Standard Operating Procedure for NPS (Non-Program of Record) Multirotor and Fixed-Wing Unmanned Air Systems up to 55 lb MGTOW

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1. PURPOSE
The purpose of this Standard Operating Procedure (SOP) is to define standard operating procedures for safe operation of electrically powered multirotor and fixed-wing unmanned air systems up to 55lbs.

2. BACKGROUND
Small Unmanned Air Systems (sUAS) may serve as a cost effective and safe means to provide services to customers with unique requirements associated with Unmanned Air System (UAS) operations such as high definition mapping, range surveys, technology development, etc. This SOP is intended to be utilized for operations within Restricted Areas, Warning Areas, Prohibited Areas, and U.S. National Airspace (NAS).

2.1 SMALL UAS PHILOSOPHY
Consistent with NAVAIR IFC Category 3 UAS and the higher probability of loss letter it is accepted that the air vehicle is operating at a higher level of risk and may be lost, damaged, or destroyed during operations. However, recovery of the air vehicle is the goal of every flight.

2.2. SMALL UAS SYSTEM CHARACTERISTICS
This SOP addresses the safe and efficient operation of electrically powered UAS weighing up to 55 lb.

2.3. SMALL UAS CONFIGURATION
UAS covered by this SOP shall fall within the following configuration envelope:
- Electrically powered
- 55 pounds or less
- Utilize flight controllers and/or C² radios capable of demonstrating containment and failsafe protocols
- Multirotor (two or more electric motors with electronic speed controls and fixed pitch propellers/rotors) as well as fixed-wing air vehicles.

2.4. OPERATING LIMITATIONS
Flight operations will be in accordance with the most restrictive of the operating limitations in this SOP, applicable approved flight clearances, test plan or support plan, or applicable Range SOPs or Range Safety Rules (RSR).

3. OPERATIONS
3.1. GENERAL
This section addresses the operating procedures for UAS weighing 55 lb or less. General No Go / Holds are provided in Appendix A. Specific No Go / Holds criteria may be provided in an approved NPS Test Plan.

3.1.1. Indoor flight procedures
NAVAIR INSTRUCTION 13034.1 [1] specifies that air vehicles weighing less than 5 pounds do not require a flight clearance while conducting indoor flights as long as there is no potential for open-air flight. However, it is desirable that even indoor flights comply with the applicable portions of this SOP to the maximum extent possible in preparation for future outdoor flights in order to maximize safety and to build a history on each air vehicle.

3.1.2. Flight checklist
Prior to each flight, the Air Vehicle Operator (AVO) shall conduct a preflight inspection and determine that the UAS is in a condition for safe operation. Pre-flight, in-flight and post-flight checklists are provided in Appendix A.

3.1.3. Aircraft Inventory
Each aircraft will be numbered with a serial number beginning with “A” followed by a sequential
numerical indicator. These aircraft numbers will be kept via electronic data archive and updated when new aircraft are added to the inventory or when aircraft are removed from the inventory. This list will be submitted monthly to NAVAIR Aircraft Controlling Custodian Office.

3.1.4. Aircraft regular maintenance
No regular maintenance will be conducted. However, issues requiring maintenance during routine visual inspections and preflight checks will be conducted as necessary.

3.1.5. Airspace Coordination
Restricted and Warning Area usage will be coordinated via Range Control or applicable airspace controlling authority / using agency. For operations at Camp Roberts, CA, this function will be performed by the assigned Range Test Manager / Air Space Control (ASC) / CIRPAS Air Boss. Flight in U.S. National Airspace outside of active Restricted and Warning areas will be conducted under an approved FAA Certificate of Waiver or Authorization (COA), and will be coordinated with the airspace controlling authority/using agency.
UAS shall only be operated from sites within approved airspace. Area of operations are approved when indicated on the IFC, COA NOTAM, and or Range Airspace approvals or other appropriate authority.

3.1.6. Schedule and Frequency Coordination
The UAS Mission Commander (UMC) or designated team member will coordinate with the assigned Range Test Manager or other local range authority to ensure spectrum coordination.
The UMC or designated team member will coordinate with the assigned Range Test Manager or other local range authority to schedule flight time.
The UMC or designated team member will coordinate with the FAA when operations occur in NAS outside of Restricted and Warning areas.

3.1.7. Test Plan
NAVAIRINST 3960.4 [2] provides project test plan policy for testing air vehicles and air vehicle installed systems. Those efforts requiring formal test plans will undergo the appropriate test planning and approval process by civilian GS 14/15 (AD06/07 equivalent) authority.

3.1.8. Night Operations
Air vehicles operated at night shall have sufficient lighting to maintain visual orientation during night operations.
Site access for night operations may require additional access controls and safety precautions.
Launch and recovery areas used for night flights must have appropriate lighting or other means to support night launch and recovery operations.

3.1.9. General Operating Procedures
Air Vehicle Operator shall
- Ensure operations are in accordance with applicable NAVAIR IFC
- Yield right of way to all manned aircraft. AVO shall not operate an unmanned aircraft so close to another aircraft as to create a collision hazard
- Avoid endangering persons and property
- Only be flown with automated waypoint routes if the UMC has the ability to immediately deactivate such automated functions and return to manual control of the air vehicle at any time
- Not be intentionally flown over non-essential personnel or vehicles unless barriers or structures are present that protect non-essential personnel from the air vehicle and/or debris in the event of a mishap
- Not be flown closer than 25 feet (multirotor) or 50 feet (fixed-wing) to non-essential personnel, or as further restricted by the IFC
- Not be touched by any person while in flight except to divert the air vehicle from striking an individual
- Not be flown by unqualified personnel unless that person is under training by a qualified instructor
- Not be flown for the first time or after repairs without conducting a successful flight operations checklist as described in Appendix A
- Multiple air vehicle operations from a single GCS are prohibited outside of restricted or warning areas

3.1.10. Mishap Plan
A mishap plan shall be established for each operating location (e.g., range/facility). In the event of a mishap at Camp Roberts range, the procedures in the CIRPAS Mishap Plan (Appendix C) shall be followed. The UMC, team lead, or other designated individual shall be responsible for establishing a local mishap plan prior to flight operations outside Camp Roberts range. A copy of the Mishap Plan shall be available on site for all flight operations. In the case that a mishap occurs on other than a Camp Roberts range, local procedures, agreed-to in advance of operation, will be followed. An example of a generic mishap plan is provided in Appendix D. The UMC shall be responsible for documenting failure(s) and lessons learned, and distributing that information to other NPS UAS operators. Mishap reporting shall be in accordance with OPNAVINST 3750.6S [3].

3.1.11. Operational Risk Management and Crew Resource Management (ORM/CRM)
ORM and CRM requirements under OPNAVINST 3710.7U will be compliant with the concepts NPS of related policies.

3.1.12. Video/Telemetry and Other Data
Flights frequently involve video/telemetry data transmissions, still photography, non-transmitted video captures, and other types of potential payload data. Any recorded imagery captured on ranges will be subjected to range security review per existing policy and processes, if applicable. Program security reviewers will determine release criteria for images that contain program specific items, personnel, or images that are deemed sensitive to the program.

