored), to determine worst-case, operational endurance, under load
    - A maximum test duration of 30 minutes, per platform, is anticipated
    - Final assignments to operate and test specific sUAS will be made on each day of testing, in accordance with availability, demonstrated proficiency, and need
    - If testing concludes earlier than expected on day 1, an attempt will be made to exchange sUAS (1-6 and 7-12) between locations, to advance schedule

- An effort will be made to ensure that at least one faculty member and two students will conduct operational testing, per platform
- Each platform should be tested by a two-person team, one to operate and the other to observe flight, while making necessary recordings, measurements, and test step data entries

- *Public COA UAS Operations* - outdoor operations will be conducted under the NIAS COA
  - A notice to airman (NOTAM) will be filed covering the outdoor operation environment for planned operational periods; if operations are cancelled (e.g., weather), the NOTAM will be cancelled
  - All applicable operational information will be logged and reported (to appropriate body; e.g., NIAS, FAA, or ERAU), including number of takeoffs and landings, operational hours, crashes, accidents, mishaps, and injury)
  - UAS must operate with equivalent level of safety as manned aircraft
    - Collision avoidance with other airspace operators
    - Ground safety under flight path
  - Observers must be utilized at all times to provide see- and-avoid capability
    - Ground based
    - Chase plane
  - Visual Observer Requirements
    - Visual observer assists in collision avoidance, which includes other traffic, clouds, obstructions, and terrain
    - PIC cannot operate UAS beyond unaided[3] visual range of observers
    - Observer must inform the PIC before losing sufficient visual contact with the UAS
    - Observers must maintain direct communication with operator at all times
    - Observers cannot perform other duties or have other responsibilities – put your cell phones away
    - UAS operators and observers must be responsible for only one UAS at a time
  - FAR 91.111 – Operating near other aircraft
    - No person may operate an aircraft so close to another aircraft as to create a collision hazard
    - Per COA, concurrent UAS and manned aircraft operations prohibited
  - FAR 91.113 (b, d, and f) Right of Way, Well Clear, and Converging and Overtaking rules
    - See and avoid other aircraft
    - When aircraft approach head-on, each shall alter course to the right
    - Aircraft on final approach for landing have right of way
  - FAR 91.155 – Basic VFR weather minimums
    - Per COA, UAS operations must be conducted under visual flight rules (VFR)
    - Weather minimums
    - Must stay clear of clouds
    - 500 feet below cloud ceiling
    - Minimum 3 miles visibility
  - Freedom from Unwarranted Surveillance Act (SB 766: Surveillance by a Drone; enacted June 2015)
  - Florida Statute 860.13 Operation of aircraft while intoxicated or in careless or reckless manner
- *Privacy* – requirements associated with ensuring and confirming privacy will be met
  - Permission to capture video and photography will be secured from a representative of property owner
  - A release form will be secured from each participant not employed by ERAU

[3] Except for the use of sunglasses and/or corrective lenses per FAA Order 8900.1 Volume 16 *Unmanned aircraft systems*

Operational Environments

As previously noted, operations are planned for two separate venues, indoor operations at the ERAU-Daytona Beach Field House and outdoor operations on private property (under the NIAS-COA). The ERAU-Daytona Beach Field House has been reserved from 8AM to 5PM for Saturday 23 April and 8AM to 1PM for Sunday 24 April. Appropriate documentation regarding certification of privacy secured from landowner, in accordance with the State of Florida's Freedom from Unwarranted Surveillance Act (SB 766: Surveillance by a Drone; enacted June 2015).

Indoor Operations

The indoor operations will be conducted, simultaneously within two operational envelopes limited to a radius of 25 feet (horizontal) and an altitude of approximately 10 feet (above ground level). Entrance into the envelope (across or within perimeter; to be marked with safety cones) will be limited to the operational aircrew (primary operator, observer/backup, and oversight faculty member; see Figure 6).

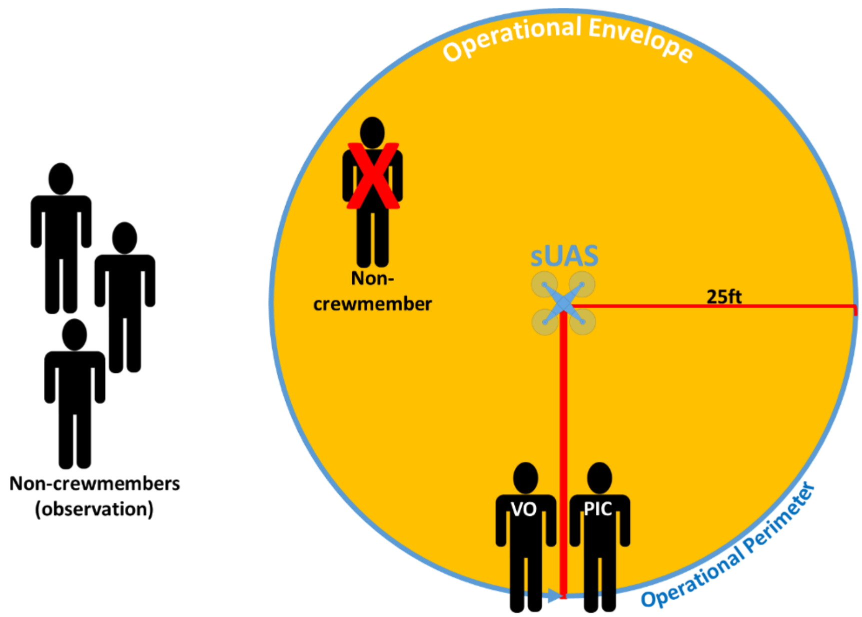

Figure 6. Indoor sUAS operations perimeter and layout (individual sUAS)

The two indoor operational envelopes will be offset from one another to maximize separation (see Figure 7 and Figure 8) and minimize risk to other participants. The movements of all non-crewmember participants during flight operations will be limited to the bottom right of the bleachers (located on leftmost wall) and the walkway connecting the entrance to the gymnasium (see Figure 7 and Figure 8). Entry to the operational environment (i.e., gymnasium) will be limited and controlled with entrance approved by responsible ERAU-W UAS faculty group leaders. Enforcement of entry (i.e., security) will be performed by those participants not conducting operational assessment (crewmembers) or other assigned duties. All moveable obstacles will be cleared from the environment, prior to initiating operations. It has been requested that ERAU-W and testing participants be the only occupants of the gymnasium, all basketball hoops be retracted, and that the folding bleachers should be stored (right-most bleachers, as depicted in Figure 7 and Figure 8, are permanent).

