TEST/QA PLAN FOR THE VALIDATION OF THE VERIFICATION PROTOCOL FOR HIGH SPEED PESTICIDE SPRAY DRIFT REDUCTION TECHNOLOGIES FOR ROW AND FIELD CROPS

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Signed by D.E. Martin — *March 30, 2009*
D. E. Martin, Quality Manager, U.S. Department of Agriculture — Date

Signed by J. W. Thornburg — *March 12, 2009*
J. W. Thornburg, Project Leader, RTI International — Date

Signed by W. C. Eaton — *March 17, 2009*
W.C. Eaton, Quality Manager, RTI International — Date

Signed by M. Kosusko — *March 18, 2009*
M. Kosusko, EPA Project Manager — Date

Signed by P. W. Groff — *March 24, 2009*
P. W. Groff, EPA Quality Manager — Date

A2: Table of Contents

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List of Acronyms/Abbreviations

ADQ	audit of data quality
ANSI	American National Standards Institute
APCT Center	Air Pollution Control Technology Center
ASABE	American Society of Agricultural and Biological Engineers
ASAE	American Society of Agricultural Engineers (precursor to ASABE)
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	ASTM International, formerly American Society for Testing and Materials
ºC	degrees Celsius
cfm	cubic feet per minute
cm	centimeter
cP	centipoise
CV	coefficient of variance
DQIG	data quality indicator goal
DQO	data quality objective
DRT	drift reduction technology
$D_{v0.x}$	droplet diameter (µm) at which 0.x fraction of the spray volume is contained in smaller droplets
dyne/cm	dynes per centimeter
EC	emulsifiable concentrates
EPA	United States Environmental Protection Agency
ESTE	Environmental and Sustainable Technology Evaluations
ETV	Environmental Technology Verification
fpm	feet per minute
ft	foot
gal/acre	gallons per acre
gpm	gallons per minute
GVP	Generic Verification Protocol
HELOS	helium neon laser optical system
HSWT	high speed wind tunnel
Hz	hertz
in.	inches
ISO	International Standards Organization
kPa	kilopascal
L	liter
m	meters

mg	milligram
min	minute
mL	milliliter
mm	millimeter
mph	miles per hour
ms	millisecond
m/s	meters per second
NIS	nonionic surfactant
NIST	National Institute of Standards and Technology
µL	microliter
µm	microns
OPP	Office of Pesticide Programs
ORD	Office of Research and Development
PE	performance evaluation
PES	performance evaluation system
PMT	photo multiplier transistor
psi	pounds per square inch
QA	quality assurance
QC	quality control
QM	quality manager
QMP	quality management plan
QSM	quality system manual
RH	relative humidity
RTI	Research Triangle Institute
s	second
SNR	signal to noise ratio
SOP	standard operating procedure
TSA	technical systems audit
USDA-ARS	United States Department of Agriculture – Agricultural Research Service
VMD	volume median diameter
v/v	volume/volume

A3: Distribution List

U.S. EPA

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Group A: Project Management

A4: Project/Task Organization

The U.S. Environmental Protection Agency (EPA) Office of Research and Development (ORD) has overall responsibility for the Environmental Technology Verification (ETV) Program and for the *Verification of Pesticide Drift Reduction Technologies* project under the Environmental and Sustainable Technology Evaluations (ESTE) Program. The EPA's Office of Pesticide Programs (OPP) is a major contributor to the project.

Management and testing of pesticide drift reduction technologies (DRTs) will be performed in accordance with procedures and protocols defined by a series of Air Pollution Control Technology Center (APCT Center) quality management documents. The primary source for the APCT Center quality system is EPA's Policy and Program Requirements for the Mandatory Agency-Wide Quality System, EPA Order 5360.1 A2 (May 2000). The quality system that will govern testing under this plan is in compliance with the following:

- EPA *Requirements for Quality Management Plans* (EPA QA/R-2)
- EPA *Environmental Technology Verification Program, Quality Management Plan* (EPA ETV QMP), for the overall ETV program
- APCT Center's *Verification Testing of Air Pollution Control Technology —Quality Management Plan* (APCT Center QMP)[1]
- RTI's *Draft Generic Verification Protocol for the Verification of Pesticide Spray Drift Reduction Technologies for Row and Field Crops* (GVP)
- USDA-ARS's Standard Operating Procedures (SOPs)
- This test/quality assurance plan (test/QA plan).

Appendix A lists full citations for these documents. This test/QA plan is in conformance with EPA Requirements for Quality Assurance Project Plans (EPA QA/R-5), EPA Guidance for Quality Assurance Project Plans (EPA QA/G-5), and the documents listed above.

USDA-ARS will perform the testing, evaluate the data, and submit a report documenting the results to RTI. RTI will use the data to prepare the project reports and recommend revisions to the GVP. The various QA and management responsibilities are divided among USDA-ARS, RTI, and EPA key project personnel as defined below. The lines of authority among key personnel for this project are shown on the project organization chart in **Figure B-1**.

A4.1 Management Responsibilities

Project management responsibilities are divided among the USDA-ARS, RTI, and EPA staff as described below.

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[1] Each ESTE project is required to have a QMP in place and is allowed to use the QMP of an existing ETV Center. This project has elected to use the QMP from the Air Pollution Control Technology Center (APCT Center). The verification organization for DRT verifications that occur after completion of this ESTE project is anticipated to be the APCT Center and this document reflects that assumption. This does not preclude other testing organizations from using the protocol.

A4.1.1 EPA Project Manager

The EPA project manager, Michael Kosusko, has overall technical responsibility for the program. He is responsible for obtaining final approval of GVPs, test/QA plans, and reports, and he recommends the resources necessary to meet project objectives and requirements.

A4.1.2 RTI Project Leader

The RTI project leader is Jonathan Thornburg. He has overall responsibility for liaison with the EPA project manager and technical and administrative oversight of project activities. He prepared this test/QA plan and technical questions should be directed to him. He will assign task leaders and review project documents, as appropriate.

