University of Michigan Unmanned Aircraft Systems (UAS) Outdoor Flight Operations Manual

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Revision Log

Rev #	Rev Date	Page #	Summary of Changes	Updated by
IR	9/3/15	ALL	Initial Release	-

Symbols and Abbreviations

AGL	Above Ground Level
AIM	Aeronautical Information Manual
ARF	Almost Ready to Fly
ARP	Airport Reference Point
ATC	Air Traffic Control
ATO	Air Traffic Organization
CFR	Code of Federal Regulations
COA	Certificate of Authorization
FCC	Federal Communication Commission
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FPV	First Person View
FSDO	Flight Standards District Office
GCS	Ground Control Station
GPS	Global Positioning System
IASC	Institutional Autonomous Systems Committee
MTR	Military Training Route
NAS	National Airspace System
nm	Nautical mile
NOTAM	Notice to Airmen
NTSB	National Transportation Safety Board
OSPO	Operating Site Property Owner or Manager
PEERRS	Program for Education and Evaluation in Responsible Research and Scholarship
PI	Principal Investigator
PIC	Pilot in Command
R&D	Research and Development
SVFR	Special Visual Flight Rules
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
UM	University of Michigan
VFR	Visual Flight Rules
VLOS	Visual Line of Sight
VO	Visual Observer
VMC	Visual Meteorological Conditions

Preamble

This University of Michigan UAS Operations Manual ("Manual") is for members of the University that intend to operate small unmanned aerial vehicles (*i.e.*, "small unmanned aircraft systems" or "UAS") under a Grant of Exemption pursuant to Section 333 of the FAA Modernization and Reform Act of 2012. This Manual does not address every possible contingency that may arise or every rule of safety and good practice. As a result, operators must be aware of their surroundings and take into account any special characteristics of the area or the mission being flown.

All faculty, staff, students, and other personnel operating under the privileges of the University's Grant of Exemption and Certificate of Authorization ("COA"), must be in compliance with all applicable Federal Aviation Regulations ("FARs"), and State and local laws. In the event of a discrepancy between this Manual and the terms of the Exemption and COA, the conditions and limitations contained in the University's Grant of Exemption or COA will take precedence and must be followed.

This document covers the operations for University of Michigan unmanned aircraft systems (UAS) that have been approved and validated by both the FAA and the University. University approval and validation processes are administered by a University-managed Autonomous Systems Committee (ASC). These preparatory processes check that the entire system is envisioned to function safely and is appropriate to operate with the procedures described here. The term "system" is comprehensive and is composed of at least the vehicle, payload, operating environment, and the personnel involved (e.g. Pilot in Command (PIC), Visual Observers (VO), Operating Site Property Owner and/or manager (OSPO), Principal Investigator (PI), Staff, Students).

While this Manual is intended to be a convenient source of the University's UAS policy and procedure, it should not be used as an occasional operating reference. Everyone participating in outdoor University UAS operations should study this entire Manual to familiarize themselves with its requirements before participating in any UAS operation on behalf of the University.

Always remember –everyone operating UAS under the University's banner shares responsibility for compliance and ensuring safety.

People and Roles

This section describes requirements, roles and responsibilities for personnel managing and operating UAS in accordance with this Manual. The term "Flight Personnel" includes pilot(s), visual observer(s), and any other personnel necessary for the safe conduct of flight operations. The University shall ensure that all Flight Personnel are fully qualified to perform their duties safely and effectively and is responsible for evaluating Flight Personnel qualifications. All Flight Personnel must be in a condition fit to perform their duties safely under this Manual. No person may act as a member of the Flight Personnel if they are under the influence of any drug, alcohol, or medication likely to impair judgement or attention. Below, roles and responsibilities, qualifications, and training requirements for a University-wide oversight committee and flight personnel are described.

Institutional Autonomous Systems Committee (IASC)

The University will designate and support a committee to serve as the IASC. This committee shall be responsible for and have authority over all UAS operations conducted under this Manual.