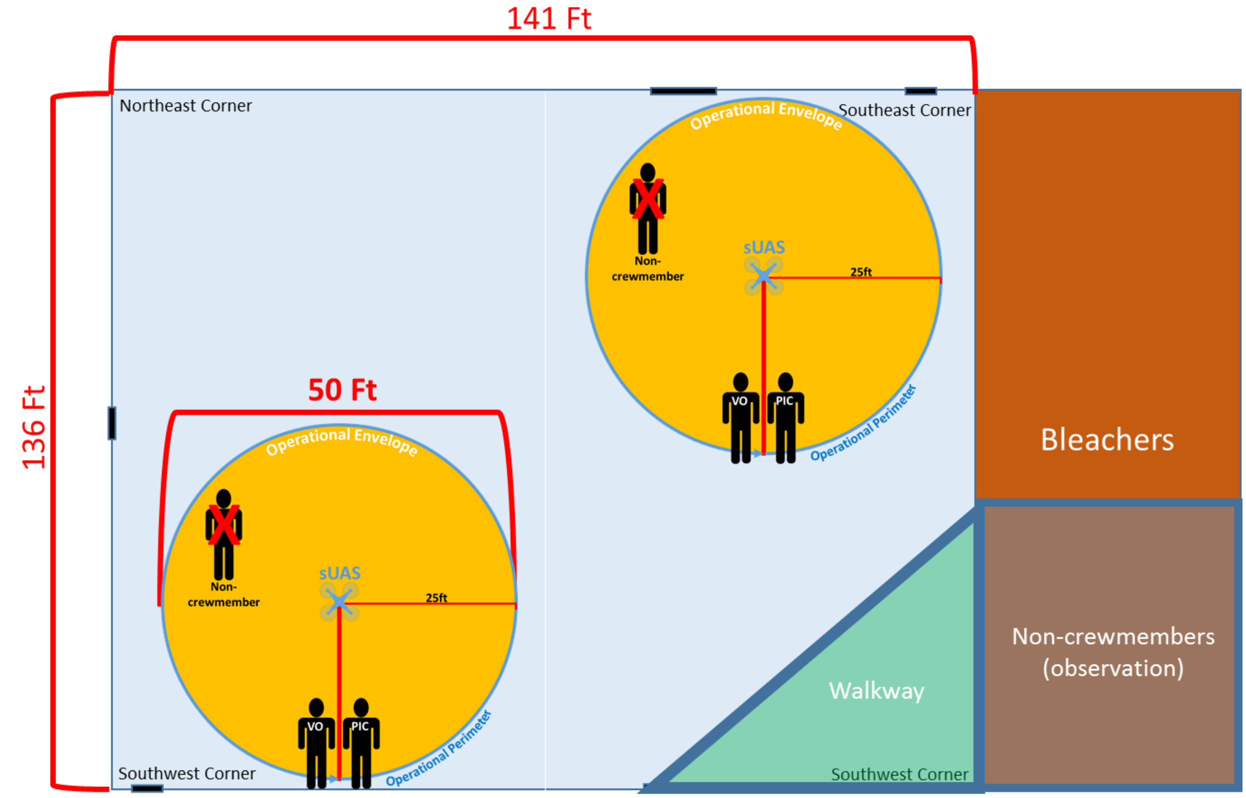

Figure 7. Indoor operational layout

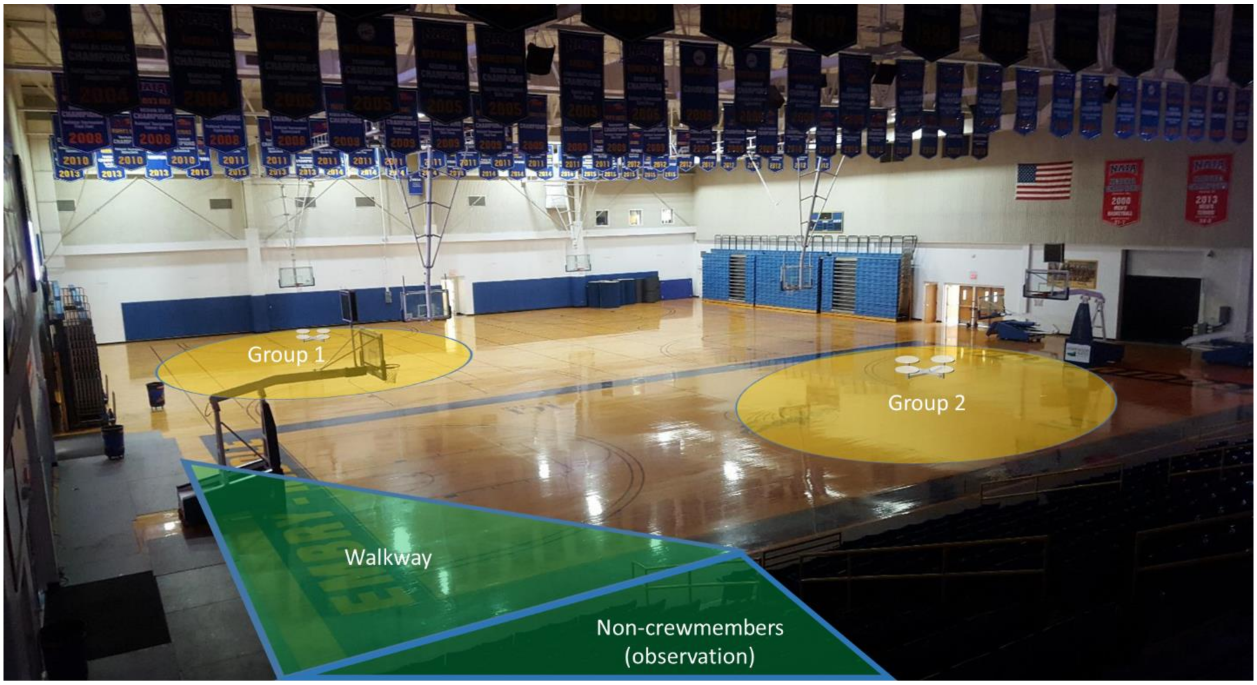

Figure 8. Rendering of indoor operational layout and setting[4]

[4] ***Note:*** *Depicted obstacles, such as basketball nets, will be retracted or removed from operational area.*

Outdoor Operations

The outdoor operations will be conducted, individually within the provisions of the NIAS COA and Federal, State, and local laws. The use of the private-property has been provided by an ERAU alumnus; the area is more than five-nautical miles from the closest towered airports and greater than two-nautical miles from closest untowered airport/heliport/seaplane-base. Based on the distance to local airports and airfields, a "full COA" and letter of agreement (LOA) with local airports will not be required to conduct operations at this location ("blanket COA" suitable). A specific operational launch and recovery position will be determined after site-inspection by the NIAS designated COA Pilot-in-command and Visual Observer. These representatives will ensure the site meets all requirements associated with conducting flight operations under the NIAS COA. The specific details of the operational environment have not been included to protect the privacy of the landowner, as this document is expected to be published and made available to the public. These details can be made available, privately, to support appropriate safety review and operational planning evaluation.

Test Procedures

A series of test flights will be performed, using documented steps, including safety checks and operational maneuvers. The procedures feature several common flight maneuvers, designed to assess ease and intuitiveness of operation, control response, and stability. These common maneuvers include commanded altitude (see Figure 9), horizontal orientation (yaw; see Figure 10), and longitudinal (see Figure 11) and lateral (see Figure 12) positional changes.