A4.1.3 RTI Field Auditor

The RTI field auditor is Jonathan Thornburg or his designee, who will:

- Review test/QA plans,
- Conduct technical systems audits (TSA) at USDA-ARS, and
- Provide oversight of test site activities.

A4.1.4 Testing Organizations' Technical Leaders

The USDA-ARS technical leader is W. Clint Hoffmann, who will:

- Assist the RTI project leader with the test scope,
- Review/prepare operating procedures applicable to the testing,
- Review test apparatus and procedures prior to commencement of testing,
- Oversee testing of the pesticide spray DRT systems,
- Review test data/results for attainment of data quality indicator goals (DQIGs) and reasonableness,
- Initiate corrective actions when needed,
- Review test results, and
- Submit test results to the RTI project leader.

Hoffmann has overall responsibility for technical and administrative activities, and exercises technical leadership to promote quality in project performance. He will also function as liaison to RTI and U.S. EPA in specific technical areas and supervise the activities of project leaders at USDA-ARS.

A4.2 Quality Assurance Responsibilities

QA responsibilities are divided among the EPA, RTI, and USDA-ARS personnel as listed below.

A4.2.1 EPA Quality Manager

The EPA quality manager (EPA QM), Paul Groff, will conduct audits of RTI's QA system and of specific technical activities on the project. He will be available to resolve any QA issues relating to performance and EPA's QA requirements. Specific functions and duties of the EPA

QM include approving the contents of this test/QA plan and subsequent revisions and reviewing QA reports prepared by RTI, including QA evaluations and audits. In addition, the EPA QM will:

- Communicate quality systems requirements, quality procedures, and quality issues to the EPA project manager and the RTI project leader,
- Review and approve this test/QA plan specific to USDA-ARS,
- Oversee technical systems audits (TSAs) as appropriate,
- Review and approve project test reports, and
- Provide assistance to project personnel in resolving QA issues.

A4.2.2 RTI Quality Manager

The RTI quality manager (RTI QM), W. Cary Eaton, is organizationally independent of the RTI project leader and is responsible for ensuring that QA/quality control (QC) procedures described in this test/QA plan are followed. In addition, Eaton will:

- Maintain regular communication with the EPA QM and RTI project staff regarding QA issues,
- Report on the adequacy, status, and effectiveness of the QA program on a regular basis to the RTI project leader,
- Conduct audits of lab activities as necessary and prepare audit reports,
- Ensure that corrective action, if necessary, is properly implemented and documented,
- Review and approve test/QA plans and SOPs,
- Review the TSA reports of USDA-ARS testing,
- Review the audit of data quality (ADQ) reports of USDA-ARS testing,
- Review and approve test (including QC) reports, and
- Prepare the QA section of the project report.

A4.2.3 Testing Organizations' Quality Managers

The USDA-ARS QM, Daniel E. Martin plays a central role in the introduction, implementation, and consistent application of continuous quality improvement at USDA-ARS. He will fulfill the role as quality management representative for the department and conduct audits of all pertinent quality standards to ensure compliance, and is organizationally independent of the unit generating the data. Martin will:

- Maintain regular communication with the RTI QM and testing staff regarding QA issues,
- Report on the adequacy, status, and effectiveness of the QA program on a regular basis to the USDA-ARS technical leader,
- Conduct audits of lab activities as necessary and prepare audit reports,
- Ensure that corrective action, if necessary, is properly implemented and documented,
- Review and approve input of the test organization to the test/QA plans and SOPs,
- Review and approve test data and documentation submitted to RTI reports (including QC), and
- Provide input to the QA section of the project report.

A5: Problem Definition/Background

In 2007, U.S. EPA completed a draft protocol for the verification of pesticide spray drift reduction technologies for row and field crops. The *Draft Generic Verification Protocol for the Verification of Pesticide Spray Drift Reduction Technologies for Row and Field Crops* (http://www.epa.gov/etv/pubs/600etv07021.pdf) was developed by U.S. EPA with input and commentary from stakeholders that included academia, industry, and other government agencies. Before the pesticide spray DRT protocol can be implemented as an approved protocol for use by the ETV APCT Center, the draft protocol will be tested and evaluated. This test/QA plan for high speed wind tunnel testing at USDA-ARS describes how the draft protocol for pesticide spray DRTs verification at high speeds, to simulate aerial applications, will be validated. Once U.S. EPA approves the final report, U.S. EPA, RTI, vendors, test facilities, and other stakeholders will use the validation report to evaluate the high speed pesticide spray DRT protocol and suggest changes that will provide improvements.

Pesticide spray drift is defined as the movement of spray droplets through the air at the time of application or soon thereafter from the target site to any non- or off-target site, excluding pesticide movements by erosion, migration, volatility, or windblown soil particles after application. High speed drift reduction technologies include nozzle designs and chemical adjuvants. High speed is defined as a speed of the air in the wind tunnel crossing the nozzle representative of aerial application. Within this test/QA plan, the pesticide spray DRT protocol was validated only for nozzle designs. Validation of the protocol through modification of spray liquid formulation characteristics (e.g., viscosity or surface tension) was not part of the planned effort.

A6: Project/Task Description

A6.1 Description

This test/QA plan describes the test and QA procedures that will validate the *Generic Verification Protocol for the Verification of Pesticide Spray Drift Reduction Technologies for Row and Field Crops* for spray nozzles in a high speed wind tunnel. This test/QA plan is written to conform to all specifications of *EPA Requirements for Quality Assurance Project Plans, EPA QA/R-5*, the EPA ETV QMP, and the ETV APCT Center QMP. It describes the quality system required of USDA-ARS and the procedures applicable to meeting EPA quality requirements that are common to all ETV tests. This document will be reviewed and approved by EPA prior to testing.

This testing will gather information and data for evaluating the applicability of the pesticide spray DRT protocol for successfully testing commercially ready pesticide spray DRT nozzles that will be used for aerial spraying applications. All high speed tests will be conducted in the USDA-ARS wind tunnel located in College Station, TX. The specific operating conditions used during the testing will be documented as part of the testing process. **Table 2** in element B2 of this test/QA plan presents a summary of measurements that will be made to evaluate the performance of the DRT and document the test conditions.