3.1.13. Failsafe and Containment
The primary purpose of fail-safe and containment modes is protection of personnel and containment of the air vehicle within the designated airspace. The total of all safety measures, operational checks, and failsafe behaviors constitute the overall containment strategy. These items should complement each other. The overall strategy or method may vary from one air vehicle to another depending on the autopilot and/or command and control strategy. At least one failsafe and containment mode shall be used for each flight operation. Aircrews are responsible for ensuring that the containment methods used take into account the air vehicle, the approved working area, surroundings, and personnel involved. The fail-safe and containment modes of each air vehicle shall be programmed and checked prior to each flight as appropriate. Fail safe modes shall be initiated automatically in the event of a lost Command and Control (C²) link, lost GPS, or airspace boundary/geofence breach. Failsafe modes may be initiated by the AVO if he/she becomes disoriented or otherwise loses control
of the air vehicle.
In the event that the air vehicle exits the designated airspace under a flyaway condition, the UMC shall notify the using agency immediately and provide as much information as possible on location, direction of travel, altitude and expected air vehicle behavior.

3.1.13.1. Failsafe and Containment Modes
“Lost link - Kill Power” will-mode may be used as a containment behavior method. This mode can be programmed such that the UAS Remotely Controlled (R/C) radio receiver commands zero throttle to the flight controller. This mode can be programmed to trigger automatically by the flight controller or receiver, or manually by the AVO by turning off power to the R/C radio transmitter. Fixed-wing aircraft will have control surfaces commanded to servo limits to reduce glide distance. This mode may be enabled if
- Manually commanded by AVO (if programmed)
- The R/C radio transmitter is powered off
- The UA has flown out of effective R/C radio transmitter and/or telemetry (TM) radio communication range
- There is an obstacle obstructing the signal between the remote controller and the UA
- Electromagnetic interference causing degradations of communications between the UA and the R/C radio transmitter and/or TM radios

“Lost link - Return Home”, “Lost Link - Return to Launch” or “Lost link - Land Immediately” mode may be used as containment method. UAS equipped with flight controllers with Global Positioning System (GPS) functions will be programmed to return to a designated home location, return to a designated launch location, or land immediately upon loss of radio control link. These modes can be programmed to trigger automatically by the flight controller, or manually by the AVO by turning off power to the radio control transmitter.

“Geofencing fail” mode may be used as a containment method. UAS equipped with flight controllers with GPS and geofence functions can be programmed to Return to Launch (RTL) or land immediately upon breach of pre-programmed distance from home or launch point, and altitude above ground level.

3.1.13.2. Failsafe and Containment Procedures
The following failsafes shall be used either individually or in combination to provide containment during flight operations:
- Loss of Radio Control Link
  - Program the UAS to RTL or land immediately
  - For UAS with flight controllers without GPS functions, the R/C radio transmitter and receiver shall be programmed to command zero throttle
- Loss of GPS
  - Program the UAS to land immediately or switch to a mode that does not require OPS (e.g., STABILIZE, ALT Hold, ACRO, SPORT or LAND). If programmed to switch to a non-OPS mode, AVO will assume manual control and land as soon as possible
- Loss of Telemetry Link (GCS Failsafe)
  - Program the UAS to Continue, STABILIZE/Manual, ALT Hold, or RTL
- Loss of Video
  - If executing a First-Person View (FPV) flight, program AUTO, RTL, or if flying with flight controllers without GPS functions, remove goggles and continue flight or command zero throttle
  - Navigation Error, Compass Error, Kalman filter failure, attitude and heading reference system (AHRS) failure, unpredictable auto mode
  - If flying in a mode that requires OPS, the air vehicle will switch to Program STABILIZE/Manual, ALT Hold, ACRO, or Disarm
• Battery Failsafe
  o For UAS with flight controllers with battery failsafe functions, battery failsafe can be set to disarm motors, RTL or land. Battery failsafe shall not be set lower than 3.3V per cell
  o If failsafe triggers during normal flight operations AVO return to launch or land immediately. Cause of failsafe trigger shall be determined and resolved prior to next flight

3.1.14. Flight Operation Personnel
A minimum crew of two personnel, one of which will be the designated Air Vehicle Operator (AVO) and the other serving as an Observer (OBS) is required. Either the AVO or the OBS can be the UMC. Additional crewmembers may support the aircrew with functions such as ground support, payload operation, air vehicle position monitoring, airspace containment, etc. Additional qualified personnel as well as non-essential personnel (such as observers) may be present as approved by the UMC. Non-essential personnel shall observe safety hazard keep-out zones prescribed for non-essential personnel.
The number of personnel will be kept to a minimum in the interest of personnel safety.
AVOs will gain and maintain medical qualifications in accordance with all relevant NPS policy and regulatory documents, if applicable [4].
Responsibility for training AVOs / maintaining flight currencies reside with the Group Leads.

3.1.15. Multiple Air Vehicle Operations
Simultaneous operation of multiple Air Vehicles on a single Ground Control Station (GCS) within U.S. NAS outside of Restricted Areas or Warming Areas is prohibited.
Simultaneous operation of multiple air vehicles within the same assigned airspace, not separated by altitude, may require one AVO and one OBS per air vehicle.
Simultaneous operation of multiple air vehicles on multiple GCS will require one AVO and a minimum of one OBS per air vehicle. For example, two air vehicles simultaneously operating could require a crew of four (each air vehicle will have a crew of two, AVO + OBS). A UMC is required to oversee this type of operation.

3.1.16. Communications Procedures
The UMC or designee shall ensure an agreed-to communications plan is in place prior to commencing operations.
The UMC or designee shall ensure adequate communications are available (range radio, satellite phone, etc.) so that the UMC and/or AVO can be contacted by Range personnel or ASC during operations.
Prior to engaging in flight operations, the UMC shall advise ASC or appropriate range control authority prior to and upon completion of any event.

3.1.17. Air Vehicle Monitoring
Air vehicle operations shall be monitored when employed in automatic flight modes with flight controllers that have GCS features, which allow for telemetry downlink and/or monitoring (i.e. computer, tablet, video downlink to include FPV, telemetry downlink, etc.).
Flight controllers not possessing GCS monitoring functionality shall be limited to VLOS or FPV operations.

3.2. 55LB OPERATOR GENERAL QUALIFICATIONS
UAS crewmembers as defined in Table 1 shall be qualified and designated by an appropriate reporting custodian [4]. For the purposes of common terminology, Table 1 defines qualifications and responsibilities of up to 55 lb crew members.
Table 1. Qualification levels and requirements.