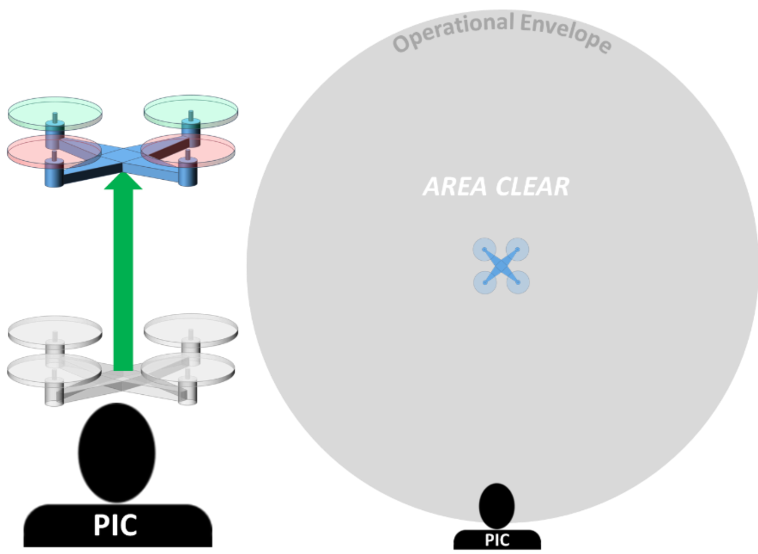

Figure 9. sUAS indoor altitude change

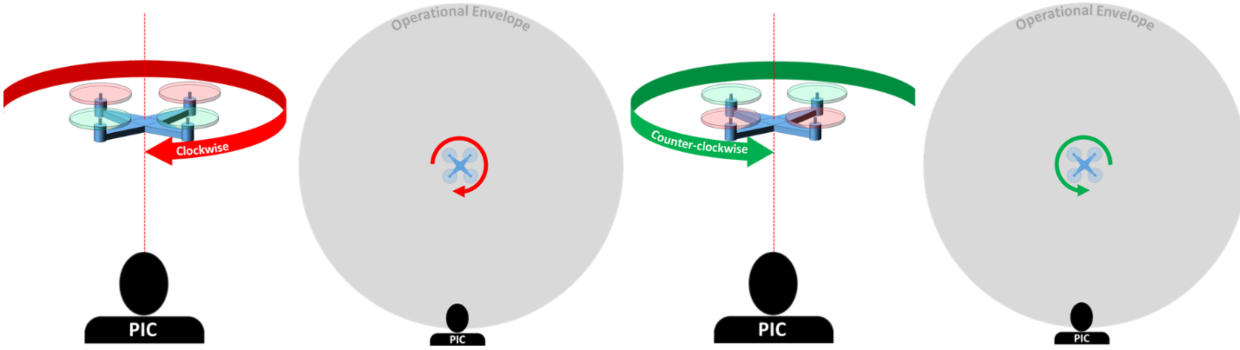

Figure 10. sUAS indoor horizontal orientation-yaw maneuvering

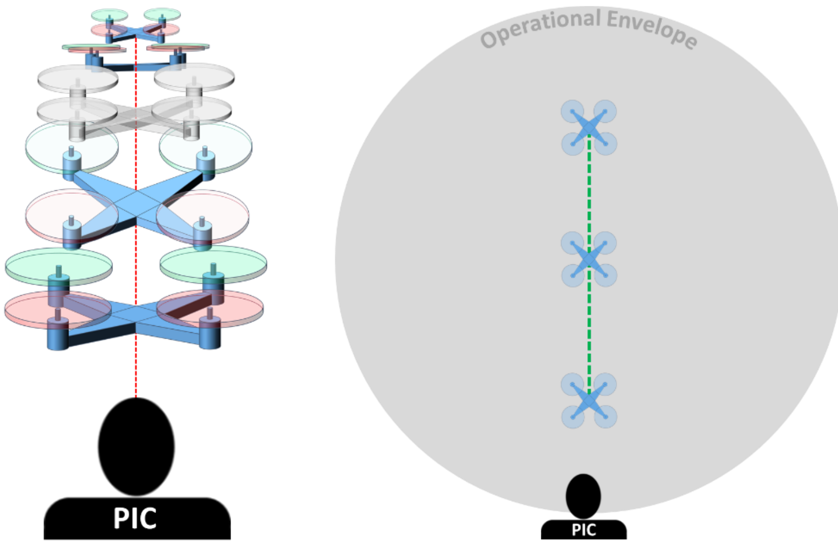

Figure 11. sUAS indoor longitudinal maneuvering

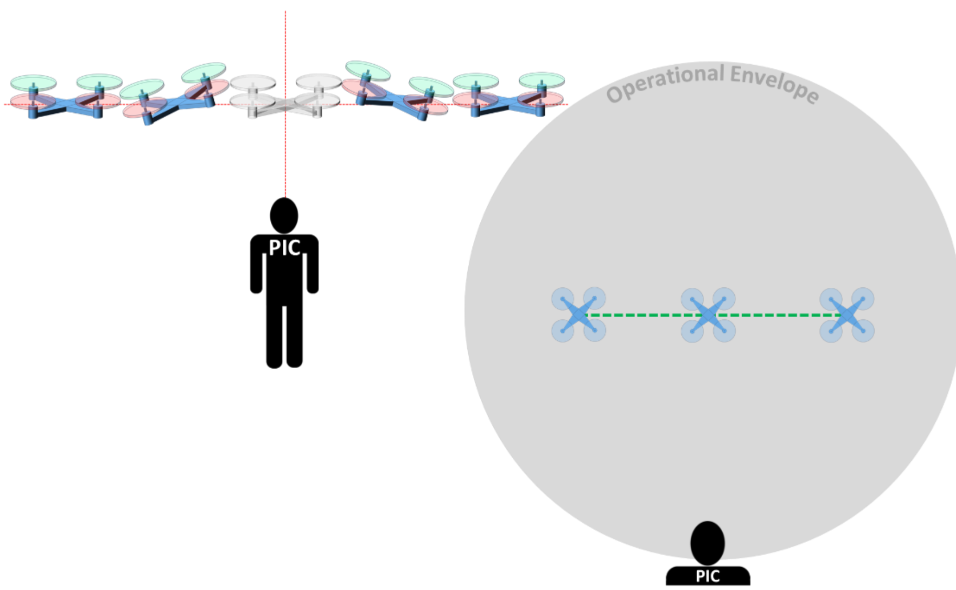

Figure 12. sUAS indoor lateral maneuvering

Two separate sets of procedures will be used for the indoor flight tests, operational assessment and maximum hover endurance under load. The indoor operational assessment has been designed to provide evaluation and rating of platform performance in a tightly controlled environment, to capture qualitative and quantitative data points for operational endurance, camera sensor quality and performance, stability assistance, station keeping, and construction quality. The steps of the operational test procedure are depicted in Table 5.

Table 5. Indoor Operational Assessment Test Procedure

Step	Instruction (Actions)	Recorded Values	Pass/Fail	Notes (Observations)
1)	Record battery voltage			
2)	Assemble system, according to manufacturer guidelines	N/A		
3)	Prepare for operation, according to manufacturer guidelines	N/A		
4)	PIC, visually inspect platform	N/A		
5)	Clear operational area	N/A		
6)	START motors, set idle	N/A		
7)	Record start time (HH:MM:SS)			
8)	Perform/assess manual LAUNCH capability, when cleared	N/A		
9)	Perform control check: yaw, pitch, roll, throttle	N/A		
10)	Use controls to capture still photo image	N/A		
11)	Use controls START video record, adjust gain features	N/A		
12)	Station Keeping: manual hover, 5 feet AGL	N/A		
13)	Assess z coordinate, altitude hold	N/A		
14)	Assess x, y coordinates, position hold	N/A		
15)	Station Keeping: manual hover, 10 feet AGL	N/A		
16)	Assess z coordinate, altitude hold	N/A		

Step	Instruction (Actions)	Recorded Values	Pass/Fail	Notes (Observations)
17)	Assess x, y coordinates, position hold	N/A		
18)	Rotate platform right (yaw) 0-360 degrees (clockwise)	N/A		
19)	Rotate platform right (yaw) 0-360 degrees (counter-clockwise)	N/A		
20)	Transition to lateral flight left, 10 feet AGL for 10 feet with nose facing 0 degrees **(same direction PIC facing)**, then hover	N/A		
21)	Return to center position, then hover	N/A		
22)	Transition to lateral flight right 10 feet AGL for 10 feet, then hover	N/A		
23)	Return to center position, then hover	N/A		
24)	Transition to longitudinal flight forward (10 feet), then hover	N/A		
25)	Return to center position, then hover	N/A		
26)	Transition to longitudinal flight reverse for 10 feet, then hover	N/A		
27)	Return to center position, then hover	N/A		
28)	Rotate 180-degrees, then hover	N/A		
29)	Transition to lateral flight left, 10 feet AGL for 10 feet with nose facing 180 degrees **(opposite direction PIC facing)**, then hover	N/A		
30)	Return to center position, then hover	N/A		
31)	Transition to lateral flight right 10 feet AGL for 10 feet, then hover	N/A		
32)	Return to center position, then hover	N/A		
33)	Transition to longitudinal flight forward (10 feet), then hover	N/A		
34)	Return to center position, then hover with platform facing 0 degrees	N/A		