Duties and Responsibilities of the IASC include:

- Act as a central point of contact for University UAS activities, including establishing and maintaining contact with the FAA, the university community and public. This also includes maintaining compliance with FAA and NTSB reporting requirements.
- Approve the entire flight system, ensuring that the proposed activities comply with Federal, State, and local laws, as well as University policies.
- As technologies and activities evolve, oversee the validation of the flight system with preparatory tests.
- Maintain documentation, including updates to this manual, records and logbooks.
- Periodically inspect the documentation with respect to the flight system to ensure accuracy and completeness.

Pilot in Command (PIC)

The Pilot of the UAS shall be the Pilot-in-Command ("PIC") who has all the responsibility and authority of the PIC as described by 14 CFR 91.3, *Responsibility and Authority of the Pilot in Command*. The PIC has ultimate responsibility for the safe operation of the UAS. As a result, the PIC has the final decision on whether to initiate or terminate any flight.

PIC Duties and Responsibilities:

- The PIC will evaluate each mission. It is the PIC's responsibility to recognize risk and refuse all missions with unacceptable risk. The PIC's word is final as to whether the flight is safe to conduct.

- If at any time, the operating site property owner and/or manager (OSPO) (see below) feels that a flight or operation is unsafe or deviates from the mission parameters, it is the PIC's responsibility to comply with such requests in a professional manner.
- Before launch, the PIC must understand the mission request and have all applicable documentation at the ground control station.
- The PIC/pilot is required to be aware of weather forecasts, winds, hazards, temporary flight restrictions, and all pertinent information necessary to perform the mission.
- The PIC must keep all UAS operations within visual-line-of-sight range. Any flight supported by a FPV (first person view) capability must be approved by the IASC and involve at least two PIC-qualified personnel, one of whom will always maintain direct line of sight.

Qualifications:

- The PIC must hold a valid U.S. driver's license issued by a state, the District of Columbia, Puerto Rico, a territory, a possession, or the Federal government.
- The PIC must possess one of the following current pilot certificates: Commercial, Private, Recreational, or Sport.
- The PIC shall maintain an appropriate level of understanding of the FARs applicable to the airspace where UAS operations will occur.
- No one may act as PIC unless they have read and familiarized themselves with the contents of this Manual and the specific Operator's Manual for the UAS they will fly.
- All PIC candidates must be approved by the University of Michigan IASC before serving as PIC for a University UAS flight operation.

Training and Currency:

- Completed University of Michigan Program for Education and Evaluation in Responsible Research and Scholarship (PEERRS) certification.
- The PIC must be able to safely operate the UAS in a manner consistent with how the UAS will be operated under the University's Grant of Exemption, including evasive and emergency maneuvers and maintaining appropriate distances from persons, vessels, vehicles, and structures.
- In order to be current, the PIC must have conducted and logged at least 3 launch and 3 recovery operations within the previous ninety 90 days. These operations must have been conducted on a registered UAS of the same class as the UAS to be flight tested, and in a comparable environment.

Visual Observer (VO)

All flight operations require at least one visual observer to offer a viewpoint that is distinct from the PIC. Depending upon the requirements of the entire system, multiple observers may be required by the IASC.

VO Duties and Responsibilities:

- Assist and advise the PIC in maintaining situational awareness and complying with his/her "see-and-avoid" duties.
- Maintain a view of the flight operations and surrounding areas to scan for potentially conflicting traffic or other hazards.
- Maintain communication with the PIC.

Qualifications:

- Have sufficient knowledge of the airspace in which the work detailed in this Manual will be performed to permit them to adequately assess the risks posed by other aircraft or objects.
- At a minimum, Observers will have training in the rules and responsibilities described in 14 C.F.R. § 91.111, § 91.113, and § 91.115. The UAS should never be intentionally operated in the vicinity of manned aircraft, and is to give the right-of-way under all circumstances.
- Shall have knowledge of basic VFR weather minimums.
- Shall maintain a thorough understanding of all normal, abnormal, and emergency operational aspects of the UAS.
- No one may act as an Observer unless they have read and familiarized themselves with the contents of this Manual.
- All VO candidates must be approved by the University of Michigan IASC before serving as PIC for a University UAS flight operation.

