Operation S.A.F.E. Remote-Analyst Fly-In Protocol

Version 0.3

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1 Overview

Operation S.A.F.E.[1] is a comprehensive program of education, professional analysis of application, and commitment to clearly demonstrate that ag aviation recognizes its responsibility to minimize the potential for adverse health and environmental effects of agricultural chemical application. The program was formally approved by the NAAA[2] in 1981.

The backbone of Operation S.A.F.E. is the Professional Application Analysis Clinic – the Operation S.A.F.E. Fly-In. The professionals who conduct these Fly-Ins are NAAREF[3] approved as Operation S.A.F.E. Analysts or Technicians.

While physical attendance at a Fly-In is often the easiest option for an aerial applicator, scheduling or geographic limitations may preclude this as an option. For these cases, a Remote-Analyst Fly-In can allow an applicator to perform thier own data collection with minimal support equipment and only off-site assistance from an Operation S.A.F.E. Analyst (phone, email, etc.)

[1] Self-Reguating Application and Flight Efficiency
[2] National Agricultural Avaition Association
[3] National Aerial Application Research and Education Foundation

2 Materials

A Remote-Analyst Fly-In is conducted using only spray-cards for pattern sampling. Aside from the spray-cards themselves, a means of retaining their position during the test as well as a means for measuring application conditions will also be required. The cards must be scanned for digital analysis. Unless you wish to physically mail the cards to an Analyst, you will also need a flatbed scanner. The items listed below are for reference only; names and links do not constitute endorsement.

2.1 Spray-Cards

Cast-coat or water-sensitive type cards may be used. Generally, cast-coat cards are recommended because their more uniform sampling surface facilitates significantly higher scanning resolutions and recognition of smaller spray droplets.

- **Cast-coat cards:** White cardstock with a cast-coating on one side, resulting in an extremely uniform sampling surface. A tank-mixed dye is required in order for the collected droplet stains to stand out agains the white card. When purchasing choose *White* as color, *C/1/S* as type and a thickness of *10pt-12pt*. Purchase in any dimensions and cut to suit.
  - **Kromekote** manufactured by CTI Paper USA
  - **Chromolux** manufactured by Mohawk Paper
- **Water-sensitive cards:** Chemically-coated cards whose yellow sampling surface turns blue with contact to moisture. No tank-mixed dye is required. Special care must be used when handling, as exposure to fingerprints or overly-humid conditions can contaminate the sampling surface. There are differences in performance by manufacturer.
  - **SpotOn Paper** manufactured and sold by InnoQuest Inc.
  - **Syngenta** manufactured cards are sold by TeeJet
  - **WSPaper** manufactures and sells cards from Brazil

2.2 Dye

If cast-coat cards are to be used, dye must be tank-mixed to allow spray droplets to stand out on the cards. Any color or type of dye should be usable, however, the following have been tested to work well.

- **VisionPink** manufactured by GarrCo Products

2.3 Spray-Card Holders

Blocks, stakes or holders of some sort are required to affix the spray-cards to during each test pass. Cards will typically need to be held at an angle of 30-45° from horizontal (See Setup - Step 3).

The simplest holder to create is short section of 2x4 with both 30° and 45° mitred edges on one side. Screw in a paperclip to the center of both mitred edges and one to the horizontal surface between them. In this way, a single block can be used to hold cards at 0°, 30°or 45° depending on conditions.

2.4 Measurement and Marking

For the A-B line marking, a minimum of 3 cones or flags are required. A 150+ FT Open Reel Tape measure is required to set the perpendicular sampling line and spacing for the spray-card holders.

2.5 Application Conditions Monitoring

As with a standard Fly-In, recording hyper-local meteorological conditions is critical to subsequent spray-pattern analysis. For this purpose, if the aircraft is not equipped with AIMMS[4], a ground-based weather station, such as a Kestrel weather meter with vane mount and tripod (and a ground-crew helper with a notepad) should be used.

Application height and ground speed also must be recorded for each test pass. Experienced estimates for these values are generally acceptable, but observed values are preferred. An inexpensive radar gun will allow a ground-crew helper to meausre speed. Spray-height measurement is a little more challenging, but can be accomplished with the Aircraft Height Meaurement System available from *WRK of Oklahoma*.

2.6 Flatbed Scanner

[Note: An iOS device will replace the need for a flatbed Scanner if using the DropFlight app]

Unless physically mailing spray-cards to an Analyst, a flatbed scanner is required to digitize the cards for subsequent analysis. Any scanner with a resolution of at least 1200 dpi should be sufficient. The following have performed admirably for the task:

- Epson Perfection V39
- Epson Perfection V600
- Canon CanoScan LiDE 400

2.7 Remote-Analyst Fly-In Kits

In an effort to minimize friction, prefabricated kits are available for purchase to give you everything you need to perform your own spray-pattern testing. Kits can be obtained from the following sources:

- DropFlight

[4] Aircraft-Integrated Meteorological Measurement System, Aventech Research

3 Setup

1. **Choose Flightline Location:** Find an unobstructed area with at least 150 FT of paved or closely mowed ground available. Place a cone or flag in the center of that area. Standing near that center and using a weather meter or flag, determine the prevailing wind direction. Re-evaluate the area for obstructions, including ingress and egress on an A-B line into the wind and passing through the center cone/flag. Consider also A-B lines along forcasted wind vectors. Continue ONLY if this area provides a safe flight path for testing.