Step	Instruction (Actions)	Recorded Values	Pass/Fail	Notes (Observations)
35)	If system has an automatic functionality, place in automatic hover and assess response; otherwise place in hover until battery warning is exhibited and proceed to step 42.	N/A		
36)	Station Keeping: automatic hover, 5 feet AGL	N/A		
37)	Assess z coordinate, altitude hold	N/A		
38)	Assess x, y coordinates, position hold	N/A		
39)	Station Keeping: automatic hover, 10 feet AGL	N/A		
40)	Assess z coordinate, altitude hold	N/A		
41)	Assess x, y coordinates, position hold	N/A		
42)	Use controls to STOP video record	N/A		
43)	Land platform (upon battery warning)	N/A		
44)	Record recovery time (HH:MM:SS)			
45)	STOP motors	N/A		
46)	Turn platform OFF	N/A		
47)	Remove battery	N/A		
48)	Record battery voltage, post-flight			
49)	Disassemble system, as directed by manufacturer	N/A		
50)	**END OF FLIGHT OPERATIONS**	N/A		
51)	Record operational endurance (MM:SS)			
52)	Assess quality of captured still image	N/A		
53)	Assess quality of recorded video	N/A		
54)	Assess ease of assembly and preparation	N/A		

Step	Instruction (Actions)	Recorded Values	Pass/Fail	Notes (Observations)
55)	Assess placement of controls	N/A		
56)	Assess experience level adjustment (rate gains)	N/A		
57)	Assess gimbal stability	N/A		
58)	Assess responsiveness of platform (given rate gain settings)	N/A		
59)	Assess recoverability (forgiveness of flight controls)	N/A		
60)	Assess automatic features (score 0, if N/A)	N/A		
61)	Assess quality of construction	N/A		

The indoor indoor maximum hover endurance under load test has been designed to capture quantitative data points for operational endurance. For this test, the aircraft will be secured to the ground (tethered and anchored) and powered to a hover throttle setting, simulating operation under maximum loading. The results are anticipated to identify a worse-case operational endurance value that can assist with future safety analysis and operational planning. The steps of the indoor maximum hover endurance under load test procedure are depicted in Table 6.

Table 6. Indoor Maximum Hover Endurance Under Load Test Procedure

Step	Endurance Test	Recorded Values	Pass/Fail	Notes (Observations)
1	Record battery voltage			
2	Assemble system, as directed by manufacturer	N/A		
3	PIC, visually inspect platform	N/A		
4	Clear operational area	N/A		
5	Connect tie down mechanism (lanyard, tether, etc.) to platform	N/A		
6	START motors (idle)	N/A		
7	Record start time (HH:MM:SS)	N/A		
8	Set to hover flight (hold throttle controls at applicable setting)	N/A		

Step	Endurance Test	Recorded Values	Pass/Fail	Notes (Observations)
9	Record low battery warning indication (HH:MM:SS)			
10	Land platform	N/A		
11	Record recovery time (HH:MM:SS)			
12	Stop motors	N/A		
13	Turn platform OFF	N/A		
14	Remove battery	N/A		
18	Record battery voltage	N/A		
19	**END OF FLIGHT OPERATIONS**	N/A		

The outdoor operational assessment has been designed to provide evaluation and assessment of platform performance in an actual sUAS operational environment, to capture qualitative and quantitative data points for operational endurance, camera sensor quality and performance, stability assistance, maneuverability, station keeping and waypoint following. The steps of the operational test procedure are depicted in Table 7.

Table 7. Outdoor Operational Assessment Test Procedure

Step	Instruction (Actions)	Recorded Values	Pass/Fail	Notes (Observations)
1)	Record battery voltage			
2)	Assemble system, according to manufacturer guidelines	N/A		
3)	Prepare for operation, according to manufacturer guidelines	N/A		
4)	PIC, visually inspect platform	N/A		
5)	Set HOME position	N/A		
6)	Clear operational area	N/A		
7)	START motors, set idle	N/A		

Step	Instruction (Actions)	Recorded Values	Pass/Fail	Notes (Observations)
8)	Record start time (HH:MM:SS)			
9)	Perform/assess manual LAUNCH capability, when cleared	N/A		
10)	Perform control check: yaw, pitch, roll, throttle	N/A		
11)	Use controls to capture still photo image	N/A		
12)	Use controls START video record, adjust gain features	N/A		
13)	Station Keeping: set automatic hover, 10 feet AGL	N/A		
14)	Assess z coordinate, automatic altitude hold	N/A		
15)	Assess x, y coordinates, automatic position hold	N/A		
16)	Station Keeping: set automatic hover, 5 feet AGL	N/A		
17)	Assess z coordinate, automatic altitude hold	N/A		
18)	Assess x, y coordinates, automatic position hold	N/A		
19)	Measure maximum speed, GPS ON			
20)	Measure maximum speed, GPS OFF			
21)	Assess operational range of video link	N/A		
22)	Assess operational range of data link	N/A		
23)	Assess visual orientation of platform at distance	N/A		
24)	Enter oval pattern, manual control	N/A		
25)	Assess FPV display	N/A		
26)	Assess Geo-fencing limits	N/A		
27)	Assess Follow-me feature	N/A		

Step	Instruction (Actions)	Recorded Values	Pass/Fail	Notes (Observations)
28)	Perform manual recovery procedure	N/A		
29)	Set automatic route waypoints	N/A		
30)	Perform/assess automatic LAUNCH capability	N/A		
31)	Enter automatic waypoint to waypoint flight pattern	N/A		
32)	Assess pattern integrity	N/A		
33)	Enter oval pattern, automatic control	N/A		
34)	Use controls to STOP video record	N/A		
35)	Automatic recovery, upon battery warning	N/A		
36)	Record recovery time (HH:MM:SS)			
37)	STOP motors	N/A		
38)	Turn platform OFF	N/A		
39)	Remove battery	N/A		
40)	Record battery voltage			
41)	**END OF FLIGHT OPERATIONS**	N/A		
42)	Record operational endurance (MM:SS)			

Step	Instruction (Actions)	Notes (Observations)
43)	Assess quality of captured still image	
44)	Assess quality of recorded video	
45)	Assess ease of assembly and preparation	
46)	Assess placement of controls	

Step	Instruction (Actions)	Recorded Values	Pass/Fail	Notes (Observations)
47)	Assess experience level adjustment (rate gains)			
48)	Assess response of platform (given rate gain settings)			
49)	Assess recoverability (forgiveness of flight controls)			
50)	Assess automatic features (score 0, if N/A)			

Safety and Risk Assessment

This section represents an outline of the actions taken and documentation produced to identify, analyze, and mitigate (control) potential risk, while achieving desired benefit in operation of sUAS.