Training and Currency:

- Completed University of Michigan Program for Education and Evaluation in Responsible Research and Scholarship (PEERRS) certification.
- The VO must understand how the UAS will be operated under the University's Grant of Exemption, including evasive and emergency maneuvers and maintaining appropriate distances from persons, vessels, vehicles, and structures.
- The VO must be briefed by the PIC prior to each flight to ensure a consistent understanding of each operation.

Operating Site Property Owner / Manager (OSPO)

The flight operations team must have permission to occupy and operate immediately over each flight test site. The property over which the mission is performed is governed by some authority (e.g. property-owner, facility manager), referenced as the OSPO in this document. UAS operations will only occur with the explicit permission of this site authority (the OSPO). The OSPO can revoke this permission at any time, including issuing real-time requests for the PIC to immediately and safely recover or terminate the UAS flight.

Principal Investigator (PI)

The Principal Investigator (PI) is the administrative point of contact for the mission.

PI Duties and Responsibilities:

- Serve as the budgetary authority for all missions.
- Organize flight team.
- Work with PIC and IASC to generate all required documentation and acquire all the necessary University and FAA approvals for flight.
- Schedule and gain necessary approvals for specific flight test dates/times in coordination with the PIC.
- Maintain a copy of all flight and incident logs.
- Work with PIC to ensure any modification-related and maintenance items are fully resolved and approved as required.

PI Qualifications

- Hold an appointment at the University of Michigan.
- Have read and familiarized themselves with the Section 333 and associated (blanket or additional) CoA.
- Have read and familiarized themselves with the contents of this Manual and the specific Operator's Manual for the UAS they will be administering.

Training and Currency:

- Completed Program for Education and Evaluation in Responsible Research and Scholarship (PEERRS) certification.
- The PI must understand how the UAS will be operated under the University's Grant of Exemption, including evasive and emergency maneuvers and maintaining appropriate distances from persons, vessels, vehicles, and structures.

Support Personnel

Depending upon the vehicle, payload, and its operating environment, additional personnel may be required for a mission. This may include one or more ground operators to monitor UAS data, non-safety-critical observers, etc. These personnel are distinct from the PIC and VO. Support personnel not serving in any of the aforementioned roles must be briefed by the PIC and remain in a designated safe area throughout all flight operations.

It also feasible to have an additional pilot to support UAS flight operations. To be given status as (secondary) PIC, this second pilot needs to have the same qualifications, training, and approval as the primary PIC. A primary PIC maintains overall authority for the mission, but a secondary PIC can support the team in the same manner as a co-pilot supports manned flight operations.

Flight Vehicles

A summary of the list of vehicles covered with this Manual is provided below. Vehicles that are not listed here are not approved for flight under the University's Section 333 Exemption. The listed vehicles fall under two classes: small multicopter (multirotor) UAS and small fixed-wing UAS. Each vehicle must have its own operations manual to serve as an addendum to this document with vehicle-specific operating procedures and safety protocols.

Faculty PI	**University Unit**	**Vehicle(s)**	**N - Numbers**	**Flight Approval Status**
Ella Atkins	Aerospace Engineering	Skyspecs Model X1 Quadrotor	N559TM, N559JM, N5583M, N558XM, N559NC	pending
		A2SYS Model X1	N559PM, N559SM	pending
Stanley Baek	Electrical & Computer Engineering	3D Robotics (3DR) X8		pending
Mark Brehob	Electrical Engineering and Computer Science	Pillar custom		pending
Carlos Cesnik	Aerospace Engineering	X-HALE		pending
Jason Corso	Electrical Engineering & Computer Science	3DR Quadrotor Kit		pending
Ryan Eustice	Naval Architecture and Marine Engineering	Ascending Technologies Pelican		pending
		Parrot AR.Drone2		pending
Vineet Kamat	Civil and Environmental Engineering	DJI F550; Pixhawk Px4		pending
Kevin Fu	Computer Science and Engineering	DJI Phantom 2		pending

Jerome Lynch	Civil and Environmental Engineering	3DR Robotics Model X8+		pending
		DJI Phantom 2 Vision+		pending
		Bergen Octocopter		pending
		Bergen Quad 8		pending
Stephen Musko	Space Physics Research Lab	AeroQuad Cyclone ARF		pending
Jacob Napieralski	Department of Natural Sciences	3DR X8+		pending
Dimitra Panagou	Aerospace Engineering	Ascending Technologies, Hummingbird		pending
		Lumenier QAV250		pending
		Walkera Master CP		pending
David Wehe	Nuclear Engineering	Paralax ELEV 8V2		pending

Flight Operations

Flight operations are divided into three distinct categories. These include *validation* flights, *normal* flights, and *abnormal* flights. More detailed descriptions for each are below.