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<th>Description of Qualification</th>
<th>Requirements for Qualification</th>
<th>Responsibilities</th>
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<tbody>
<tr>
<td>Air Vehicle Operator Under Instruction (AVO-UI)</td>
<td>Candidates that will be trained to become a qualified operator.</td>
<td>• Determined by the team lead to possess a desirable level of intellectual and motor skills.</td>
<td>• Study materials associated with specific air vehicle and GCS.</td>
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<td>• Study relevant NPS policies and instructions associated with Group 1 and 2 UAS operations.</td>
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<td>• Study applicable SOPs.</td>
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<td>• May perform observer duties.</td>
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<tr>
<td>Air Vehicle Operator (AVO)</td>
<td>Responsible for flight operations of the air vehicle.</td>
<td>• Demonstrate knowledge of air vehicle and GCS operations.</td>
<td>• Safely operate air vehicle within its flight envelope.</td>
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<td>• Demonstrate knowledge of all navigation and guidance modes as it relates to operating of the air vehicle to include fail safe modes.</td>
<td>• Safely operate air vehicle within all NPS policies and instructions.</td>
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<td>• Demonstrate knowledge of local ranges.</td>
<td>• Safely operate air vehicle within assigned airspace.</td>
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<td>• Demonstrate knowledge of aviation principles.</td>
<td>• Make every attempt possible not to place team members in an unsafe situation during operations.</td>
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<td>• Demonstrate knowledge of pre-mission planning to include emergency procedures.</td>
<td>• Responsible for his/her air vehicle</td>
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<td>• Demonstrate the ability to operate the air vehicle in a control manner.</td>
<td>• Gather weather, tactical, and other information required for mission brief and completion.</td>
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<td>• Qualified to BUQ Level II</td>
<td>• Perform mission brief and debrief.</td>
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<td>• Designated in writing by the reporting custodian as a qualified AVO.</td>
<td>• Gather discrepancies and ensure these are addressed or passed down for repair.</td>
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<td>• May perform OBS duties.</td>
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<td>Air Vehicle Instructor (AVO-I)</td>
<td>Able to train/mentor Operators Under Training or other Instructors.</td>
<td>• Shall be a Qualified Operator</td>
<td>• Safely train and mentor AVO-UI.</td>
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<td>• Demonstrate a high level of understanding of UAS operations, site safety, and professionalism.</td>
<td>• Evaluate AVO-UI and recommend AVO qualification.</td>
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<td>• Demonstrate the ability to efficiently train / mentor new operators.</td>
<td>• Can perform OBS duties.</td>
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<td>UAS Mission Commander (UMC)</td>
<td>Assumes full responsibility of site operations. UMC does not need to be a qualified operator.</td>
<td>• Demonstrate a high level of understanding of aviation principles, ranges / airspace and UAS operations.</td>
<td>• During his/her assigned missions, responsible for the overall safe and professional completion of missions in accordance with applicable policies, procedures, and priorities.</td>
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<td>• Familiar with the operation and function of air vehicles and payload.</td>
<td>• Has situational awareness over all air vehicles in operations with multiple simultaneous air vehicles in flight.</td>
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<td>• Notify personnel of equipment, safety, or other issues requiring attention for effective completion of missions.</td>
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<td>• Can perform OBS duties.</td>
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<tr>
<td>Observer (OBS)</td>
<td>Observes Air Vehicle, Assists AVO with situational awareness.</td>
<td>• As required per Qualified Observer.</td>
<td>• Observe general airspace and notify the AVO of any incidences of unauthorized/unexpected air/ground vehicles or personnel.</td>
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3.3. GROUND OPERATIONS
All personnel handling air vehicles and associated equipment or conducting ground operation of the UAS shall follow the procedures contained in this SOP.

3.3.1. Operating Site Considerations
Within Camp Roberts range, there are multiple operating sites that support UAS operations. Other ranges and sites also exist that support safe operation of up to 55lb UAS operations. While each site is unique, Figure 1 provides guidelines for operating site set.

![Figure 1. Notional operational site setup.](image)

Non-essential personnel shall stay a minimum of 25 feet (multirotor) or 50 feet (fixed-wing) from the air vehicle during take-off and landing operations, and while the air vehicle is flying in the immediate vicinity of the take-off/landing area.

Non-essential personnel shall not approach or talk to mission essential personnel during flight operations unless a safety concern is present.

UMC shall ensure a sterile flight environment.

Inbound and outbound flight paths shall be defined as to avoid overflight of structures, equipment or personnel. In some cases overflight of structures, equipment or essential personnel may be required in order to support the event.

Operating site selection will consider the assigned airspace.

Inspect flight operations area prior to flight ops and leave area as found, clean and free of Foreign
Object Debris (FOD).

3.3.2. Frequency Approval
Frequency approval for all radio frequency (RF) emissions associated with UAS operations shall be obtained from Local Frequency Management authority or the assigned Range Test Manager prior to flight operations. The UMC shall ensure all RF emissions are within the approved frequencies during operations. Any deviations (intentional or inadvertent) shall be reported to the local Range Test Manager or Frequency Management or other responsible party(ies) immediately.

3.3.3. Battery Handling and Storage
All Lithium chemistry batteries must have an approved Lithium Battery Safety Certification prior to use. Lithium chemistry batteries shall be charged, stored, and transported in accordance with Original Equipment Manufacturer (OEM) procedures and applicable Lithium Battery Safety Certifications. Lithium chemistry batteries will only be removed from appropriate containers when inspected, for charging, and prior to being installed onto an Air Vehicle or GCS/transmitter for flight or ground test purposes. When not in use, Lithium chemistry batteries shall be stored in a fire rated container in accordance the Lithium Battery Safety Certification, and applicable OEM procedures. Batteries shall not be left unattended during charging. In the event of Lithium battery water exposure, batteries shall be stored in a fire resistant container away from flammable substances, and disposed of in accordance with local HAZMAT procedures.

WARNING
LITHIUM CHEMISTRY BATTERIES HAVE THE POTENTIAL TO RELEASE VAPOR CLOUDS OF CHEMICALLY ACTIVE TOXIC, FLAMMABLE, OR CORROSIVE MATERIALS WHICH MAY CAUSE INJURY TO PERSONNEL, DAMAGE TO EQUIPMENT, AND/OR LOSS OF AIRCRAFT.

WARNING
LITHIUM BATTERIES IMMERSED IN WATER MAY OUTGAS, RESULTING IN OVERHEATING AND/OR FIRE CAUSING DAMAGE TO AV AND/OR INJURY TO PERSONNEL.

3.3.4. Emergency Equipment
A first-aid kit and class ABC Fire Extinguisher shall be available within easy access of the crew at any time ground or flight operations are conducted. If aircraft components contain Magnesium, a class D Fire Extinguisher shall also be available.
4. REFERENCES

5. LIST OF ACRONYMS

AHRS  Attitude and Heading Reference System
ALF   After Last Flight
ALT   Altitude
ASC   Air Space Control
ATC   Air Traffic Control
AVO   Air Vehicle Operator
AVO-I  Air Vehicle Operator Instructor
AVO-UI Air Vehicle Operator Under Instruction
BAT   Blood Alcohol Test
BUQ   Basic UAV Qualification
BVLOS Beyond Visual-Line-of-Sight
C²    Command and Control
CIRPAS Center for Interdisciplinary Remotely-Piloted Aircraft Studies
COA   Certificate of Waiver or Authorization
CRM   Crew Resource Management
DoD   Department of Defense
EM    Electromagnetic
EMC   Electromagnetic Compatibility
EMI   Electromagnetic Interference
FAA   Federal Aviation Administration
FOD   Foreign Object Debris
FOOUO For Official Use Only
FPV   First-Person View
GCS   Ground Control Station
GPS   Global Positioning System
HAZMAT Hazardous Material
IFC   Interim Flight Clearance
IMU   Inertial Measurement Unit
LED   Light Emitting Diode
LOS   Line-of-Sight
MGTOW Maximum Gross Take-off Weight
MOA   Military Operations Area
NAS   U.S. National Airspace
NATOPS Naval Air Training and Operating Procedures Standardization (program)
NAV AIR Naval Air Systems Command
NOTAM Notices to Airmen
NPS   Naval Postgraduate School
OBS   Observer
OEM   Original Equipment Manufacturer
ORM   Operational Risk Management
PAO   Public Affairs Office
PM    Program Manager
POV   Point of Contact
PPE   Personnel Protective Equipment
R&W   Restricted & Warning
R/C   Remotely Controlled
RF    Radio Frequency
RSR   Range Safety Rules
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>RSSI</td>
<td>Received Signal Strength Indication</td>
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<td>RTL</td>
<td>Return to Launch</td>
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<tr>
<td>SOFT</td>
<td>Safety-of-Flight Test</td>
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<tr>
<td>SOP</td>
<td>Standard Operating Procedure</td>
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<td>sUAS</td>
<td>Small Unmanned Aircraft System</td>
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<td>U</td>
<td>Unclassified</td>
</tr>
<tr>
<td>UA</td>
<td>Unmanned Aircraft</td>
</tr>
<tr>
<td>UAS</td>
<td>Unmanned Aircraft System</td>
</tr>
<tr>
<td>UMC</td>
<td>UAS Mission Commander</td>
</tr>
<tr>
<td>VHF</td>
<td>Very High Frequency</td>
</tr>
<tr>
<td>VLOS</td>
<td>Visual Line-of-Sight</td>
</tr>
</tbody>
</table>
Appendix A: Flight Checklist

This appendix describes the flight checklist used during each daily flight operation. Some sections are performed prior to first flight of the day and some sections are performed prior to each flight (sortie). Specific checklist usage is shown in Table 2.