Two candidate nozzles and a reference nozzle will be tested using the pesticide spray DRT protocol. The AI-11003 VS nozzle (Teejet Technologies, Wheaton, IL) is one nozzle to be tested. This air eduction nozzle will produce a “very coarse” spray, as defined by ASAE S572 (1999), at the operating conditions defined in element B1. This nozzle is used extensively by industry and its performance characteristics have been extensively studied. The ULD 120-04 nozzle (Hypropumps, New York, NY) is the second nozzle to be tested. This dual air eduction nozzle also is extensively used by industry. The ULD 120-04 nozzle will produce a “coarse” spray at the operating conditions defined in element B1. The characteristics of the reference nozzle to be used during the testing are specified in element B1. USDA-ARS will provide the reference nozzle.

A report containing results of the pesticide spray DRT protocol validation tests will be prepared by USDA-ARS; see element B10.2. RTI will review and approve the report before submittal of the entire data package to U.S. EPA.

A6.2 Schedule

Figure 1 shows the schedule for completion of the high speed wind tunnel pesticide spray DRT protocol validation. Testing was completed March 30-31, 2009.

Item	Milestone	By Whom?	Schedule
1	Test/QA Plan – Submission to EPA for Approval	RTI	January 30, 2009
2	Test/QA Plan – Review Comments	EPA	February 27, 2009
3	Final, Revised, Approved Test/QA Plan	RTI	March 24, 2009
4	Testing	USDA-ARS	March 30-31, 2009
5	Report – Draft to RTI	USDA-ARS	April 29, 2009
6	Report – Review Comments	RTI	May 13, 2009
7	Final Report to EPA	RTI	September 9, 2009

Figure 1. Schedule

A7: Quality Objectives and Criteria

The DQO of this testing focus on the direct or indirect measurements of spray drift deposition using wind tunnel testing. For wind tunnel testing, the testing organization (USDA-ARS) will measure droplet size and spray volume data.

For wind tunnel testing, the primary product of this test design will be the measurement of a droplet size distribution consisting of 32 or more droplet size bins (32 droplet size bins are necessary for input to the models). The degree of consistency of volume median diameter (VMD), droplet diameter (µm) at which 10% of the spray volume is contained in smaller droplets ($D_{v0.1}$) and droplet diameter (µm) at which 90% of the spray volume is contained in smaller droplets ($D_{v0.9}$) are used as a measure of data quality. Variation of less than ± 3% is considered acceptable.

Secondary measurements to be collected during testing include spray material conditions (flow, pressure, temperature, etc.), wind tunnel air speed, and ambient environmental conditions. These measurements may provide explanations if the droplet size distribution data quality indicator is not achieved. This information may also be used for other potential revisions to the pesticide spray DRT protocol.

The DQIG for individual measurements will conform to those specified in relevant sections of the test protocols and referenced procedures, as shown in **Table 1**. The DQO for this testing is to meet the Table 1 DQIGs. One purpose of performing protocol evaluation testing is to assess the appropriateness of the DQIGs. (NOTE: Once the generic verification protocol is final, tests will be repeated if DQIGs for the primary measurements listed in Table 1 are not achieved.)

Table 1. Data Quality Indicator Goals (DQIGs)

Parameter	Standard Operating Procedure (if applicable)	Acceptance Criteria
Spray Liquid DQIGs		
Nozzle spray angle	n/a	Variation within ± 5% during test.
Spray liquid pressure (nozzle operating pressure)	ASAE S572	± 3.4 kPa of values specified in the ASAE standard for reference and evaluation nozzles.
Spray liquid temperature	ASHRAE Standard 41.1	Measured within 0.1 ºC
Spray liquid flow rate	ASAE S572	± 0.04 L/min of values specified in the ASAE standard for reference and evaluation nozzles.
Dynamic surface tension of spray liquid	USDA SOP-4.2	52 ± 4 dynes/cm at surface lifetime age of 10 to 20 ms for test fluids with adjuvants. 70 ± 4 dynes/cm for water, if used as test fluid.
Viscosity of spray liquid	USDA SOP-4.2	1.1 ± 0.1 cP at 20 ºC
Droplet Size Distribution DQIGs		
Spray volume in largest and smallest droplet size class bands in laser diffraction measurements	USDA SOP-4.4	< 1% of total volume in each case (i.e., < 2% total of the spray volume)to be achieved through selection of appropriate lens and instrument configuration for the dynamic size range of the spray being sampled
Number of size class bands for reported data	USDA SOP-4.4	≥ 32
Standard deviation around mean $D_{v0.5}$ for three replicate droplet size measurements	USDA SOP-4.4	Vary by less than ± 3% for replicate measurements with the same nozzle
Measured volume median diameter (VMD), $D_{v0.1}$ and $D_{v0.9}$ (i.e., the droplet diameter bounding the upper and lower 10% fractions of the spray)	USDA SOP-4.4	Vary by less than ± 7% for replicate measurements with the same nozzle

Parameter	Standard Operating Procedure (if applicable)	Acceptance Criteria
Obscuration for spray measurements across a spray diameter (for laser diffraction systems)	USDA SOP-4.4	< 60% unless corrected for multiple scattering, whereupon the report shall include the measured obscuration, the algorithm used to correct for multiple scattering, and the manufacturer-stated limits of applicability for that algorithm.
Minimum obscuration for sampling to achieve cross-section average spray (e.g., start and end trigger using traverse with laser diffraction systems)	USDA SOP-4.4	2%
Sample size per replicate measurement	USDA SOP-4.4	> 10,000 droplets for particle counting instruments or > 5 s for laser diffraction instruments
Diode suppression (laser diffraction systems)	n/a	Diodes may not be suppressed (no channels may be killed) in sampling. Correct selection of focal length lens, system alignment, avoidance of vibrations, and cleanliness of optical surfaces should prevent the need for diode suppression (data loss). (If the laser is displaced during sampling, all diodes will measure incorrect scattering angles, and diode suppression is not an appropriate solution to such sampling problems.)
HSWT Operation DQIGs		
Air speed inside wind tunnel	USDA SOP-4.4	Between 50 mph (22 m/s) and 180 mph (80 m/s), and measured to an accuracy within 5 mph (2 m/s), close to nozzle location (with nozzle absent). Acceptance criteria between measurements ± 5%.
Wind tunnel cross-section diameter	n/a	Cross-section at least three diameters larger than spray plume diameter (at size distribution measurement location).
Wind tunnel ambient air temperature	ASHRAE Standard 41.1	Measured within 0.1 ºC.
Wind tunnel wet bulb/dew point temperature or percent relative humidity	ASHRAE Standard 41.1	Measured within ± 0.1 ºC or ± 1%.
Relative spray material and air temperatures	USDA SOP-4.4	Spray material temperature must be within 2 ºC of the air temperature to avoid atomization anomalies.