ERAU UAS Safety Review Board

An application for review of proposed sUAS flight test operation was submitted and approved by the the ERAU safety review board (SRB; approved April 7th, 2016) to identify potential risk and benefits; the anticipated benefits *MUST* outweigh risk. It is critical to ensure that all hazards are managed through appropriate controls (mitigation actions) and that a culture of safety be perpetuated throughout all planned UAS operations. In support of this review, the following were produced and added to this document:

- Operator qualifications (identified under *Operational Criteria*)
- Risk assessment and mitigation analysis (matrix; see Table 11-Table 14)
- Emergency response guide/steps (including applicable notification)
- Identification of a non-punitive reporting mechanism and contacts (to report issues with safety)

Proposed sUAS flight operations will not be conducted until all applicable requirements of the SRB have been satisfactorily met and permission has been granted to proceed.

Anticipated Benefits

The anticipated benefits of the proposed sUAS operation, testing, and assessment include the following:

1) Building student experience conducting collaborative research and UAS operation among peers, ERAU faculty, and industry representatives
2) Establishing cooperative engagement between ERAU-Daytona Beach and Worldwide students and faculty
3) Accumulating further ERAU UAS operational experience, observations, and data (indoor flight and outdoor flight under a FAA UAS Test Site COA)
4) Capturing data necessary to develop an sUAS Consumer Guide for first-time operators/purchasers, in support of public outreach and education
5) Providing valuable industry outreach and cooperation with UAS donors (Yuneec, 3DR, and Hobbico) and stakeholders (NIAS)
6) Providing opportunity to capture marketing materials (e.g., video and photography) of ERAU UAS operations and cooperative research

Risk Assessment and Mitigation Analysis

After review of the technical specifications of the 12 identified sUAS, the systems were categorized as *simple*, *intermediate*, and *complex* (see Table 8). This categorization was based on weight and functional capability (e.g., control stability augmentation, sensor fidelity, autopilot, and design complexity). After categorization and review of operational documentation, an analysis of potential hazards was conducted. This analysis features a series of likelihood and severity ratings (see Table 9) that are used to define potential outcome (low [1E] to high [5A]) as depicted in ERAU's Risk Matrix (see Figure 13). Operation requires approval of a specific approval authority, as specified in Table 10, based on a risk rating. Each of the subject sUAS categories (e.g., simple, intermediate, and complex) were examined and analyzed for indoor operations in the ERAU Field House (see Table 11,Table 12, and Table 13). Additionally, outdoor operations were analyzed, as a collective set, rather than by category, using results of a previous analysis conducted to approve ERAU-W UAS operations under the NIAS COA (see Table 14).

Table 8. sUAS Platform Details and Categorization

MANUFACTURER	PLATFORM	MTOW (lbs)	CATEGORY
3DR	Solo	5.25	Complex
DJI	Inspire 1	7.50	Complex
DJI	Phantom 3 Standard	2.82	Complex
Elanview	Cicada	0.52	Intermediate
Parrot	BeBop 2	1.10	Intermediate
Helimax	FORM500 Utility Drone	6.11	Complex
Yuneec	Typhoon 4K	3.81	Complex
Syma	X8W FPV Drone	1.32	Intermediate
Dromida	Vista	0.22	Simple
Dromida	Kodo	0.11	Simple
Hubsan	X4 Pro	3.10	Complex
Xiro	Xplorer G	2.65	Complex

Table 9. Likelihood and Severity Ratings

LIKELIHOOD	DESCRIPTION
Frequent	Likely to occur often OR continuously experienced
Probable (Likely)	Will occur several times OR will occur often
Occasional	Likely to occur sometime OR will occur several times
Remote (Seldom)	Unlikely to occur, but possible OR unlikely, but can reasonably be expected to occur
Improbable	So unlikely, it can be assumed it will not occur
SEVERITY	**DESCRIPTION**
Catastrophic	Results in fatalities and/or loss of the system
Critical	Severe injury and/or major system damage
Moderate	Moderate injury and/or system damage
Marginal (Minor)	Minor injury and/or system damage
Negligible	Less than minor injury and/or system damage

Risk Likelihood	Risk Severity				
	Catastrophic A	Critical B	Moderate C	Minor D	Negligible E
5 – Frequent	5A	5B	5C	5D	5E
4 – Likely	4A	4B	4C	4D	4E
3 – Occasional	3A	3B	3C	3D	3E
2 – Seldom	2A	2B	2C	2D	2E
1 – Improbable	1A	1B	1C	1D	1E

Figure 13. ERAU Risk Matrix

Table 10. ERAU Risk Assessment and Approval

Assessment Risk Index	Criteria	Accountability
5A, 5B, 5C, 4A, 4B, 3A	Unacceptable under existing circumstances, requires immediate action.	President
5D, 5E, 4C, 3B, 3C, 2A, 2B	Manageable under risk control & mitigation. Requires authorized decision.	Dean of Appropriate College
4D, 4E, 3D, 2C, 1A, 1B	Acceptable after review of the operation. Requires continued tracking and recorded action plans.	Program Administrator
3E, 2D, 2E, 1C, 1D, 1E	Acceptable with continued data collection and trending for continuous monitoring.	Department Chairman

Table 11. Simple sUAS Indoor Operational Risk Assessment and Mitigation Analysis

Simple sUAS (< 1lb.)	Pre-mitigation				Post-mitigation		
Hazard	**Likelihood**	**Severity**	**Outcome**	**Mitigation**	**Likelihood**	**Severity**	**Outcome**
Blade strike with ground during operation (startup, flight, shutdown)	Frequent	Negligible	MED-HIGH (5E)	Operational checklist will be followed to confirm suitability to operate; operators will have passed an internal assessment confirming suitable knowledge/skill to operate platform and maintain control; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Blade strike with person (crewmember or bystander) during operation (startup, flight, shutdown)	Occasional	Negligible	LOW (3E)	Operational radius will be limited to within 25 feet (horizontal and vertical); only crewmembers (operator, visual observer, and oversight faculty) will be permitted to be within operational radius and to approach airframe; all other personnel will be located in area reserved in bleachers or outside of environment (gymnasium); appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Propeller departure from motor mount	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Operational checklist will be followed to confirm suitability to operate; proper maintenance and inspection will be conducted to ensure system integrity; appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Uncommanded/unintentional loss of positive control (e.g., flyaway or unintended trajectory)	Occasional	Negligible	LOW (3E)	Operations to be monitored by experienced faculty member, able to take immediate control; operators will have passed an internal assessment confirming suitable knowledge/skill to operate platform; operator to check link quality before take-off per checklist with connections checked in preflight inspection; aircrew will be only persons authorized to approach aircraft; appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Loss of propulsion power	Remote (Seldom)	Negligible	LOW (2E)	Batteries will be checked prior to takeoff to confirm appropriate charge; operational radius will be limited to within 25 feet (horizontal and vertical); positive control will be confirmed at startup and reaffirmed through observation during operation; upon observation of any errant behavior, system will be landed, inspected, and diagnosed; verbal warning will be issued; appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)