Validation Flights

Validation flights are used to prove that the entire system is functioning properly. This includes the training of personnel and test flights to prove vehicle performance after maintenance or flight-configuration changes.[1] Normal flight operations can only occur after the system has been proven to the

[1] The term "flight-configuration" is used here to distinguish between other types of changes in the configuration. If a parameter is varied and it has potential to influence flight performance it is considered a change to the "flight-configuration". For example changing the outside profile of the payload can influence the aerodynamics of the system. Similarly a change in the mass properties of the payload (e.g. center of mass or mass moment of inertia) may mean that the on-board flight controller needs to be

satisfaction of the ASC. The University and ASC will encourage flight data to be collected during all operations (validation and normal) to maximize ability to identify and resolve potential technical, operational, and other safety-related issues.

Validation flights are to be conducted when there is a change in the configuration of the system. This includes changes in PIC, hardware (e.g. airframe, sensors, data link), software, or operating site (location and/or environment characteristics). Since the system is being validated, extra precautions are necessary. At the discretion of the IASC, required precautions may include one or more of the following:

- Operation at a specific remote or protected test site or in an indoor test arena.
- Employing additional layers of control, e.g., tethers and/or independent kill switch operated by the VO.

The validation tests should stress the system and explore the behavior near the limits of the operating envelope. For instance, at a minimum, the vehicle should demonstrate its behavior under the following conditions:

- Immediate (emergency) landing and flight termination
- Lost link
- Critically-low energy (e.g. Battery) state

Normal Flight Operations

A *normal flight* is an operation from launch through recovery that is completed consistently with the mission specification (personnel, site, and platform) approved by the IASC and included under the Section 333 and associated (blanket or additional) CoA, excluding validation flights. A flight is classified as *normal* when PIC, VO, and OSPO (if present) all agree the flight is *normal*. If one or more of the primary personnel (PIC, VO, and OSPO (if present)) consider the flight to be *abnormal* it must be classified as *abnormal* in the logs and any follow-on paperwork.

Before flight, the PIC is responsible for ensuring all permissions have been obtained and manuals and approval paperwork is current and available. The PIC is responsible for completing preflight procedures from the UAS manufacturer's manual, with the VO providing backup and support for preflight activities. The PIC is responsible for obtaining local weather and wind information, checking for TFRs (temporary flight restrictions) and NOTAMs impacting the flight volume, and issuing any NOTAMs required per Section 333 and CoA instructions. The PIC is responsible for ensuring primary flight personnel are qualified and ready to assume their roles prior to launch, and that the area of operation is safe for flight. The PIC is responsible for obtaining ATC clearances and maintaining voice communications required per any CoA supporting flights in the proximity of towered or non-towered airports. All flight, recovery, and post-flight activities must be conducted per checklists from the UAS Manufacturer's Manual, Section 333

re-tuned. In contrast, a change in the software that is isolated from the safety-critical flight system is not considered a change in the flight-configuration.

and CoA instructions, and this manual. Appendix C provides a general checklist intended to supplement the vehicle-centric Manufacturer's Manual checklist.