Table 2. Checklist usage selection chart.

<table>
<thead>
<tr>
<th>Checklist</th>
<th>Prior to daily flight operations</th>
<th>Prior to each flight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Environmental</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>2. Preflight Briefing</td>
<td>x</td>
<td>As required</td>
</tr>
<tr>
<td>3. Hardware / Equipment Visual Inspection</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>4. Preflight Run Up</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>5. Post Flight Checks</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

1. Environmental
   - Check for people, animals, buildings and equipment in flight vicinity
   - Notify mission essential personnel and non-essential personnel in the vicinity of the operation of your intentions
   - Setup operational site in accordance with SOP
   - First Aid kit on hand, stocked, readily accessible, and visible to anyone in the area
   - Ensure a charged class A, B and C fire extinguisher is present and visible. Use a class D fire extinguisher if the air vehicle contains magnesium
   - Conduct pre-flight briefing with OBS
   - Notify airspace authority of your intentions via predetermined/pre-planned communication methods

2. Preflight Briefing
   The UMC shall hold a pre-flight briefing with all essential personnel. Assigning of team member responsibilities (to include designation of AVO, OBS, and UMC) shall be established during the Pre-flight brief. Pre-flight briefings shall address the following topics when applicable:
   - Mission objectives
   - UAS configuration
   - Crewmember assignments
   - Weather conditions
   - Local airspace and any flight restrictions
   - Frequency allocation
   - Limitations and restrictions
   - Location of persons and property on the ground, ground hazards
   - Intended mode(s) of flight (e.g., R/C, FPV, VLOS, etc.)
   - Take-off and landing plan briefed to appropriate flight controller (i.e., auto, manual, etc.)
   - Containment procedures/methods
     - Lost link procedures
     - Fail safe modes
   - High risk / High work load points
   - Possible project related emergency procedures
   - Special precautions
   - Review of applicable hazards
   - Review of Go/No Go criteria in Table 3
   - Medical emergencies/pre-existing medical conditions
   - Mission loaded into flight controller for waypoint locations/mapping
• Mishap plan and assign responsibilities
• Location of first aid kit
• Location of fire extinguisher

Table 3. No Go / Hold criteria.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Participants</td>
<td>a) Non-participant (surface or ground) conflicting with flight operations</td>
<td>Hold</td>
</tr>
<tr>
<td>Weather</td>
<td>a) Visibility - Less than specified in IFC, FAA COA; or Range / airspace control limits</td>
<td>No-Go</td>
</tr>
<tr>
<td></td>
<td>b) Wind outside sUAS operating limits</td>
<td>No-Go</td>
</tr>
<tr>
<td></td>
<td>c) Thunderstorms or observed lightning outside IFC limits</td>
<td>No-Go</td>
</tr>
<tr>
<td>UAS</td>
<td>a) Air vehicle or control station is In-Op</td>
<td>No-Go</td>
</tr>
<tr>
<td></td>
<td>b) Air vehicle fails preflight checklist</td>
<td>No-Go</td>
</tr>
<tr>
<td>Essential Personnel</td>
<td>a) Minimum crew is not available</td>
<td>No-Go</td>
</tr>
<tr>
<td></td>
<td>b) Insufficient crew rest (&lt;8hrs)</td>
<td>No-Go</td>
</tr>
</tbody>
</table>

3. Hardware / Equipment Visual Inspection
• Visually inspect the airframe and landing gear for damage, cracks, loose, missing or damaged screws/fasteners/bands/straps/ties
• Visually inspect air vehicle for loose or damaged wiring
• Ensure all equipment is secure and in good condition
• Inspect for loose or damaged wiring connections (solder, plugs, etc.)
• Ensure all antennas are oriented and properly and secure
• Visually inspect all propellers for cracks or gouging and replace as required
• Ensure all propellers are tightly attached to the motors in the correct order and spin freely
• Visually inspect motor mounts and ensure all motors are firmly attached.
• For FPV, inspect/clean FPV and/or capture camera lens and ensure that cameras are secured
• Battery/batteries fully charged, properly seated & secured in the proper location
• Check failsafe behavior at the beginning of each flight day or after major maintenance, remove props during checks
• Props are smooth and free of damage/defect (check blade, surface, & hub)
• Tighten prop adapters in accordance with OEM recommendations
• Ensure voltage alarm is connected (if applicable)

4. Preflight Run Up
• Power up R/C radio transmitter, ground station, video receiver, goggles, etc. as appropriate and verify sufficient charge for duration of mission
• Mount battery to air vehicle and verify air vehicle batteries charged and secured
• Position airframe in a level, safe location for takeoff
• If using on board video capture camera, turn on camera
• Check transmitter to ensure range and centering for all sticks is good
• All transmitter controls move freely in all directions
• All transmitter trims in neutral position (or as required by air vehicle)
• All transmitter switches in correct position (away)
• Transmitter throttle at zero
• Radio transmitter on
• Check transmitter to ensure proper model is selected
• Connect power on battery to airframe
• Ensure LED indicators and audible tones are all correct (as applicable)
• Timer on (if applicable)
• Connect GCS to air vehicle
• Check all flight modes by toggling appropriate transmitter switch. Verify GCS registers modes accurately (if applicable)
• Verify flight controller firmware matches that of the desired firmware
• Check/calibrate compass, accelerometer, and IMU as required
• Verify failsafe and geofence settings/behavior/alarms/idle timeouts are set as desired
• Ensure arming/idle timeout is properly configured (6 - 15 seconds) (if applicable)
• Generate or load waypoints as applicable
• Verify waypoints are within airspace boundaries
• Write and verify flight controller waypoints
• Verify battery voltage, telemetry and GPS solution as applicable
• For FPV, check video
• Scan for nearby people or animals
• Arm flight controller (if applicable)
• Stand clear - audibly, loudly announce the word “CLEAR!”
• Set throttle slightly above idle, and turn off transmitter - verify failsafe mode functionality

**Daily Range and Failsafe Checks**
Prior to the first flight of the day and with all radio links and payloads turned on and transmitting as appropriate, conduct the following:
A range test of the R/C radio transmitter in accordance with OEM instructions. Note, it is recommended to conduct the range test with propulsion system powered on and at full power if safe to do so.
A range test of the TM radios in accordance with OEM instructions. If none are available, at a minimum verify in the GCS that the Received Signal Strength Indication (RSSI) is greater than 90% with the vehicle at the launch area.
Failsafe tests as applicable using OEM test procedures
It is prudent to shield or remove propellers to prevent injury or flyaway.