2. **Establish Flightline:** Extend an open-reel tape measure to 150 FT. Orient it on the ground in a straight line exactly perpendicular to the prevailing wind direction, with the center point (75 FT) at the center cone/flag. While standing in the center, looking into the wind, the start of the tape measure (0 FT) should be on your left and the reel side (150 FT) should be on your right.

3. **Layout Spray-Card Holders:** Align spray-card holders to the tape measure every 2 FT. The spray-card orientation angle will be INTO the wind. Use the following guidelines for the proper orientation angle to use on the spray-card holder:

   - **0°:** Very large droplets expected, little/no wind
   - **30°:** 3-10 MPH winds (generally recommended)
   - **45°:** 10-15 MPH winds

4. **Layout A-B Line:** Place additional cones/flags 50-100 Yards upwind and downwind of the center cone/flag. This will form the A-B line for the test and should be exactly perpendicular to the tape measure. Record the upwind vector along this line (in degrees) as the *Pass Heading*.

4 Testing Procedure

For any desired configuration, a replicated set of test passes is required. The terminology for each replicated set is a *Series*. Each *Series* consists of 3-6 good *Passes*.

4.1 Preparation

The following is performed prior to each *Series* and as needed.

1. **Record Aircraft Setup:** Fill out a *Pattern Test Worksheet* for the intended *Series*. Fill out each field within the dashed box. Do not guess on any field. Do not leave any field blank; mark *N/A* if needed.
2. **Perform a Flow Check:** It is important to ensure all your nozzles and check valves are operating as expected prior to performing a test. Pressurize the spray system and observe each nozzle for leaks, spray orientation, abnormally low/high flow or other anomolies. If your aircraft utilizes a wind-driven pump, aattach a load hose to a boom-end to pressurize the booms on the ground. Fix any irregularites found before spray-pattern testing. Take 4-8 photographs from behind the spray booms looking forward at the nozzles while they are flowing. Take enough photographs so that all actively spraying nozzles can be seen.
3. **Mix Dye:** With a minimum of 50 GAL of water in a clean hopper, add the dye directly to the hopper at the labeled rate.
4. **Purge Booms:** Once airborne and over a proper (downwind) area, spray until dye is visible from all nozzles, paying special attention to outboard-most nozzles. This is a good time to record the boom pressure.

4.2 Application

The following is performed for each *Pass*.

1. **Re-Evaluate Winds:** Ensure that the A-B line is still within 5-10° of the prevailing wind direction. If not, repeat applicable Setup steps.
2. **Place Cards:** Mark the location (e.g. 0 FT, 2 FT, etc.) by writing on the non-coated side, if they are not already labeled. Starting at the 0 FT mark, place cards into their respectively located holders.
3. **Line up with A-B Line:** Once airborne and with clear airspace, line up with the established A-B line using an upwind heading. It may be helpful to perform a dry-run over the test setup, marking the A-B line on the GPS.
4. **Pass Ingress:** Using your typical operating airspeed and spray height, approach the test setup on the established A-B line. Aim to be in stable flight with the spray system ON at least 400 Yards before the test setup, this allows the aircraft to bleed off approach speed on the entry and not send control surface inputs back into the pattern as you pass the test setup.
5. **Pass Egress:** Aim to maintain stable flight with the spray system ON at least 200 Yards after the test setup. Minimize control surface usage until after this point. If you find yourself somewhat off your A-B line, do not attempt to correct it.
6. **Record Application Conditions:** A ground-crew helper should record the *Wind Speed (MPH)*, *Wind Direction (°)*, *Temperature (° F)* and *Humidity (%)* at the precise time the aircraft passes over the test setup. Additionally, measured (or estimated) ground speed and spray height should be recorded.

7. **Collect Cards:** Wait until the spray-cards have dried, and then collect them. *Or scan them in-place if using the DropFlight app!* If using water-sensitive cards pay special attention that the coated surface is not touched and that they are promptly moved to a low-humidity environment. Place the cards in an envelope or bag which is clearly marked with the *Series* and *Pass* identified.

8. **Replace and Repeat As-Needed:** It is recommended to perform 5 *Passes* for each *Series*. This is to enable the exclusion from the average of 1 or 2 passes which may have had unintended crosswind or other issues. Place new spray-cards out as before and repeat this procedure starting with Application - Step 1.