Simple sUAS (< 1lb.)	Pre-mitigation				Post-mitigation		
Hazard	Likelihood	Severity	Outcome	Mitigation	Likelihood	Severity	Outcome
Loss of communication	Remote (Seldom)	Negligible	LOW (2E)	Positive control will be confirmed at startup and reaffirmed through observation during operation; upon observation of any errant behavior, system will be landed, inspected, and diagnosed; verbal warning will be issued; appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Loss of component integrity during takeoff/landing (e.g., landing gear collapse or blade shatter)	Occasional	Negligible	LOW (3E)	System will be shutdown immediately; airworthiness will be assessed and repaired, if possible; appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Command, control, and communication (C3) interference	Remote (Seldom)	Negligible	LOW (2E)	Spectrum analyzer will be used at onset of operations to confirm environment is free from problematic interference; operator to check link quality before take-off per checklist with connections checked in preflight inspection; upon observation of any errant behavior, system will be landed, inspected, and diagnosed; verbal warning will be issued; to be covered in safety briefing	Improbable	Negligible	LOW (1E)
Unexpected entry of non-participants to operational environment	Remote (Seldom)	Negligible	LOW (2E)	Personnel not engaged in operational testing will observe perimeters and entrance points, alerting aircrews to any unexpected changes to environment, including entrance of non-participants; verbal warning will be issued and non-participant will be intercepted; aircrews will immediately land aircraft, if non-participants do not respond to operational perimeter warning; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Battery fire hazard during recharge	Remote (Seldom)	Critical	MED-HIGH (2B)	Batteries to be charged under supervision; Proper grounding /adherence to charging procedures, as identified by manufacturer; verbal warning to be provided if fire is observed and procedures identified in Emergency Response Guide (ERAU-Daytona Beach, 2013) to be followed; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)

The findings of the risk analysis for operation of *simple* sUAS indoors indicate that the majority of risk outcomes are low (2D, 2E, and 3E) without mitigation, with two specific hazards providing the potential to result in medium-high (5E and 2B), if not mitigated. Most of the risk associated with these systems is due to their lightweight construction and unstable operational profile (over-responsive control); however, their lightweight design (.11 to .22 pounds) also substantially limits the severity and outcome of risk. Through implementation of appropriate controls, including use of pre-flight inspection and checklists, observation, verbal warnings, wearing of safety apparel, and safety briefing, all risks can be reduced to low (1E and 2E). Based on these results, and concurrence of the SRB, such operations are permissible under approval of the Chairman of the Flight Department (rated by ERAU UAS SRB as 2E [low] on April 7th, 2016).

Table 12. Intermediate sUAS Indoor Operational Risk Assessment and Mitigation Analysis

Intermediate sUAS	Pre-mitigation				Post-mitigation		
Hazard	**Likelihood**	**Severity**	**Outcome**	**Mitigation**	**Likelihood**	**Severity**	**Outcome**
Blade strike with ground during operation (startup, flight, shutdown)	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Operational checklist will be followed to confirm suitability to operate; operators will have passed an internal assessment confirming suitable knowledge/skill to operate platform and maintain control; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Blade strike with person (crewmember or bystander) during operation (startup, flight, shutdown)	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Operational radius will be limited to within 25 feet (horizontal and vertical); only crewmembers (operator, visual observer, and oversight faculty) will be permitted to be within operational radius and to approach airframe; all other personnel will be located in area reserved in bleachers or outside of environment (gymnasium); appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Propeller departure from motor mount	Remote (Seldom)	Moderate	MED-LOW (2C)	Operational checklist will be followed to confirm suitability to operate; proper maintenance and inspection will be conducted to ensure system integrity; appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Uncommanded/unintentional loss of positive control (e.g., flyaway or unintended trajectory)	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Operations to be monitored by experienced faculty member, able to take immediate control; operators will have passed an internal assessment confirming suitable knowledge/skill to operate platform; operator to check link quality before take-off per checklist with connections checked in preflight inspection; aircrew will be only persons authorized to approach aircraft; appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Loss of propulsion power	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Batteries will be checked prior to takeoff to confirm appropriate charge; operational radius will be limited to within 25 feet (horizontal and vertical); positive control will be confirmed at startup and reaffirmed through observation during operation; upon observation of any errant behavior, system will be landed, inspected, and diagnosed; verbal warning will be issued; appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Loss of communication	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Positive control will be confirmed at startup and reaffirmed through observation during operation; upon observation of any errant behavior, system will be landed, inspected, and diagnosed; verbal warning will be issued; appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)

Intermediate sUAS	Pre-mitigation				Post-mitigation		
Hazard	Likelihood	Severity	Outcome	Mitigation	Likelihood	Severity	Outcome
Loss of component integrity during takeoff/landing (e.g., landing gear collapse or blade shatter)	Occasional	Marginal (Minor)	MED-LOW (3D)	System will be shutdown immediately; airworthiness will be assessed and repaired, if possible; appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Command, control, and communication (C3) interference	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Spectrum analyzer will be used at onset of operations to confirm environment is free from problematic interference; operator to check link quality before take-off per checklist with connections checked in preflight inspection; upon observation of any errant behavior, system will be landed, inspected, and diagnosed; verbal warning will be issued; to be covered in safety briefing	Improbable	Negligible	LOW (1E)
Unexpected entry of non-participants to operational environment	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Personnel not engaged in operational testing will observe perimeters and entrance points, alerting aircrews to any unexpected changes to environment, including entrance of non-participants; verbal warning will be issued and non-participant will be intercepted; aircrews will immediately land aircraft, if non-participants do not respond to operational perimeter warning; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Battery fire hazard during recharge	Remote (Seldom)	Critical	MED-HIGH (2B)	Batteries to be charged under supervision; Proper grounding /adherence to charging procedures, as identified by manufacturer; verbal warning to be provided if fire is observed and procedures identified in Emergency Response Guide (ERAU-Daytona Beach, 2013) to be followed; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)

The findings of the risk analysis for operation of *intermediate* sUAS indoors indicate that majority of risks are low (2D) without mitigation, with two specific hazards providing the potential to result in medium-low (2C and 3D) and one for medium-high (2B), if not mitigated. Most of the risk associated with these systems is due to the potential for operator error or inexperience in setup; however, their relatively lightweight design (.52 to 1.32 pounds) also limits the severity and outcome of risk. Through implementation of appropriate controls, including use of pre-flight inspection and checklists, observation, verbal warnings, wearing of safety apparel, and safety briefing, all risks can be reduced to low (1E and 2E). Based on these results, and concurrence of the SRB, such operations are permissible under approval of the Chairman of the Flight Department (rated by ERAU UAS SRB as 2E [low] on April 7th, 2016).

Table 13. Complex sUAS Indoor Operational Risk Assessment and Mitigation Analysis

Complex sUAS (2.5lbs and greater)	Pre-mitigation				Post-mitigation		
Hazard	**Likelihood**	**Severity**	**Outcome**	**Mitigation**	**Likelihood**	**Severity**	**Outcome**
Blade strike with ground during operation (startup, flight, shutdown)	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Operational checklist will be followed to confirm suitability to operate; operators will have passed an internal assessment confirming suitable knowledge/skill to operate platform and maintain control; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Blade strike with person (crewmember or bystander) during operation (startup, flight, shutdown)	Remote (Seldom)	Critical	MED-HIGH (2B)	Operational radius will be limited to within 25 feet (horizontal and vertical); only crewmembers (operator, visual observer, and oversight faculty) will be permitted to be within operational radius and to approach airframe; larger airframes (2.5lbs and greater) will be tethered; all other personnel will be located in area reserved in bleachers or outside of environment (gymnasium); appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Propeller departure from motor mount	Remote (Seldom)	Moderate	MED-LOW (2C)	Operational checklist will be followed to confirm suitability to operate; proper maintenance and inspection will be conducted to ensure system integrity; appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Uncommanded/unintentional loss of positive control (e.g., flyaway or unintended trajectory)	Remote (Seldom)	Moderate	MED-LOW (2C)	Operations to be monitored by experienced faculty member, able to take immediate control; operators will have passed an internal assessment confirming suitable knowledge/skill to operate platform; operator to check link quality before take-off per checklist with connections checked in preflight inspection; aircrew will be only persons authorized to approach aircraft; larger airframes (2.5lbs and greater) will be tethered; appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Loss of propulsion power	Remote (Seldom)	Critical	MED-HIGH (2B)	Batteries will be checked prior to takeoff to confirm appropriate charge; operational radius will be limited to within 25 feet (horizontal and vertical); positive control will be confirmed at startup and reaffirmed through observation during operation; upon observation of any errant behavior, system will be landed, inspected, and diagnosed; verbal warning will be issued; appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Marginal (Minor)	LOW (2D)