n/a = not applicable

Standards Cited

ANSI/ASHRAE 41.1 (1986) *Standard Method for Temperature Measurement*, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. 1791 Tullie Circle, NE, Atlanta, GA 30329.

ASAE S572 (1999) (sometimes referred to as ASABE S572) *Spray Nozzle Classification by Droplet Spectra*. Standard No. S572, American Society of Agricultural and Biological Engineers, St. Joseph, MI.

A8: Special Training/Certifications

All USDA personnel associated with this program must have completed the training specified in USDA SOP-4.1: "Personnel Records, Training Logs, and Laser Safety." This training encompasses general laboratory safety and laser safety. Training specific for spray drift reduction technology evaluation includes wind tunnel operation, laser-diffraction instrument operation, and data handling procedures. The USDA-ARS test leader will ensure that all persons assigned to the field crew have appropriate training and are fully capable of performing the tasks assigned to them. Each field crew member will be thoroughly familiar with this test/QA plan, the measurement equipment, procedures, and methods for their assigned jobs. All field test personnel will receive the required and appropriate safety training, and a safety briefing will be given to all test team members by the USDA-ARS test leader.

A9: Documentation and Records

All information associated with data collection during a test will be recorded. Test data will be recorded legibly on a standardized form in permanent ink and initialed and dated by the person making the entry. At a minimum, the test data recorded will include information specified in **Table 1** that is not recorded electronically. In accordance with Part A, sections 5.1 and 5.3 of EPA's QMP, USDA-ARS will retain all test-specific documentation and records for 7 years after completion of the tests. RTI will retain all reports for 7 years after completion of the project. Archived raw data, documents, and electronic files will be easily accessible.

Group B: Data Generation and Acquisition for High Speed Wind Tunnel Tests

B1: Sample Process Design (Experimental Design)

All of the measurements in this section of the test/QA plan will be conducted in the high speed wind tunnel at the USDA-ARS in College Station, TX. The validity of and applicability of the pesticide spray DRT protocol will be evaluated using two test nozzles and a reference nozzle. Measurements of the droplet size distribution produced by the candidate test systems will be compared to the reference spray system based on the ASAE S572 standard for droplet size.

Two candidate nozzles and a reference nozzle will be tested using the pesticide spray DRT protocol. The AI-11003 VS nozzle (Teejet Technologies, Wheaton, IL) and the ULD 120-04 nozzle (Hypropumps, New York, NY) are the nozzles to be tested. Both test nozzles will be operated at 300 kPa (43.5 psi). The AI-110 flow is 1.13 L/min (0.3 gpm). The ULD 12-04 flow is 1.51 L/min (0.4 gpm).The reference nozzle will be the ASAE S572 nozzle associated with the fine/medium boundary. Specifically, this nozzle is a 110° flat-fan nozzle operated at 300 kPa (43.5 psi) and 1.18 L/min (0.31 gpm). The spray solution for all nozzles will be a distilled water solution containing a 0.25% volume/volume (v/v) of a 90% nonionic surfactant (NIS) (R-900, Wilbur-Ellis Company, San Antonio, TX).

The primary performance measure for the high speed pesticide spray DRT protocol will be derived from droplet size distribution measurements. The basic experimental design will be to measure the droplet size spectrum under targeted test conditions with the DRT operating at the specified spray pressure, air speed, and the ambient environmental conditions. Droplet size spectrum is the critical measurement for this test. Droplet size measurements of interest are the $D_{v0.5}$, $D_{v0.1}$, and $D_{v0.9}$. $D_{v0.5}$ is the volume median diameter (μm) where 50% of the spray volume is contained in droplets of smaller diameter. Similarly, $D_{v0.1}$ and $D_{v0.9}$ describe the percentage (10% or 90%, respectively) of the droplet volume in the specified size or less. Wind tunnel and spray liquid conditions measurements, see section B2, are supplemental measures that will establish the bounds of the spray size distribution data.

To meet the DQO, at least three replicate experiments using each nozzle will be performed. As required by the DQO in element A7, the product of this test design will be the measurement of a droplet size distribution consisting of 32 or more droplet size bins for the specified operating range. The DQIGs for appropriate parameters identified in **Table 1** must be achieved for acceptance of the test data.

B2: Sampling Methods for Measurement of Droplet Size and Test Conditions

The sampling system is comprised of the HSWT at USDA-ARS, as depicted in **Figure 2**. The USDA-ARS HSWT consists of a high speed centrifugal blower powered by a 48.5 kw (65 hp) gasoline engine. The blower speed is controlled by adjusting the engine's throttle. The high speed air generated by the blower exhausts through a 30 x 30 cm outlet. Prior to leaving the outlet, the high speed air passes through air straighteners mounted inside the tunnel. Airspeed is measured directly at the outlet using a pitot tube attached to an airspeed indicator. A 30 cm section of aircraft boom is mounted directly at the tunnel's outlet. The boom is affixed to a pair of linear slides and a linear motor to allow it to be traversed vertically across the length of the outlet. The boom section is plumbed to a pressured spray tank. The center of the boom has a fitting to mount the required check valves and nozzles. A pressure gauge is also plumbed to the boom to monitor pressure at the nozzle. A movable 40 x 40 cm plexiglass tunnel is positioned in line with the airstream flush against the tunnel's outlet. This section is moveable to allow access to the spray boom and nozzle. The plexiglass tunnel has a pair of access holes downwind of the nozzle through which the laser diffraction instrument operates.