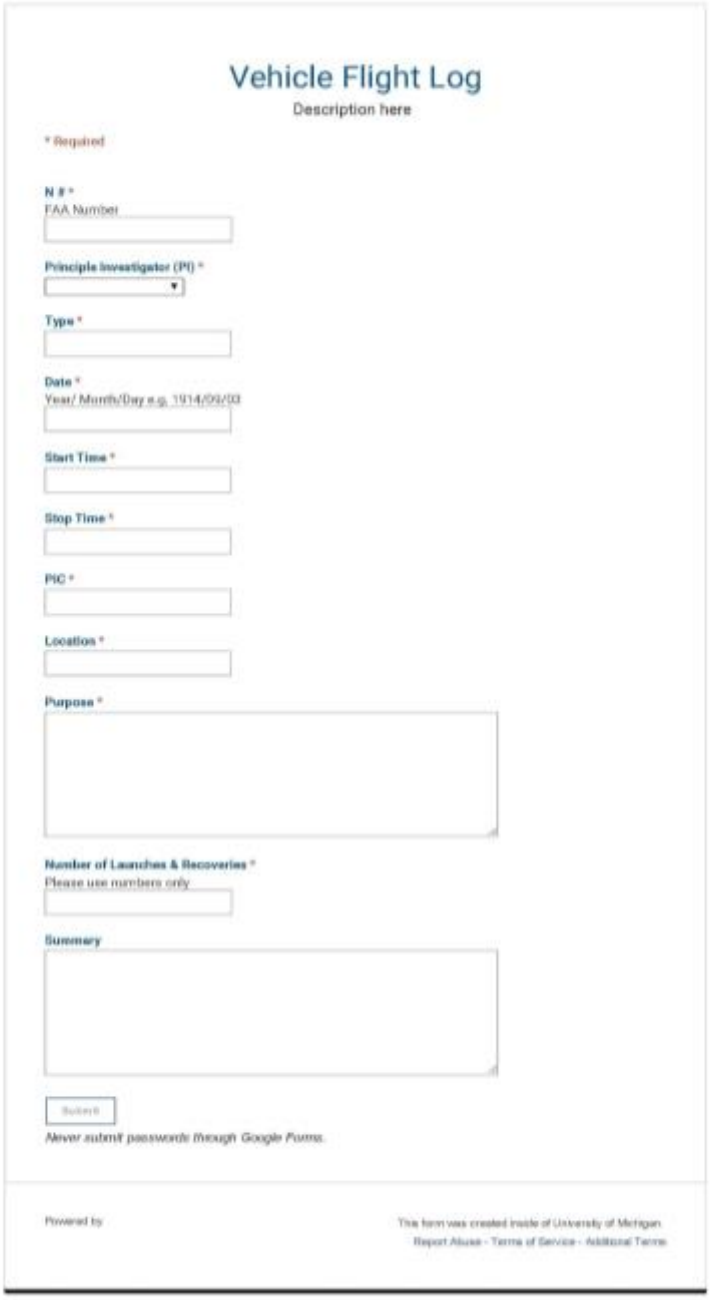
Abnormal Flight Operations

Any flight that deviates from expected mission parameters is classified as *abnormal*. Examples of abnormal flights include any departure from the approved test range (altitude as well as latitude and longitude), flight system malfunction or failure (e.g., motor, sensor, lost link), and/or activation of a flight termination system. It is the responsibility of the PIC to adequately brief all flight personnel on known possible threats surrounding the operation. Response to UAS system failures and malfunctions including lost link shall be in accordance with the University's predetermined, site-specific contingency plans and abort procedures for emergency flight termination, as well as any additional guidance provided by the UAS Manufacturer's Manual.

For reporting purposes, any of the primary personnel (PIC, VO, or OSPO (if present)) can require a flight to be classified as abnormal based on their observations. The flight summary and logs from any flight classified as abnormal will be shared with the IASC via a University incident report within 48 hours of completion. Each abnormal flight will be reviewed by the IASC which will collectively decide if the flight should be classified as an incident to be reported to the FAA. The IASC will transmit information on each flight incident to the FAA within 5 days following the incident and will act as the University liaison to the FAA throughout any subsequent investigation.

Appendix A - University and PIC Flight Log Requirements

Each flight test must be logged by the PIC. Statistics over all flight logs will be compiled by the ASC. The ASC will share flight statistics and individual or complete flight summary logs with the FAA annually and upon request. The PIC must submit the online form "https://docs.google.com/a/umich.edu/forms/d/1mxSmbNNdnNeUIUHtvgkwid_fQmgo4aT7ymRdUpUaEDY/viewform" for each flight test within two days of test conclusion. A snapshot of this web-based form is found below. Any *abnormal* flight must be further logged as described below in Appendix B.