Complex sUAS (2.5lbs and greater)	Pre-mitigation				Post-mitigation		
Hazard	Likelihood	Severity	Outcome	Mitigation	Likelihood	Severity	Outcome
Loss of communication	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Positive control will be confirmed at startup and reaffirmed through observation during operation; upon observation of any errant behavior, system will be landed, inspected, and diagnosed; larger airframes (2.5lbs and greater) will be tethered; appropriate clothing will be worn to prevent injury; verbal warning will be issued; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Loss of component integrity during takeoff/landing (e.g., landing gear collapse or blade shatter)	Occasional	Marginal (Minor)	MED-LOW (3D)	System will be shutdown immediately; airworthiness will be assessed and repaired, if possible; appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Command, control, and communication (C3) interference	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Spectrum analyzer will be used at onset of operations to confirm environment is free from problematic interference; operator to check link quality before take-off per checklist with connections checked in preflight inspection; upon observation of any errant behavior, system will be landed, inspected, and diagnosed; larger airframes (2.5lbs and greater) will be tethered; verbal warning will be issued; to be covered in safety briefing	Improbable	Negligible	LOW (1E)
Unexpected entry of non-participants to operational environment	Remote (Seldom)	Critical	MED-HIGH (2B)	Personnel not engaged in operational testing will observe perimeters and entrance points, alerting aircrews to any unexpected changes to environment, including entrance of non-participants; verbal warning will be issued and non-participant will be intercepted; aircrews will immediately land aircraft, if non-participants do not respond to operational perimeter warning; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Battery fire hazard during recharge	Remote (Seldom)	Critical	MED-HIGH (2B)	Batteries to be charged under supervision; Proper grounding /adherence to charging procedures, as identified by manufacturer; verbal warning to be provided if fire is observed and procedures identified in Emergency Response Guide (ERAU-Daytona Beach, 2013) to be followed; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)

The findings of the risk analysis for operation of *complex* sUAS indoors indicate that risks range from low (2D) to medium-high (2B) without mitigation, with three specific hazards providing the potential to result in low (2D) risk, three in medium-low (2C and 3D) risk, and four in medium-high (2B) risk, if not mitigated. Most of the risk associated with these systems is due to the potential for operator error or inexperience in setup; however, their intuitive and operational stabilizing features (inclusion of sensors, such as inertial measurement units and ranging) and weight (2.65 to 7.50 pounds) limits the severity and outcome of risk to no more than medium-high. Through implementation of appropriate controls, including use of pre-flight inspection and checklists, observation, verbal warnings, wearing of safety apparel, and safety briefing, all risks can be reduced to low (1E and 2E). Based on these results, and concurrence of the SRB, are permissible under approval of the Chairman of the Flight Department (rated by ERAU UAS SRB as 2E [low] on April 7th, 2016).

Table 14. Outdoor Operational Risk Assessment and Mitigation Analysis

Outdoor Operations of sUAS	Pre-mitigation				Post-mitigation		
Hazard	**Likelihood**	**Severity**	**Outcome**	**Mitigation**	**Likelihood**	**Severity**	**Outcome**
The following were adapted using subtasks, hazards, initial risk levels, controls, residual risk levels, and implementation criteria contained in the NIAS & PARTICIPATING ORGANIZATION RISK MANAGEMENT WORKSHEET produced in support of ERAU-W operations under the NIAS UAS Test Site Certificate of Waiver or Authorization (COA). This information has been adapted to confirm risk and approval requirements for use in the ERAU UAS Safety Review Board (SRB).							
Battery fire hazard during recharge	Remote (Seldom)	Critical	MED-HIGH (2B)	Batteries to be charged under supervision; Proper grounding /adherence to charging procedures, as identified by manufacturer; verbal warning to be provided if fire is observed and procedures identified in Emergency Response Guide (ERAU-Daytona Beach, 2013) to be followed; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Blade strike to observers (bystander)	Remote (Seldom)	Critical	MED-HIGH (2B)	Only crewmembers (operator, visual observer, and oversight faculty) will be permitted to be within operational radius and to approach airframe; all other personnel will be located in area reserved for observation; Visual Observer and non-aircrew participants will scan area for obstacles and non-participants; aircrews will immediately land aircraft, if non-participants enter operational perimeter; verbal warning will be issued and non-participant will be intercepted; appropriate clothing will be worn to prevent injury; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)
Bird Strike	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Ground Crew/Observers clear for birds before launch; check controllability, RTB if able; If degraded flight control, RTB if able or force UA down in remote area, if able	Remote (Seldom)	Negligible	LOW (2E)
Loss of propulsion power	Remote (Seldom)	Critical	MED-HIGH (2B)	Batteries will be checked prior to takeoff to confirm appropriate charge; upon observation of any errant behavior, system will be landed, inspected, and diagnosed; verbal warning will be issued; maintain sufficient altitude to reach an acceptable landing area; if failure occurs, RTB otherwise execute belly landing at most suitable site; to be covered in safety briefing	Remote (Seldom)	Marginal (Minor)	LOW (2D)
Video failure	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Proper maintenance and inspections to ensure system integrity; camera not required for recovery; Trouble shoot transmitters; if required for mission RTB	Remote (Seldom)	Negligible	LOW (2E)
Data link loss (C2)/Lost Link	Remote (Seldom)	Moderate	MED-LOW (2C)	Operator checks link quality before take-off per checklist – all connections checked during maintenance and preflight inspection; utilize back up antennae/RTB with handheld (RC) controller; upon observation of any errant behavior, system will be landed, inspected, and diagnosed; verbal warning will be issued; to be covered in safety briefing	Remote (Seldom)	Negligible	LOW (2E)