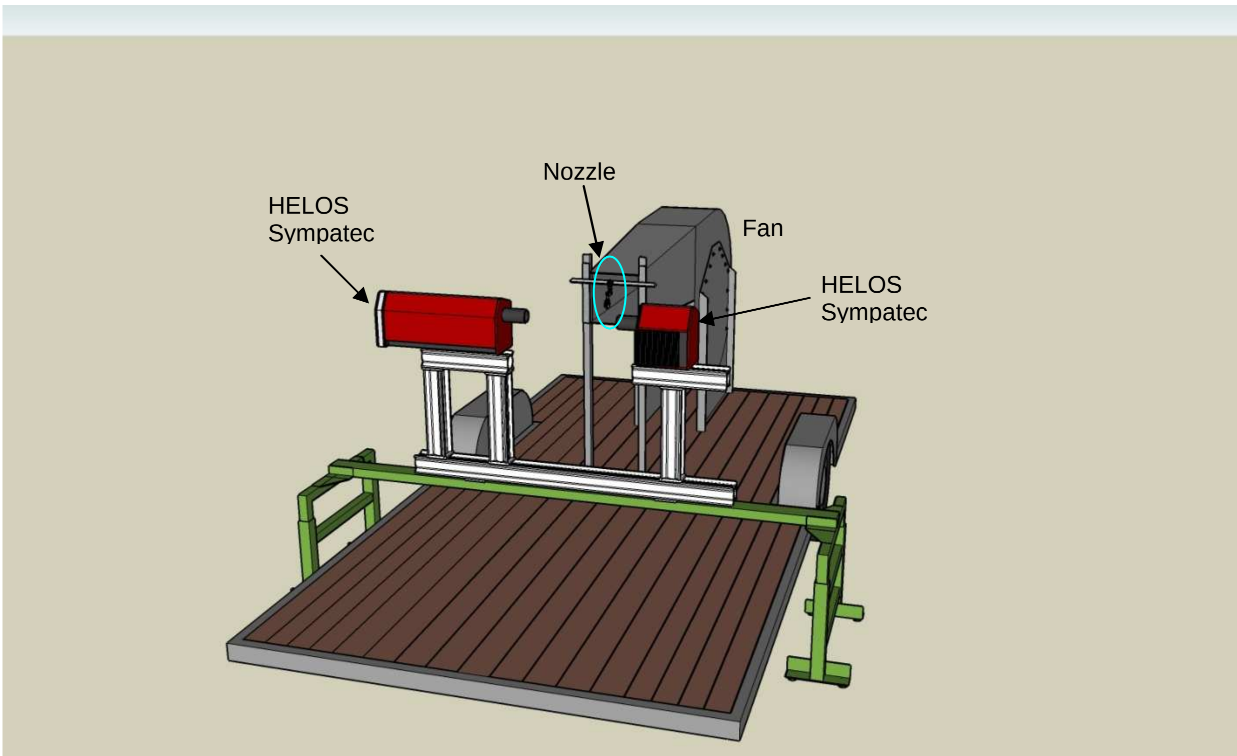

Figure 2. Overview of HSWT with enclosure removed for clarity.

Table 2 lists all the measurements required for each test. The measurements are categorized as performance factors and test conditions. Performance factors verify the performance of the DRT, and test conditions are important to understand the environmental conditions during the evaluation.

Table 2. Summary of Spray and Test Condition Measurements for High Speed Wind Tunnel Tests.

Parameter to Be Verified	Set-Point	Sampling and Measurement Method	Comments
Performance Factors			
Droplet size distribution at the atomizer	n/a	Non-intrusive sampling methods appropriate for the spray material such as laser diffraction, phase-Doppler, laser imaging instruments.	Document operating conditions and experimental data to satisfy all droplet size distribution DQIGs listed in Table 1.
Test Conditions Documentation			
Spray liquid pressure (nozzle operating pressure)	43.5 psi	See ASAE S572, section 3.	1 reading per test
Spray liquid flow rate	Reference: 1.2 L/min AI-11003: 1.1 L/min ULD 120-04: 1.5 L/min	See ASAE S572, section 3.	1 reading per test
Spray angle	Reference: 110 degrees AI-11003: Angle specified by Manufacturer ULD 120-04: Angle specified by Manufacturer	See ASAE S572, section 3 Manufacturer specified Manufacturer specified	Measurement before and after test
Spray liquid viscosity	1.1 cP at 20 ºC	Calibrated viscometer	1 measurement per test
Spray liquid surface tension	52.5 dynes/cm	Calibrated tensiometer	1 measurement per test
Spray liquid temperature	n/a	Calibrated thermometers accurate within 0.1 ºC	Temperature of the ambient air and spray mixture should be within 2 ºC
Wind tunnel air speed	100 mph	An appropriate and calibrated anemometer such as hot wire or pitot-static tubes. Measurement should occur as close as possible to the atomizer without affecting its performance.	The air speed measured in the wind tunnel will be used to define acceptable field conditions of use. Testing organization conducts air speed, temperature, and humidity measurements concurrently.
Wind tunnel ambient temperature	n/a	Calibrated thermometers accurate within 0.1 ºC	
Wind tunnel wet bulb/dew point temperature or percent relative humidity	n/a	Thermohygrometer equivalent to ASTM E337-84(1996)e1; or ASHRAE Standard 41.1	

Parameter to Be Verified	Set-Point	Sampling and Measurement Method	Comments
Wind tunnel cross-section diameter	n/a	Calibrated tape measure	Cross-section at least three diameters larger than spray plume diameter at size distribution measurement location.
Sympatec HELOS Laser Diffraction System	n/a	n/a	Record model number, serial number, scale ranges, software version number, and calibration verification.
Nozzle Description	n/a	n/a	Record nozzle information for each test [i.e., flat fan, cone (hollow, full), impingement (deflector), and solid stream nozzles; manufacturer; fan angle at reference operating pressure; orifice size; material of manufacture]. Nozzle part number, type of nozzle body and type of cap are also recorded for every test.