**TAKEOFF**
• Set appropriate flight mode for launch
• Ensure throttle is set to “zero”
• Arm the aircraft
• Ensure launch area is clear of personnel and obstructions and intended take-off path is clear
• Announce "Taking Off"
• Initiate manual or autonomous takeoff (as desired)

**LANDING**
• Verify intended approach/landing area is clear of personnel and obstructions
• Set appropriate flight mode for landing
• Announce intent to land
• Conduct manual or autonomous approach and landing
• Ensure throttle is set to “zero”
• Disarm air vehicle

**5. Post-Flight**
• Power off air vehicle and payloads
• Turn off capture cameras
• Remove flight batteries and note cell voltages (if applicable)
• Place flight batteries in fire safe container
• Save telemetry and/or payload data
• Inspect the Air Vehicle for any damage or loose equipment
Appendix B: Emergency Procedures for Multirotor and Fixed-Wing UAS

Emergency Procedures

- If at any time during UAS flight operations a hazard to flight safety is detected by the pilot or safety observer the flight shall be terminated in a safe manner.
- The pilot shall terminate flight operations if an incident occurs where any damage to personnel or property is observed.
- If the UAS fails to go into its lost link mode and departs the operations area ATC will be notified to include the UA’s last known direction of flight, estimated speed and remaining flight time.

Lost Voice Communications

- Local Range or ATC communications, if required, shall be through a cell phone or RF transceiver.
- If required, and communications with ATC are lost, flight operations will be terminated by standard UA recovery procedures.
- AVO and safety observer communications will be done verbally if in close proximity and using portable VHF if the situation dictates a wider separation AVO and safety observer for optimum situational awareness.
- If communication between AVO and safety observer are lost, flight operations will be terminated by standard recovery procedures.

Lost Link – R/C Radio transmitter

- For UAS with flight controllers without OPS functions, verify proper air vehicle response (zero throttle).
- For UAS with flight controllers with OPS functions, verify RTL or land response as programmed. If not, command RTL. If unable to command RTL, verify UAS is following programmed mission. Notify appropriate airspace authority if UAS is in uncontrolled flight or is beyond visual line of sight.

Lost Link -Air Vehicle Telemetry

- Command RTL via R/C radio transmitter
- If within visual line of sight
  - Monitor RTL and autonomous landing
  - If UAS is not responding to RTL, recover using manual R/C control
- If beyond visual line of sight
  - Record last known OPS location from telemetry
  - Visually scan for air vehicle RTL and autonomous landing
  - Notify appropriate range control/airspace authority

Lost/Bad OPS Fix

- Monitor for programmed response.
- AVO land air vehicle.

Airspace Boundary Violation / Geofence Violation

- For UAS with flight controllers without OPS functions
  - AVO fly air vehicle to within airspace boundary
  - If unable, land immediately, command zero throttle or turn off R/C radio transmitter
- For UAS with flight controllers with OPS functions
  - Verify on Mission Planning/Telemetry software screen that UA is executing a RTL or land as programmed
  - If UA is not executing RTL, command Air Vehicle to initiate a RTL via R/C radio transmitter or Mission Planning/Telemetry software.
  - Observe flight path and verify UA is returning to authorized airspace and/or within the Geofence
  - Once UA is within the approved airspace and/or Geofence, resume normal control of the
UA
  o Contact ATC/Range Control/others as necessary and/or required

**Engine Failure/Loss of Thrust**
- Note position of aircraft on Mission Planning/telemetry software screen
- If able, visually note UA impact point

**Low Battery Voltage**
- RTL
- Monitor flight battery voltage.
- If unable to return to launch point, land immediately.

**Aircraft Unresponsive to Control Inputs**
- If no response or questionable controllability
  o Verify immediate area under the Air Vehicle is clear of personnel and obstacles
  o Command Air Vehicle to RTL or land immediately, command zero throttle, or turn off R/C radio transmitter
- Verify visually the Air Vehicle is responding to the RTL or land immediately commands.
- Verify the R/C radio transmitter is powered on and the battery voltage is sufficient for normal operation
- Wait until aircraft lands and troubleshoot the problem
Appendix C: CIRPAS Mishap Plan

The purpose of a pre-mishap plan is to have established procedures in place that will assist personnel immediately following a mishap with required notification and reports. It is not all-inclusive since every contingency cannot be anticipated. However, reference to this plan and sound judgment will provided the foundation to get the process underway. All procedures in NPSINST 3750.1 will be complied with if an NPS aircraft or personnel are involved in a mishap. The JIFX Director is responsible for the execution of this Plan.

1. Characteristics of all aircraft will be found in the RCC Questionnaires and Risk Assessment Form DD2977 that are submitted prior to any flights. These documents will be co-located with the Air Boss during operations.

2. In case of a mishap the flying unit will immediately notify the Air Boss via Radio or phone. The Air Boss will immediately notify the following emergency control personnel: (If in the unlikely event that the flying unit cannot reach the Air Boss then they must make the attempt to contact)
   a. JIFX Director or Deputy Director
      • Ray Buettner, Director: (831) 920-8534
      • Gerald Scott, Deputy (831) 264-3294
   b. NPS Field Site Manager
      • Gregory Arenas (805) 536-9049
   c. Roberts Air Operations “Robert’s Radio”
      • (805) 238-8181
      • Handheld radio “AIR” net.
   d. Range Control
      • (805) 238-8269
      • FM 38.90 “Camp Roberts Range Control,” or Handheld radio “Range C” net
   e. Fire Department (if warranted; such as fire or injury)
      • (805) 238-8911
      • Handheld radio “Fire Dep” net.
   f. Give the following information:
      • Location of the accident, in UTM if possible
      • Type of aircraft
      • Severity of the accident, i.e., total loss, fire, etc., if known.
      • Extent of injuries, if known

   NOTE: When making phone calls, give accurate information and do not hang up until the person you are calling says he/she has all the information needed.

3. As soon as possible, the Flying unit will fill out the attached “Airborne Vehicle Lost/Crash Report.” NPS will provide a CAL Form 190-40, Incident Report Form, to Range Control whenever:
   a. Any incident leading to damage to CA-ANG property.
   b. Any incident leading to personnel injury.
   c. Any time an incident or the effects of an incident extends beyond the boundaries of Camp Roberts.
   d. If requested by Range Control or directed by NPS.

4. As soon as possible NPS will notify the NPS Aviation Safety Officer and others in the NPS Chain of Command as directed by the Director—see Emergency Assistance Contact Information.
5. What other types of accident reports that will be required will be based on the classification of the mishap. See Table C1 for guidance.

<table>
<thead>
<tr>
<th>MISHAP CATEGORY</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FLIGHT MISHAP (FM)</strong></td>
<td>Intent for flight existed, and $20,000 or more DOD aircraft/UAV damage occurred.</td>
<td>Total damage cost is $1,000,000 or more and/or aircraft destroyed and/or fatal injury and/or permanent disability.</td>
<td>Total damage cost is $200,000 but less than $1,000,000 and/or permanent partial disability and/or hospitalization of three or more personnel.</td>
</tr>
<tr>
<td><strong>FLIGHT-RELATED MISHAP (FRM)</strong></td>
<td>Intent for flight existed with less than $20,000 DOD aircraft or UAV damage.</td>
<td>Total damage cost $1,000,000 or more and/or fatal injury and/or permanent disability.</td>
<td>Total damage cost is $200,000 but less than $1,000,000 and/or permanent partial disability and/or hospitalization of three or more personnel.</td>
</tr>
<tr>
<td><strong>AVIATION GROUND MISHAP (AGM)</strong></td>
<td>No intent for flight existed</td>
<td>Total damage cost of $1,000,000 or more and/or aircraft destroyed and/or fatal injury and/or permanent total disability.</td>
<td>Total damage cost is $200,000 but less than $1,000,000 and/or permanent partial disability and/or hospitalization of three or more personnel.</td>
</tr>
</tbody>
</table>

6. Range Control may also request DA Form 2397.

7. Recovery Response Plan. Prior to any UAV flights from McMillan Airfield a Risk Assessment and RCC Questionnaire must be completed by the flying organization and approved by NPS. Due to the large variance of UAVs flown from McMillan Airfield an assessment will be made by NPS to determine the Response level and pre-position requirements. The following is a guidance:

- Minimum Risk Recovery Team: (Group 1/2 Type UAS)
  - Unit Rapid Response Members identified
  - Fire Extinguisher at GCS
  - In the event of a crash the Mission Commander will notify the Air Boss with the last known location of the UAV. NPS will help find and recover the UAV. Note: Group 1/2 Type UAVs often use Lithium batteries and can cause a fire hazard. NPS has lithium bags and gloves available in bldg. #1. In case of fire, or if fire danger is high, notify the Camp Roberts Fire Department.