Outdoor Operations of sUAS	Pre-mitigation				Post-mitigation		
Hazard	Likelihood	Severity	Outcome	Mitigation	Likelihood	Severity	Outcome
GCS Electrical Power Loss	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Battery back-up system use mandatory; utilize back-up GCS if necessary.	Remote (Seldom)	Negligible	LOW (2E)
Data link failure and GPS failure simultaneously	Remote (Seldom)	Moderate	MED-LOW (2C)	All system connections checked at regular intervals by Technician/Operator during preflight for system integrity; do not operate over populated areas; Force UA down in remote area if able; use RC mode, if able; track UA on C4VAS with xpndr/ADS-B	Remote (Seldom)	Negligible	LOW (2E)
Loss of GPS	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Proper maintenance and inspections to ensure system integrity; check and monitor GPS system throughout flight; If failure occurs, RTB using dead reckoning/ camera; utilize pre-established belly landing route	Remote (Seldom)	Negligible	LOW (2E)
Conflict with other aircraft	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Visual Observer (VO) to visually scan for other aircraft; UA will land upon PIC or VO spotting of other aircraft in vicinity	Remote (Seldom)	Negligible	LOW (2E)
Battery charge drain	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Technician/Operator ensures enough battery charge on board for duration of flight plus reserve – monitor battery drain rate closely	Remote (Seldom)	Negligible	LOW (2E)
Excessive Cross Winds	Occasional	Marginal (Minor)	MED-LOW (3D)	Monitor current and forecasted weather; upload current winds to A/C; change landing direction as appropriate; hold until winds subside	Remote (Seldom)	Negligible	LOW (2E)
Obstacle strike	Remote (Seldom)	Moderate	MED-LOW (2C)	Multiple approaches flown prior to first recovery to observe obstacles in approach and missed approach corridors; complete sight survey; communication with observer; use camera extensively prior to first recovery	Remote (Seldom)	Negligible	LOW (2E)
Wind shift	Occasional	Marginal (Minor)	MED-LOW (3D)	Technician/Operator/PIC closely monitors wind direction and speed, forecasts; change landing direction as appropriate; hold until winds subside	Remote (Seldom)	Negligible	LOW (2E)
Unsafe conditions during recovery	Remote (Seldom)	Marginal (Minor)	LOW (2D)	Technician/Operator abort if conditions warrant; Technician/ Operator/ auto-pilot/ Visual Observer initiate missed app wave-off as appropriate	Remote (Seldom)	Negligible	LOW (2E)
Missed Approach	Occasional	Marginal (Minor)	MED-LOW (3D)	Missed approach corridor and procedures identified and clear; follow missed approach procedure; initiate approach when conditions permit	Remote (Seldom)	Negligible	LOW (2E)
Unfamiliar operating area	Occasional	Marginal (Minor)	MED-LOW (3D)	Extensive site survey; multiple passes in operating area and landing zone to evaluate obstacles	Remote (Seldom)	Negligible	LOW (2E)
Technician/Operator physically incapacitated	Remote (Seldom)	Critical	MED-HIGH (2B)	Render medical assistance and utilize back-up/reserve operator; Back-up operator on standby	Remote (Seldom)	Negligible	LOW (2E)

The findings of the risk analysis for operation of *all identified* sUAS outdoors indicate that risks range from low (2D) to medium-high (2B) without mitigation, with seven specific hazards providing the potential to result in low (2D) risk, seven in medium-low (2C and 3D) risk, and four in medium-high (2B) risk, if not mitigated. Most of the risk associated with these systems is due to the uncontrollable aspects of the operational environment (e.g., weather and entry of foreign objects into area); however, the use of an NIAS approved Pilot-in-Command and Visual Observer, combined with use of detailed checklists, intuitive and operational stabilizing system features (inclusion of sensors, such as inertial measurement units and ranging) and weight (2.65 to 7.50 pounds), and a larger operating area, limits the severity and outcome of risk to no more than medium-high. Through implementation of appropriate controls, including performance of site survey and use of pre-flight inspection and checklists, observation, flight course changes, verbal warnings, wearing of safety apparel, and safety briefing, all risks can be reduced to low (2D and 2E). Based on these results, and concurrence of the SRB, are permissible under approval of the Chairman of the Flight Department (rated by ERAU UAS SRB as 2E [low] on April 7th, 2016).

Emergency Response Procedures

Any emergency response actions, such as those necessary to report, document, and respond to accidents, mishaps, or injuries will be conducted in accordance with the ERAU-Daytona Beach campus *Emergency Response Guide* (January 2013).

ERAU UAS Non-punitive Reporting Mechanism

Upon observation of any questionable practices or violation of law and/or policies, participants will be encouraged to report the details of the occurrence to one or more of the following ERAU representatives, without punitive repercussion to individual reporting issue:

Daniel McCune
Associate Vice President for Safety/Risk
Embry-Riddle Aeronautical University
Office: 386-226-4926
Cell: 386-295-2263
e-mail: mccun711@erau.edu

Dr. Kenneth Witcher
Dean, College of Aeronautics
Embry-Riddle Aeronautical University, Worldwide Campus
Office: 386-226-2926
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David Thirtyacre,
Director of Unmanned Flight Operations
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Dr. Brent Terwilliger
Program Chair, MS in Unmanned Systems
Embry-Riddle Aeronautical University, Worldwide Campus
cell: (607) 624-4275
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Appendix

The following information has been added to provide further detail regarding the planned operational flight testing. Table 15 depicts the performance attributes and characteristics (quantitative data; missing data marked in red) of the 12 sUAS to be operated and assessed in operational flight testing.

Table 15. sUAS Platform Performance Specifications[5]

Platform	Manufacturer	$Speed_{Max\ (knots)}$	Endurance (min)	Payload (lbs)	$Weight_{Empty\ (lbs)}$	MTOW (lbs)	Propulsion	System Cost[6]	Comm Range (ft)
Solo	3DR	55.00	20.00	1.95	3.30	5.25	Electric	$1,361.85	2640.00
Inspire 1	DJI	42.76	18.00	1.03	6.47	7.50	Electric	$3,421.00	16368.00
Phantom 3 Standard	DJI	31.10	25.00	.66	2.16	2.82	Electric	$777.00	3273.60
Cicada	Elanview	5.40	15.00			.55	Electric	$389.97	328.08
BeBop 2	Parrot	21.60	25.00			.88	Electric	$844.97	7392.00
FORM 500 Utility Drone	Helimax		15 .00	2.00	1.91	3.91	Electric	$362.97	
Typhoon 4K	Yuneec	14.78	25.00	1.32	2.49	3.81	Electric	$1,099.98	1200.00
X8C Venture	Syma		10.00	.18	1.15	1.33	Electric	$138.79	328.08
Vista	Dromida		12.00			0.27	Electric	$103.96	328.08
Kodo	Dromida		6.00		.11	0.11	Electric	$83.97	164.04
X4 Pro	Hubsan	11.67	25.00	.80	2.30	3.10	Electric	$599.96	3281.00
Xplorer G	Xiro	15.64	25.00			2.65	Electric	$613.67	1640.00

Initial analysis of the reported sample data indicates the following:

- Maximum Speed
  - Mean: 24.70 kts (66.67% samples reported)
  - Minimum: 5.4 kts
  - Maximum: 55 kts
- Endurance
  - Mean: 18.83 minutes (100% samples reported)
  - Minimum: 6 minutes

[5] ***Note:*** *Items marked in red are unknown (unavailable and not reported by manufacturer); the lack of operational performance data, in a consistent format, has been noted for discussion in future research literature.*

[6] Represents total cost, as configured, including sUAS, spare battery, and transport case; subject to change based on fluctuating market conditions

- Maximum: 30 minutes
- Payload Capacity
  - Mean: 1.13 pounds (58.33% samples reported)
  - Minimum: .18 pounds (reported; not inclusive of smallest sUAS)
  - Maximum: 2.00 pounds
- Empty Weight
  - Mean: 2.49 pounds (66.67% samples reported)
  - Minimum: .11 pounds (reported)
  - Maximum: 6.47 pounds
- Maximum Takeoff Weight (MTOW)
  - Mean: 2.88 pounds (100% samples reported)
  - Minimum: .11 pounds
  - Maximum: 7.50 pounds
- System Cost (as configured, with spare battery and case)
  - Mean: $816.51 (100% samples reported)
  - Minimum: $83.97
  - Maximum: $3,421.00
- Communication Range
  - Mean: 3358.44 feet (75% samples reported)
  - Minimum: 164.04 feet
  - Maximum: 16368.00 feet

Further observations

- All sUAS
  - Are electric and feature use of lithium-based batteries
  - Feature integration of OR are capable of carrying a digital camera (not all feature FPV transmission capability)
  - Could support some level of familiarization training
- Pricing
  - <$499: 5 systems
  - $500-$999: 4 systems
  - $1000-$2499: 2 systems
  - $2500+: 1 system
- Weight
  - <1lb: 4 systems
  - 1-4.4lbs: 6 systems
  - 4.4lbs+: 2 systems