B2.1 Sampling Locations

For most tests, the nominal distance between the center of the atomizer tip and the plane of the size distribution measurements will be 6 to 30 in. (15 to 76 cm), accurate to within 0.5 in. (13 mm). In general, the optimal sampling distance is 8 to 20 in. (20 to 50 cm). The sampling distance may need to be adjusted for different atomizers, flow rates, and test fluids. The plane is defined by the movement of the centerline of the laser beam as it traverses the spray. The experimental set-up must insure complete span of the spray cross-section, particularly when the atomizer orientation is perpendicular to air velocity. The nominal distance must be far enough from the atomizer to allow for both atomization of ligaments and secondary break up of droplets in the air stream to be complete. However, the sampling distance must be close enough to the atomizer that the spray plume diameter is less than one-third of the wind tunnel cross-section. A traverse must be completed in a minimum of 5 s, with 20 to 30 s the most likely range.

Air temperature, humidity, and wind speed will be measured immediately upstream of the spray nozzle. This location provides representative measurements without affecting atomizer performance or air speed within the wind tunnel. Measurement of air temperature and humidity will occur upwind of the atomizer and as close as possible to the atomizer without affecting its performance or the air speed at the atomizer.

B2.2 Process/Application Data Collection

Droplet size distribution measurements will be collected with a Sympatec HELOS laser diffraction system (Sympatec Inc., Lawrenceville, NJ). The full spray volume will be traversed three times during the test. The maximum time between traverses will be 20 s. The primary operator of the laser diffraction instrumentation control software will input all appropriate test parameter information into the software's database system which will tag each test replication with the appropriate identification data. The database software settings will be adjusted such that collected data cannot be modified or removed once collected. The primary operator of the system will back up the collected data in database format to appropriate archival media labeled with test identification parameters. Additionally, all collected data will be archived in database format on the laser diffraction system computer hard drive. Collected droplet size distribution data will be processed or analyzed to insure that the appropriate DQIGs in **Table 1** are achieved.

Wind tunnel conditions are measured at the same height as the nozzle, upwind of the nozzle in the wind tunnel working section at the time of spray release. These measurements include ambient air temperature, relative humidity, and air speed. The data will be recorded to document the DQIGs are achieved. Measurements will be collected using NIST-certified instruments.

Sprayer operational parameters will be measured. Spray pressure will be measured at the nozzle tip using a capillary connected to a NIST-certified pressure gauge. The liquid flow rate to the sprayer will be measured between the liquid tank and the nozzle using a NIST-certified flowmeter. Spray liquid temperature will be measured in the liquid tank with a NIST-certified thermometer. The sprayer performance data will be processed to insure that DQIGs are achieved. Spray liquid viscosity and surface tension will be measured using appropriate instruments with valid calibration certificates.

B2.3 Wind Tunnel Measurement of Spray Drift Potential (Droplet Size Distribution at Aerial Application Air Speeds at the Nozzle)

All sampling will follow the requirements of the specific test method being used unless otherwise stated in this document or approved by EPA project manager prior to the test. Test procedures will provide data and information to assess the DQIGs specified in **Table 1**. A summary of the experimental procedure described in USDA SOP-4.4: "Determining Cross-Section Average Drop Size Distributions of Sprays" is provided below.

1. The nozzle is installed in the wind tunnel at or near the centerline at the appropriate orientation to the airflow with the nozzle tip at an upwind distance of 15 to 60 cm from the center of the laser beam. Nozzles must be positioned in the center of the wind tunnel to be free from edge effects.

2. The fan spray angle relative to the air flow direction (i.e., predominant spray direction or axis of rotation) is measured with a protractor and recorded. During drift potential measurements, the angle of the candidate test system does not need to be identical to that of the reference spray system (See **Table 2**).

3. Droplet size shall be measured using the Sympatec HELOS laser diffraction system. The model number, serial number, scale ranges, software version number, and calibration verification will be recorded for each test. The R5 lens will be the standard lens to provide sufficient working distance along the laser beam to avoid vignetting. For a very fine spray, a shorter focal length lens, R3, may be required. In such cases, accommodation of the spray cloud must be confirmed. For coarser sprays, the R7 lens may be used.

4. The droplet size measurements will include assessments of the droplet size category of the candidate test system and reference system according to ASAE S572.

5. The test fluid will be deionized water containing 0.25% v/v 90% NIS (R-900, Wilbur-Ellis Company, San Antonio, TX). Spray material characteristics will be measured following USDA SOP-4.2: "Measurement of Physical Properties of Liquids."

6. The spraying system shall be primed with spray prior to measurements to ensure that rinsing liquid is removed from the line and the liquid discharging from the nozzle is the actual intended tank mix. In addition, sprayer systems should be "run-in" for 5 min to ensure removal machining burrs or plastic mold residue.

7. Spray material flow rate shall be measured at the operating pressure for the tests. Prior to testing each nozzle, it will be plumbed to a pressurized spray tank and operated at the specified pressure. Spray volume will be collected in a container over 60 s and weighed on a scale. This will be replicated three times. The spray rate will then be determined for each replication the average and standard deviation calculated. Nozzle output should remain constant with a maximum deviation of ± 2.5%. Spray volume will also be measured during the HSWT test by placing the pressured spray tank on a scale to measured the volume sprayed (based on the starting and ending mass and fluid density). Spray time will be measured using a stop watch to allow determination of spray rate. These liquid flow rate measurements are consistent with ISO 5682 part 1.

8. The air speed in the working section of the wind tunnel must be measured as close as possible to the nozzle without affecting nozzle performance or allowing the atomizer to influence the air speed measurement. Air speed target is 100 mph ± 5 mph.