- Medium Risk Recovery Team: (Group 3/4 Type UAS)
  - Unit Rapid Response SME identified
  - Fire Extinguisher at GCS
  - NPS Rapid Response Vehicle Pre-Positioned with TBD but may include:
    - Firefighting trailer
(b) Fire Extinguisher
(c) Crash Kit
(d) GPS locator System
(e) Radios
(f) Map
(g) Spill Kit
(h) Shovels
(i) Gloves
(j) Boundary Tape

- The NPS Rapid Response Team (RRT) identified. A judgment call will have to be made by the Safety Officer if the RRT will be located near the GCS.
- In the event of a crash the Air Boss will notify the NPS RRT with the last known location of the UAV. The RRT will be dispatched along with the unit SME. The Air Boss will notify Range Control. The NPS RRT will be in charge of the Crash Site until other Emergency Services arrive.
- The Unit will be responsible for any Hazardous Spills.
- Ensure only personnel authorized by the Director, NPS Site Manager, the local Base Commander, and the Aviation Safety Officer are allowed on a crash site. All personnel involved in crash recovery must be informed of the onboard HAZMAT (see Onboard HAZMAT Inventory in Unit’s RCC) and of appropriate precautions when approaching the accident site.

- High Risk Recovery Team
  - High Risk UAVs will not be flown w/o direct approval from the Base.
  - All of the above plus perhaps:
    (a) Fire Fighting Team on standby or Stationed at McMillan
    (b) Fly over terrain cleared of all personnel

8. In the Director’s judgment, flight crewmembers involved in all flight and flight-related mishaps in which either an aircraft is destroyed, property damage is expected to exceed $20,000, five or more personnel are inpatient hospitalized, or any permanent total or partial disability is sustained are subject to testing. In this situation, ensure that all required toxicological testing of personnel are promptly accomplished. This testing should include BAT (Blood Alcohol Test) and Urinalysis for Barbiturates/Narcotics. Star Drug Testing, (805) 434-1477, 3850 Ramada Dr., Paso Robles, CA 93446, is one option.

9. Collect and put under lock and key the following records for mishap investigation, if applicable:
   a. Aircraft maintenance records and logbooks.
   b. Records (training/qualification/currency/medical) for all crewmembers, non-crewmembers, and ground personnel involved in the mishap.
   c. AGE equipment maintenance records (if a factor in Ground Mishaps).
   d. Weather forecasted to crew.
   e. All forms completed per NPS Instructions.

10. Coordinate with the Aviation Safety Official on all reporting and investigations in accordance with NPS’ Procedures.

11. Direct all questions from Press to the JIFX Director or NPS Public Affairs Office.
EMERGENCY ASSISTANCE CONTACT INFORMATION

Key Personnel

<table>
<thead>
<tr>
<th>Position</th>
<th>Name</th>
<th>Phone Numbers</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naval Postgraduate School Field Laboratory Site Manager</td>
<td>Gregory A. Arenas</td>
<td>(805) 227-1313 X1 (805) 536-9049</td>
<td>Office</td>
</tr>
<tr>
<td>JIFX Director</td>
<td>Dr. Ray Buettner</td>
<td>(831) 656-3387 (831) 920-8534</td>
<td>Office</td>
</tr>
<tr>
<td>JIFX Deputy Director</td>
<td>Gerald Scott</td>
<td>(831) 264-3294 (831) 264-3294</td>
<td>Office</td>
</tr>
<tr>
<td>Air Boss</td>
<td>Dirk A. Hale</td>
<td>(805) 227-1313 X4</td>
<td>Office</td>
</tr>
<tr>
<td>NPS Aviation Safety Officer</td>
<td>Jennifer Keefer</td>
<td>(831) 656-3465 (404) 316-6877</td>
<td>Office</td>
</tr>
<tr>
<td>Aviation Activities Operations Officer</td>
<td>LCDR C.J. Simonsen</td>
<td>(831) 656-6565 (602) 321-6768</td>
<td>Office</td>
</tr>
<tr>
<td>NPS Public Affairs</td>
<td>LCDR Clint Phillips</td>
<td>(831) 656-3567 (804) 349-3037</td>
<td>Office</td>
</tr>
<tr>
<td>Camp Roberts Range Control</td>
<td></td>
<td>(805)238-8296</td>
<td>Office</td>
</tr>
<tr>
<td>Camp Roberts Fire Dept</td>
<td></td>
<td>(805) 238-8911 (805) 238-8117</td>
<td>Non-Emergency</td>
</tr>
<tr>
<td>Hospital (Twin Cities)</td>
<td>Emergency Room</td>
<td>(805) 434-4550</td>
<td></td>
</tr>
<tr>
<td>FAA, San Jose FSDO</td>
<td></td>
<td>(408) 291-7681</td>
<td></td>
</tr>
<tr>
<td>FAA, Oakland FSS (Off-Base Crash)</td>
<td></td>
<td>(800) 272-1180 (800) 272-0128</td>
<td></td>
</tr>
</tbody>
</table>

AIRBORNE VEHICLE LOST/CRAシュ REPORT TEMPLATE

Lost UAS: Provide last position, altitude and direction of flight.
UAS Crash: Provide known position of crash or best estimate.
Each unit should have requirements for reporting lost or crashed UASs. To ensure that CIRPAS has required information needed to answer Range Control questions, obtain the below information from the UAS Commander:

1. Type UAS:__________________________________________________________
2. Owning Unit: ______________________________________________________
3. Date of loss: ______(DD/MO/YR) Time______(Local/Zulu)
4. Site/location of incident:__________________________________________
5. Flight Log information:
   Pilot: _____________________________________________________________
   Mission Controller: _______________________________________________
   Unit: __________________ ___________________________________________
   Channel: _____GPS Keyed: _____ Y _____ N _____
   Launch Time: _____________________________________________________
   Duration of Flight: _______________________________________________
   Weather: _________________________________________________________
   Temperature: _____________________________________________________
   Wind Speed: _____________________________________________________
   Wind Direction: _________________________________________________
   Lighting: Night _____ Dawn _____ Day _____ Dusk __________
   Camera Type: _____ Day _____ F/L Night _____ S/L Night

6. Other Factors:
7. Circumstances:
   a. Origin/launch site
   b. Mission
   c. Launch problem: _______ Landing problem: __________
   d. Problem during flight:
   e. Commanded altitude or throttle setting: _______________
   f. Air vehicle altitude above ground: ___________ Feet
   g. Air vehicle heading: __________ Degrees magnetic
   h. Last known UAS location: ____________________________
   i. Rally point location and altitude
   j. Loss of Link indications:
   k. GPS startup problems:
   l. Previous problems/maintenance issue that may have contributed:

m. Flight recorded/taped? Y/N Location of tape ________________

8. Summary of mishap and damage:

_______________________________________________________________________________________
_______________________________________________________________________________________
_______________________________________________________________________________________

9. Actions taken upon/after loss (search pattern used, number of searchers, duration of search, use of aircraft to assist, etc.):

_______________________________________________________________________________________
_______________________________________________________________________________________

10. Damage
   a. Aircraft:
   b. DoD property damage:
   c. Private property damage

11. Personnel information and injuries (if any).
   • Pilot (Name, Rank):
   • Mission Controller (Name, Rank): ________________________________
   • Date and location of Pilot/Mission Controller completion of certified training:
   • Witnesses: (Name, Rank, and role (i.e., RVT Data Capture, UAV Team Leader, etc.))
   • Other personnel: (Name, Rank, and role (i.e., search))
Appendix D: Generic Mishap Plan Template

This generic mishap plan template is provided as a guide to develop a site specific plan when operating off Camp Roberts range. Its content and use should be carefully and completely coordinated with local police, fire, and emergency personnel as well as the appropriate airspace authority. Each location will be different and it is up to the UMC to ensure a comprehensive and agreed upon plan is place prior to flight operations.