Vehicle Flight Log

Description here

* Required

N # *
FAA Number

Principle Investigator (PI) *

Type *

Date *
Year/ Month/Day e.g. 1914/09/03

Start Time *

Stop Time *

PIC *

Location *

Purpose *

Number of Launches & Recoveries *
Please use numbers only

Summary

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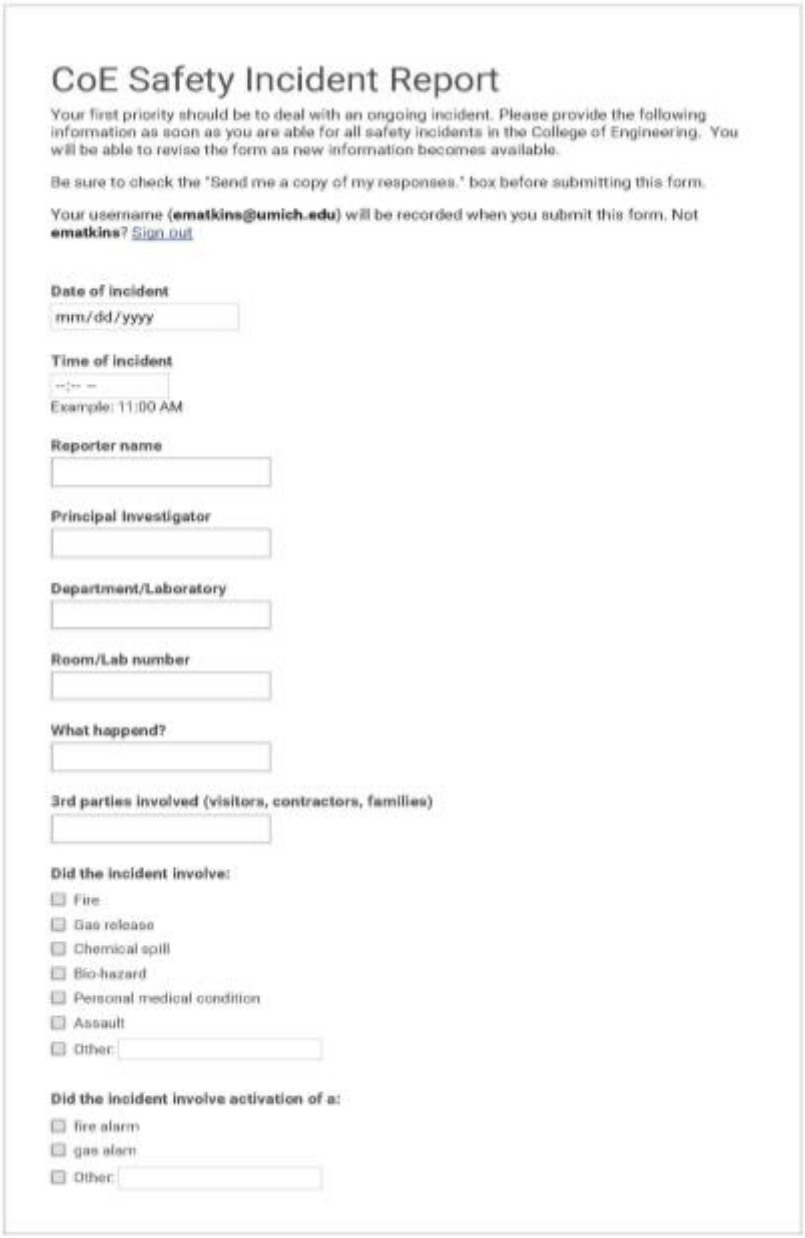
Appendix B - Incident Report Form

Each flight test classified as abnormal by the PIC, VO, and/or OSPO must be logged as an incident by one or more of the primary flight personnel (PIC, VO, OSPO). The ASC will review each incident report and follow up with the primary flight personnel to determine whether the incident must be reported to FAA. The PIC, VO, and/or OSPO will submit a web-based incident flight report form found at "https://docs.google.com/a/umich.edu/forms/d/1MjCQrD0vauH6hPzA_DNY5J4qnHWOkRTtelUhuSePJmc/viewform" to initiate ASC review of the flight. A three-page reproduction of this web-based form is provided on the following pages. Note that this form is standard across the University of Michigan's College of Engineering to facilitate its use and interpretation by the ASC and other interested University representatives.