10. The design characteristics of the test and reference nozzles must be documented as follows:

   - Flat fan, cone (hollow or full), impingement (deflector), and solid stream nozzles: manufacturer, fan angle at reference operating pressure, orifice size, material of manufacture.
   - Other types of atomizers (e.g., rotary, electrostatic, and ultrasonic): the type of nozzle must be described in the test/QA plan provided to EPA prior to testing in order to identify the appropriate parameters to be recorded.
   - Include a close-up photograph of the nozzle and manifold and a cross-sectional drawing.
   - Include the manufacturer nozzle part number.
   - Document the type of nozzle body and cap used in the tests.

B2.4 Measurement of Droplet Size Spectrum near the Nozzle, Without the Effects of Flight Speed Air Flow

The five, official reference nozzles that determined the Classification Category boundaries specified in ASAE S572 will be evaluated prior to starting any tests. Using the operational parameters specified in ASAE S572, the spray plume size distribution will be measured along the traverse plane with the Sympatec HELOS system without any high speed air. The spray solution will be deionized water with 0.25% v/v a 90% NIS (R-900, Wilbur-Ellis Company, San Antonio, TX). These tests will insure that all equipment is properly working and that HELOS calibration has not been lost. The results from the five nozzles will serve as a reference measurement between tests. The nozzle that defines the fine/medium category [flat fan 110° at 300 kPa (43.5 psi)] will serve as the reference nozzle for all subsequent tests.

The droplet size measurement and classification will be consistent with ASAE S572 in addition to the criteria below.

1. Droplet size spectra for spray drift tests will be made under the same conditions (e.g., spray material, spray pressure, nozzle settings) and following the same procedures outlined in elements B2.2 and B2.3.
2. The DQIGs specified in **Table 1** are achieved.

B3: Sample Handling and Custody Requirements

No physical samples requiring handling or custody are collected.

B4: Analytical Methods

No analytical methods are used.

B5: Quality Control

The USDA QM is responsible for ensuring that the procedures specified in this document and USDA SOP-4.4 are followed. Prior to any tests, the QM will review the data requirements with the technical leader and establish which personnel are responsible for collecting, recording, and storing all data obtained during the tests.

The USDA QM will monitor the performance factors and auxiliary test conditions described in **Table 2** and DQIGs specified in **Table 1**. These QC objectives are applicable to reference nozzles and the test DRT. If the DQIGs for the spray volume size distribution or test conditions are not achieved, the test will be repeated.

B6: Instrument/Equipment Testing, Inspection, and Maintenance

All temperature, relative humidity, pressure, and airspeed instrumentation must be NIST-traceable instruments. All procedures for calibration and testing of these instruments must be followed and recorded as required by the manufacturer's specifications.

B7: Instrument/Equipment Calibration and Frequency

The Sympatec HELOS System will be calibrated and certified by Sympatec-provided technicians on a yearly basis. A copy of this calibration procedure and all appropriate documents will be kept in the Sympatec Operator's Manual. The calibration procedure follows ASTM Standard Test Method E 1458 "Test Method for Calibration Verification of Laser Diffraction Particle Sizing Instruments using Photomask Reticles."

Calibration of all other instrumentation will be current and documented.

B8: Inspection/Acceptance of Supplies and Consumables

Inspection and acceptance criteria for vendor supplied or USDA-ARS purchased materials and equipment are coordinated by the USDA-ARS technical leader or task leader. This process is conducted in accordance with SOP-4.3: "Reception, storage and distribution of active chemicals." Water used in spray tanks should have a hardness of less than 300 ppm.

B9: Non-Direct Measurements

All data used in this project will be generated by this project. No non-measurement sources, such as computer databases, programs, literature files, and historical databases, will be used.

B10: Data Management

B10.1 Data Acquisition and Management

Data acquisition and data management are performed according to USDA SOP-4.4. The planned data, with responsibilities of the USDA-ARS technical leader and USDA-ARS QM, are depicted in **Figure 3**. This flow chart includes all data activities from the initial pretest QA steps to the passing of the data to EPA. The USDA-ARS technical leader is operationally responsible for all aspects of a test. The technical leader collects and assembles the data necessary to assess the spray volume size distribution. Documentation of auxiliary information to validate the DQIGs will also be included in the data package. The USDA-ARS QM is operationally responsible for data validation; including confirmation the DQIGs are achieved. RTI will perform an independent QA assessment of the final test report prior to submission to EPA.

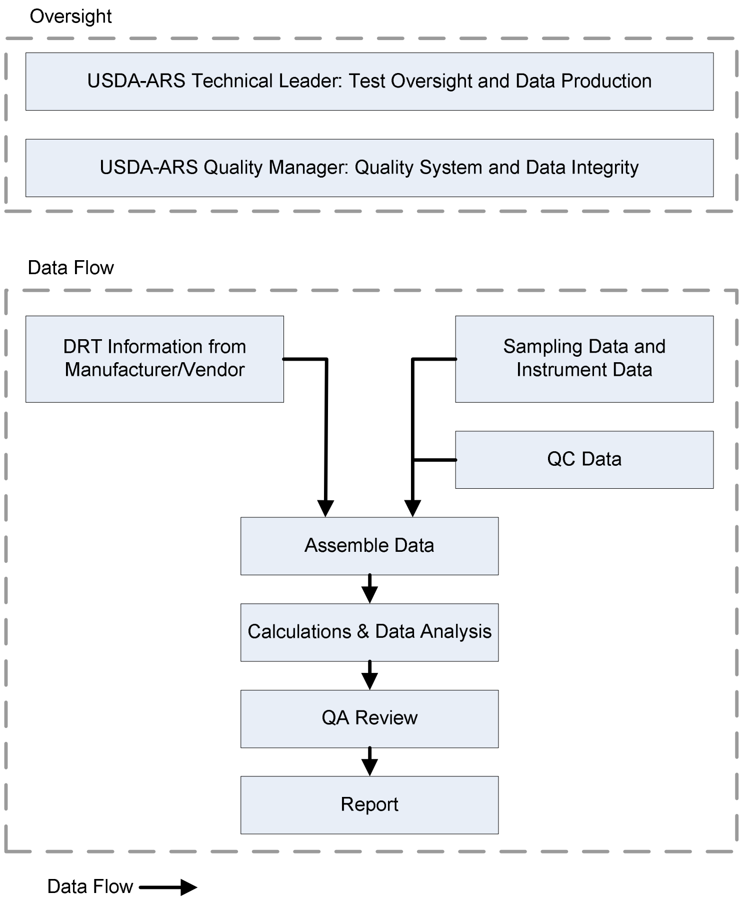

Figure 3. ETV data management system for USDA-ARS.