The purpose of a mishap plan is to establish procedures to be followed immediately following a mishap with required notification and reports. It is not all-inclusive since not every contingency can be anticipated. However, reference to this plan and sound judgment will provide the foundation to get the process underway.

Since there is a high probability of loss of Category 3 UAS, air vehicle loss is generally not considered a mishap. Incidents that cause harm or injury to personnel requiring medical attention and unplanned damage to infrastructure, non-participating assets, or the environment are considered mishaps. The UMC is responsible for the execution of this Plan.

IMMEDIATE ACTION

- Evacuate all hazardous areas. Once the immediate threat is over, follow the reporting procedures outlined below.
- Secure the mishap scene.

REPORTING PROCEDURES

1. Call for emergency assistance, if required.
   a) Local range/airspace authority control point (___) ___-____
   b) Police/Fire/Medical 911

2. Determine if other hazards exist at the site or in the vicinity (nearby explosives, duds, or continuing test operations).
   1. If danger to other personnel exists at the site, remain in control and limit access as appropriate. Brief emergency responders as to the danger and allow access only if required medically or to reduce danger (i.e., fire control).
   2. If no other hazards exist, request first emergency responder (ambulance, fire or police) to assume control. Note to whom control has been passed and be sure that they understand that they are responsible for the security of the site and the safety of all personnel present. Remain at the site to assist if needed.

3. If an injury to personnel has occurred, notify the immediate supervisor as soon as possible without interfering with the emergency response. If the immediate supervisor cannot be contacted, go directly to your second level supervisor. Continue up the chain of command until a supervisor is contacted.

4. The supervisor shall contact the _____________ Safety Office and the ____________ Safety Office as soon as possible without interfering with the emergency response
   a) __________ Safety Office (___) ___-____
   b) __________ Safety Office (___) ___-____

6. Ensure all required toxicological testing of ______ personnel involved in a related mishap(s) are promptly accomplished. Operators involved in any mishaps in which property damage is expected to exceed $20,000, five or more personnel are inpatient hospitalized, or any permanent total or partial disability is sustained are subject to testing. Those individuals whose actions or inactions, in the PM’s or the UMC’s judgment, may have been factors in the mishap sequence will be tested. This testing should include blood alcohol test (BAT) and urinalysis for barbiturates/narcotics.

7. Collect and put under lock and key the following records for mishap investigation, if applicable:
a) Records (training/qualification/currency/medical) for all crewmembers, non-crewmembers, operators and ground personnel involved in the mishap.

b) Weather forecasted to crew/operators.

c) Notice to Airmen (NOTAMS) crew used prior to flight/operations if applicable.

8. Direct all questions from Press to Public Affairs Office (PAO) to be handled appropriately with Command Leadership.

REPORT CONTENT
Incident information reported should contain the following:
- What occurred
- When the incident occurred
- Where the incident occurred
- Who was spoken to and what time (position, organization- try not to use names).

ADDITIONAL GUIDELINES
Exercise communication discipline. Whenever possible, use land lines. If it is necessary to use a radio, do not refer to names or trades of individuals involved unless the data is required for medical reasons. Do not give out names of individuals involved except to emergency responders and to your supervisor. Keep information in a timeline to avoid confusion. Write as much as possible noting dates and times. Only report what is known; do not speculate.

The ______ Ranges Associate or his acting will notify the Ranges Department and/or __________ leadership as appropriate.

The Ranges Department and the Range Safety Officer must be advised of any incident that caused personal injury or property damage.
Appendix E: Shipboard Small UAS Operations

GENERAL
Operating sUAS from a vessel presents a unique set of challenges compared to land-based operations. Maritime vessels are usually in constant motion even when not steaming, due to swell, wind, and waves. How the vessel moves depends on both the vessel characteristics (size, hull shape, etc.) and the environmental conditions. The metal structures in vessels can also negatively impact magnetic compass performance on the small UAS. Unlike on land, it is often not possible to fly in large, clear areas, free of obstruction. Vessels have superstructures, cranes, nets, and other items that must be avoided during flight operations. Also, ship decks can be busy areas, with various operations occurring simultaneously. Vessels are often places with a variety of systems that emit or receive Electromagnetic (EM) radiation (e.g. radar, communication systems, jamming systems and weapons systems) which can impact or be impacted by the C² and/or payload streams from UAS. In general, most of the procedures for land-based operations will also apply to vessel operations. However, the following procedures are intended to address those which differ and offer mitigating factors so that shipboard operations can be conducted in a safe and efficient manner.

SITE SURVEY
Maritime vessels can range in size from 12ft-long rigid-hulled inflatable boat (RHIB) or rigid-inflatable boat (RIB), to large surface combatants or research ships. As such, they have different deck and superstructure arrangements, therefore flight operations must be specifically tailored to reflect the particular vessel, recovery areas, obstructions, etc. Topside drawings and/or ship facilities resumes must be consulted before the initiation of tests. Additionally, site surveys are highly recommended, whether conducted in person or via photographic or video media. Part of the study should be to identify vessel Radio Frequency (RF) emitters.

ELECTRO-MAGNETIC INTERFERENCE
An Electromagnetic Compatibility Safety-of-Flight Test (EMC SOFT) must be conducted prior to commencing flight operations. Ship’s personnel must secure all RF emitters; then, while sUAS is in a flight representative state on deck, the ship must energize each emitter one at a time so that it may be determined if there are any Electro-Magnetic Interference (EMI) issues. Ship emitters that can be secured throughout the entire test may be omitted from the EMC SOFT as long as it is clear to the ship that they cannot energize those systems during flight ops. Emitters in the general use, unregulated, 2.40GHz to 2.48GHz range bands can be of particular concern if the transmitter/receivers are older generation and do not employ features such as spread spectrum, or frequency hopping technology to decrease their susceptibility to other “general band” users. In addition, all but the smallest vessels have radars. Although these are usually at higher frequencies than used by most small UAS, they produce powerful beams that have the potential to incapacitate the UAS or its command link. It is often not possible to specify the exact RF systems that are expected to be problematic during operations, therefore the test team has to be flexible to adapt to each vessel’s RF systems. Flight operations must not be performed if there are “source” RF systems that are shown to victimize the UAS/vessel within the intended RF operating bands.