CoE Safety Incident Report

Your first priority should be to deal with an ongoing incident. Please provide the following information as soon as you are able for all safety incidents in the College of Engineering. You will be able to revise the form as new information becomes available.

Be sure to check the "Send me a copy of my responses." box before submitting this form.

Your username (**ematkins@umich.edu**) will be recorded when you submit this form. Not **ematkins**? Sign out

Date of incident

mm/dd/yyyy

Time of incident

--:-- --

Example: 11:00 AM

Reporter name

Principal Investigator

Department/Laboratory

Room/Lab number

What happend?

3rd parties involved (visitors, contractors, families)

Did the incident involve:

- ☐ Fire
- ☐ Gas release
- ☐ Chemical spill
- ☐ Bio-hazard
- ☐ Personal medical condition
- ☐ Assault
- ☐ Other:

Did the incident involve activation of a:

- ☐ fire alarm
- ☐ gas alarm
- ☐ Other:

Did this incident involve:

- ☐ First aid on-site?
- ☐ Evaluation or first aid off-site?
- ☐ Medical treatment?
- ☐ Hospitalization?
- ☐ Death?

How was the victim transported?

Did this incident result in damage to:

- ☐ Materials?
- ☐ Equipment?
- ☐ Room?
- ☐ Multiple rooms?
- ☐ Personal property?
- ☐ Other:

Did this incident result in closure or evacuation of:

- ☐ Room
- ☐ Laboratory
- ☐ Building
- ☐ Other:

Name of room or building closed or evacuated:

How long was room or building closed?

Describe the incident in your own words:

Describe fixes:

When will all of the scheduled fixes be completed?

mm/dd/yyyy

Were approved SOPs being followed at the time of the incident?

- ☐ Yes

☐ No

If the SOPs were not being followed, why not?

If the SOPs were being followed, do they need to be changed to prevent future occurrences? How should they be changed?

Fixes to prevent recurrence:

☐ Repair/maintenance
☐ New equipment
☐ Revised SOPs
☐ Training
☐ Discipline
☐ Other:

Have your fixes been approved by:

☐ Your Department Safety Committee?
☐ OSEH
☐ Other:

Give Date of Approval:

mm/dd/yyyy

Feedback for form designer

Please enter any questions or comments regarding this form in the space provide below

☐ Send me a copy of my responses.

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Appendix C - General-Purpose UAS Checklist

A PIC will rely on checklists to ensure preflight, in-flight, and postflight checks and setup steps are always completed. UAS Manufacturer's Manuals will typically include checklists specific to a particular aircraft. This checklist is intended to supplement the Manufacturer's checklist to ensure the site, personnel, and aircraft are all properly informed and prepared for each launch, flight, and recovery.

First flight of the day Checklist:

- ❑ Ensure the aircraft is free of visible defects.
- ❑ Complete aircraft assembly per Manufacturer's Manual.
- ❑ Ensure fasteners and parts are secure.
- ❑ Ensure batteries are fully charged.
- ❑ Check NOTAMS; ensure paperwork is complete and up-to-date.

Pre-Flight Checklist:

- ❑ Establish and brief personnel on area of operation, launch/recovery zones, mission plan.
- ❑ Establish and brief personnel on contingency plans, failsafe point, and flight termination procedures.
- ❑ Ensure area is clear of spectators and hazards.
- ❑ Check that wind and weather are within acceptable operational limits.
- ❑ Power on system and check link.
- ❑ Complete Manufacturer's Manual preflight checklist.

Launch Checklist:

- ❑ Position UAS at launch point and establish personnel at designated locations.
- ❑ Verify personnel are prepared; verify cleared surrounding area and airspace.
- ❑ Initiate launch sequence per Manufacturer's Manual.

Landing Checklist:

- ❑ Line up UAS for landing.
- ❑ Execute safe recovery sequence per Manufacturer's Manual and site-specific approach/recovery pattern.

Shut Down / Secure Checklist:

- ❑ Unplug and remove UAS battery/batteries.
- ❑ Store batteries in LiPo-safe container.
- ❑ Disassemble aircraft for transport or prepare for next flight.
- ❑ Complete post-flight documentation.