5 Digitizing Spray-Cards

[Note: If using the DropFlight App, cards are scanned in-place with an iOS device and instantly digitized in lieu of the steps below.]

Spray-cards must be digitized using at a resolution of at least 1,200 DPI. Because of the large number of cards to scan, it should typically be done in batches as below. Alternatively, spray-cards may be physically shipped to a S.A.F.E. Analyst for digitization (See Shipping Cards to a S.A.F.E. Analyst).

1. **Place Cards on Scanner:** Place the cards (in order) on the scanner with some separation between each card. If using white cards, place a non-white sheet, envelope or other object between the cards and scanner lid to provide contrast.

2. **Configure Scanner:** Using the scanning software of your choice (typically what is included with the scanner), ensure the scanner is set to 1200 DPI or higher resolution, 8-bit color, no compression and output image type of either **.tiff* or **.png*. Also, ensure that all image "enhancement" or "correction" features are turned off.

3. **Scan Cards:** Depending on your software and preferences, cards can be scanned in either of the two ways:

   - **One-Image-Multiple-Cards:** Scans the entire scan-bed into one image. The spray-cards will later be cropped out of this image using analysis software. This is typically the recommended method.
   - **One-Image-One-Card:** A low-DPI preview scan locates spray-cards and highlights them with boxes or outlines of some sort. The scanner software then performs a high-DPI scan of each region (spray-card) one at a time and saves each to its own file.

4. **Name Image File:** Be sure to use a consistent naming scheme which contains the *Series* and *Pass* identifiers as well as the card number(s). For example, *S2 P4 C1-15.tiff* could be the name for the image file containing *Series* 2 *Pass* 4 cards 1-15.

5. **Repeat As-Needed:** Continue to repeat these steps until all cards from a *Pass* have been scanned. Then, perform them again for other *Passes* in each *Series*. It is recommended that you DO NOT scan cards from different passes into the same image file, even if there is room on the scanner, as this can result in confusion down the line.

6 Shipping Cards to a S.A.F.E. Analyst

Upon explicit prior consent from an Operation S.A.F.E. Analyst, cards may alternatively be shipped to them for digitization and/or analysis. The analyst should provide specific instructions, however, at a minimum, the following must be provided:

1. **Collected Cards:** Properly labeled with location (FT), pass number and series number. If labeled only with location (FT), cards should be subpackaged by pass and series with subpackages clearly marked as such.
    - **Cast-Coat Cards:** Once dry, may be stacked (in-order) and either rubber-banded together or placed in labeled pass/series bags.
    - **Water Sensitive Cards:** Once dry, using new pocket (3"x5") spiral notebooks, place cards singly between pages of notebooks. Immediately place loaded notebooks into labeled bags with dessicant packs and seal closed. Failure to adequately protect water sensitive cards from moisture contamination in-transit may result in a total loss of test data.
2. **Pattern Test Worksheet:** Completely and accurately filled out. No fields left blank. Include, in detailed notes, any procedural deviations, abnormal observations or seemingly applicable information related to the aircraft setup or test application.
3. **Aircraft Flow Check Photos:** See Preparation - Step 2. Any additional photos taken throughout the test may also be helpful, but the flow check photos MUST be included.

7 Analysis

7.1 Scan Cards In-Place with iOS Device

Using the DropFlight app for iOS devices, sprayed cards can be scanned in-place with your device's camera and pattern analysis can be done extremely quickly. This method takes the cumbersome card collection and flatbed scanner out of the equation.

- https://dropflightag.com

7.2 Upload Images to Analysis Software

Scanned images may be analyzed using any available image-analysis software. The links below will direct you to further information about acquiring and using them.

- **AccuPatt:** A tool specifically for this purpose available through NAAREF which provides both pass-wise swath analysis and series-wise (average) swath analysis.
  https://github.com/gill14/AccuPatt
- **DropletScan:** A widely-used scanning and analysis program sold through WRK of Oklahoma and Arkansas. Provides pass-wise swath analysis, but no series-wise swath analysis
  https://www.wrkofar.com/index.html
- **DepositScan:** A plugin for an open-source image analysis program (ImageJ) which provides a macro for analyzing scanned images for relevant droplet spectrum statistics. Available through USDA. No pass-wise swath analysis or series-wise swath analysis.
  https://www.ars.usda.gov/midwest-area/wooster-oh/application-technology-research/docs/depositscan/

7.3 Consultation with a S.A.F.E. Analyst

It is highly encouraged to consult with a NAAREF-approved Operation S.A.F.E. Analyst when conducting your own pattern testing. In particular, when analyzing your collected data, Analysts have experience with identifying pattern anomolies and addressing them.

If you would like to be recognized by NAAA as having officially participated in Operation S.A.F.E., you are required to consult with a NAAREF-approved Analyst. That analyst will go over your data with you, identify any concerns and make reccommendations for remediation if necessary. The analyst will then notify NAAA of your S.A.F.E. participation.