OPERATING LIMITS
Flights in the maritime environment are performed in accordance with limitations stated within the test plan, NATOPS or operator’s manual, IFC, and Shipboard Emissions Control (EMCON) bill. In addition, all flight operations must adhere to all procedures, permissions and certifications required by other agencies such as FAA (if ops are in NAS), local ATC, boat safety authorities, Ship Configuration (SHIPCO) Master, ship owners and research organizations that operate and/or fund vessel operations such as the Office of Naval Research. These organizations are typically notified at least one week before planned flight operations, and provided with a flight operations plan and any other relevant information such as personnel involved and required ship actions to support the planned flight operations.
TYPICAL SHIPBOARD PREFLIGHT OPERATIONS FOR SMALL UAS

- Consult weather forecasts; observe current weather and sea state conditions. Look for any sea spray that may be reaching operation areas. If it is suspected that the UAS has been exposed to salt water, it should not be operated until proper maintenance action is performed. Flight Operations must not occur if sea state conditions create horizontal or vertical motions exceeding launch criteria; if relative wind speeds are greater than platform limits, thunderstorms are within 20 miles of the vessel, or if there are any other conditions that prevent safe operations as specified in the flight clearance.
- In addition to using wind sensors on the ship (which are usually located high on a mast), the wind speed should be checked at the launch and recovery locations using hand-held or nearby mounted sensors. Test personnel should also check turbulence levels and presence of wind shear using applicable flow-visualization methods, bubbles, etc.
- Observe the ship motions and anticipate changes that may occur if sea state conditions change or the ship changes direction or speed. Ship personnel should be briefed to avoid course and speed changes during UAS launch and recovery and to inform aircrew at once if such changes become necessary.
- Ask ship personnel to turn-off all unneeded systems that emit EM radiation. If systems can only be temporarily turned off, test the UAS communications while these systems are turned off and on. Ask ship personnel to contact the UAS operator before turning on any EM systems during flight ops.
- Check to make sure there are not delicate electronics, antennae arrays, or other items that could be damaged by the UAS within proximity of the launch and recovery location. Be aware of any such items anywhere on the ship exterior and do not fly above or near these.
- If possible, perform test flights with increasing higher altitudes, over open deck space (such as fantail) to gain confidence in the UAS operations before attempting operations over open water. If aircraft does not appear to be responding as expected and a controlled recovery is not possible, turn motors off and let the aircraft fall on the deck, assuming it is safe to do so.

TAKEOFF AND RECOVERY CONSIDERATIONS

Crew should be aware of commencement of flight operations and non-participating personnel should be clear of the launch hazard area. Use of a hand held anemometer is recommended if a meteorological station observation is unavailable to ensure wind over deck is within limits. Notify appropriate airspace controlling agency prior to launch and recovery, and let ship operators know what ship actions are required. In most cases, the ship should stop steaming and face into the winds and/or swell to minimize ship motions. Request ship personnel to make a public announcement that aircraft recovery operations will be commencing shortly and all decks should be cleared of non-essential personnel. Persons required to be on deck should maintain visual contact with the UAS at all times during recovery operations. Often, a soft pad or net is placed on the deck as a landing pad to avoid damage caused by landing on hard deck surfaces. Flight path on departure and recovery should be tailored to avoid exhaust plumes emanating from the vessel that cause aerodynamic disturbances, as aircraft performance may be insufficient to recovery at low altitude.

SPECIAL PRECAUTIONS

- Battery and Fuel Storage - Batteries must be stored in a shaded, dry area. Fuel containers must be DOT compliant (closed container, of not more than 5 gallons capacity, having a flash arresting screen, spring closing lid and spout cover and so designed that it will safely relieve internal pressure when subjected to fire exposure).
- Battery Charging - Keep all charging equipment away from salt spray and standing water. Monitor the battery during the charging process for evidence of thermal runaway (smoking, melting, acrid fumes). If thermal runaway occurs, it may be necessary to submerge the cell in water or an aqueous firefighting solution to arrest the temperature rise.
sUAS recoveries from unplanned water landing/ditching - If able, ensure UAS is commanded off prior to retrieval. Put on appropriate Personnel Protective Equipment (PPE) and inspect the battery cell immediately after retrieving the AV from the water to assess for bulging and/or venting, and to monitor for degradation thereafter. If a cell is suspected to be compromised take the following precautions:

- Put on appropriate PPE (cover all exposed skin, safety glasses, gloves, etc.)
- Use equipment such as telescoping nets/hooks to retrieve UAS without directly handling and then place the cell in a containment box half-filled with a mixture of inert material (sand).
- If at any time a colorless to pale yellow gas with a sharp, pungent odor is detected, place the cell a safe distance away from personnel to include, in extreme circumstances, dumping the cell overboard.

**EMERGENCIES**

Emergencies while flying from vessels are addressed in much the same way as land operations; however, the primary difference while underway is that the GCS will likely be moving; therefore, if the UAS enters “lost communication” mode it may not return to the exact launch/recovery location on the vessel and may miss the vessel entirely. It is therefore extremely important that AVO understand the Return Home methodology the UAS employs and either update the Return Home point periodically throughout the flight or invoke a safe lost communication mode which will command the UAS to first go to a safe altitude before it returns to the last provided Return Home waypoint location before descending. While the UAS is attempting to return automatically, the vessel crew can often maneuver so that the UAS can descend onto an open deck. Larger ships may have difficulty performing these maneuvers or vessels may not be able to move due to other constraints, in which case the UAS will land in the water, resulting in loss of aircraft, but avoiding potential injury or damage to the ship. Consideration should be given to the feasibility of a shore based return home point.

**H-9. COLD WEATHER OPERATIONS**

The operator should expect reduced battery life if batteries are operated while cold. When operating in regions of cold weather (below freezing) the batteries must be kept in a warm location (i.e., inside the ship), until the launch procedure commences. If launch is delayed for more than a few minutes, consideration should be given to warming or replacing the batteries prior to launch. Once in flight, the batteries will self-warm during a typical duration of a flight period.

**MISHAP MITIGATION WHEN EMBARKED**

Due to the very small size and weight of the aircraft, risk of injury to personnel or damage to equipment (other than the aircraft itself) is low. However, precautions must be taken to minimize the potential for damage to personnel or shipboard equipment. Hazard zones during launch and recovery are dependent both on the UAS and launching vessel, and must be defined in the corresponding test plan. The UAC is responsible for keeping all personnel aboard the vessel appraised of the hazard zone and intended launch and recovery directions. If control of the UAS is in question, and a collision with personnel, ship structures or other assets, appears imminent, consideration must be given to ditching UAS.

**SHIPBOARD-RELATIVE ROUTES AND AREA SPILLAGE**

When operating UAS capable of ship-relative routes, ship positioning may cause the UAS to exit designated airspace. Ship personnel must be made aware of UAS requirements such as boundary standoff ranges. If a system is capable of displaying UAS position over boundaries and/or charts, that feature must be used to the maximum extent practicable.
Appendix F: Camp Roberts Test Range

Aeronautical chart of Roberts MOA and R-2504

Directions to McMillan airfield
Upon entering Camp Roberts, you will need to stop by the Pass and ID building to your right, showing them your Driver License and telling that you are going to McMillan Airfield / CIRPAS (PoC - Ray Jackson) for NPS experiments. Having your pass issued, proceed to the guard and further on to the East Perimeter Rd.

When arrived, you need to stop by the buildings and ask for the Air Boss, who will clear you to drive along the runway (if needed) to the specific launch side (midfield).
R-2504 operating zones
Appendix G: MOUT Test Site in Impossible Canyon

Aeronautical chart of MOUT (within Class C airspace)

Military Operations Urban Terrain Test Site
Directions to MOUT

This is a gated test site within Fort Ord. A permit is needed to drive to the site. The key is needed to access MOUT.
Appendix H: Carmel River Operations Area

Aeronautical chart of Carmel River Test Site (Class G, just outside Class C airspace)

Carmel River Operations area