B10.2 Reporting

The data report will contain sufficient details and background information to provide a complete description of the testing in the report. The minimum information to be contained in the report is detailed in **Table 3**. The USDA-ARS will prepare the draft test report which will be reviewed by the USDA-ARS project manager and then by the USDA-ARS QM prior to submission to the RTI project leader for RTI and vendor reviews. After comments from RTI and the vendor are addressed, RTI (with assistance and review by the USDA-ARS) will revise the draft report and prepare a draft executive summary for EPA's review.

The final test report, which will be prepared by RTI, includes a results summary and a detailed discussion of the testing, as outlined in **Table 3** below.

Table 3. Summary of Data and Background Information to Include in the Test Report

Report Section	Contents
Executive Summary	DRT manufacturer/vendor information
	Summary of the test program, including test location and type
	Results (tabular or graphical format)
	Droplet size classification using ASAE S572
	Discussion of limitations of the results
	Brief QA statement
Introduction	Description and identification of the DRT
Procedures and Methods	Brief description of instrument used for droplet size measurement (including name and type, model number, serial number, scale ranges, software version number, and date of most recent calibration)
	Nozzle conditions: including nozzle manufacturer, nozzle model number, spray pressure at nozzle, volume per unit time produced by the nozzle
	Spray liquid conditions: including chemical composition, chemical sources, surface tension, viscosity, and temperature
	Wind tunnel conditions: including all measurement locations, temperature, humidity, and wind speed
Summary and Discussion of Results	Results of the ASAE S572 droplet size measurements for reference nozzle(s) and test nozzle
	Discussion of test results
	Explanations for deviation from test plan
	QA statement and discussion
References	List of cited materials
Appendices	QA/QC activities and detailed results
	Raw test data
	Equipment calibration results (if applicable)

Group C: Assessments and Oversight Elements

C1: Assessments and Response Actions

C1.1 Internal Audits

Internal audits by USDA-ARS are conducted as specified in the USDA-ARS SOP-4.4: Determining Cross-Section Average Drop-Size Distributions of Sprays, which conforms to required element C1 (Assessments and Response Actions) and C2 (Reports to Management) of EPA QA/R-5.

C1.2 Audits of Data Quality

In accordance with Table 9.1 of the EPA ETV QMP, the USDA-ARS QM will conduct an audit of data quality (ADQ) of at least 10% of all test data collected during testing at the respective test sites. The ADQ will be conducted in accordance with EPA's *Guidance on Technical Audits and Related Assessments for Environmental Data Operations, EPA QA/G-7*, including:

- a written report detailing the results of custody tracing,
- a study of data transfer and intermediate calculations,
- a review of QA and QC data, including reconciliation to user requirements (e.g., DQOs and DQIGs), and
- a study of project incidents that resulted in lost data, and a review of study statistics.

The USDA-ARS ADQ report will end with conclusions about the quality of the data from the project and their fitness for their intended use.

C1.3 External Audits

USDA-ARS will cooperate with any external assessments by the EPA or RTI. RTI or EPA will conduct a single technical systems assessment of USDA-ARS during the test. The external assessments will be conducted as described in EPA QA/G-7.

C1.4 Corrective Action

Corrective action to any audit or assessment at USDA-ARS is performed according to USDA-ARS SOP-4.5 "Corrective and Preventive Actions," which conforms to required elements B5 (Quality Control) and C1 (Assessments and Response Actions) of EPA QA/R-5.

C2: Reports to Management

Internal assessment reports will be reviewed by the USDA-ARS QM, who will respond as noted in element C1 of EPA QA/R-5. The written report of the ADQ will be submitted for review as noted in element C1.2 of this test/QA plan.

Group D: Data Validation and Usability Elements

D1: Data Review, Verification, and Validation

Data review and validation will primarily occur at the following stages:

- On the USDA-ARS test site following each test run
- On the USDA-ARS test site test site following completion of the test program
- Before writing the draft data report – by the USDA-ARS QM
- During QA review of the draft report and audit of the data – The criteria used to review and validate the data will be the QA/QC criteria specified in each test procedure, protocol, guideline, or method (see **Table 1**) and the DQIG analysis of the parameter test data. Those individuals responsible for onsite data review and validation are noted in **Figure 3**, element B10, and above. The USDA-ARS technical leader is responsible for verification of data with all written procedures. Finally, the USDA-ARS QM reviews and validates the data and the draft data report using the site-specific test/QA Plan, test methods, general SOPs, and project-specific SOPs.
- RTI will QA review the data reports.

The data review and data audit will be conducted in accordance with USDA-ARS's SOP.

D2: Verification and Validation Methods

Activities are specified in USDA-ARS SOP-4.4: Determining Cross-Section Average Drop-Size Distributions of Sprays, which conforms to required element D2 (Verification and Validation Methods) of EPA QA/R-5.

D3: Reconciliation with Data Quality Objectives

Activities are specified in USDA-ARS SOP-4.4: Determining Cross-Section Average Drop-Size Distributions of Sprays, which conform to requirement element D3 (Reconciliation with User Requirements) of EPA QA/R-5.

Appendix A: Applicable Documents and Procedures

1. EPA Documents

EPA. Policy and Program Requirements for the Mandatory Agency-wide Quality System. EPA Order 5360.1 A2. U.S. Environmental Protection Agency. May 2000.

EPA. *EPA Requirements for Quality Management Plans*. *EPA QA/R-2*, EPA Publication No. EPA/240/B-01/002. U.S. Environmental Protection Agency, Office of Environmental Information. Washington, DC. March 2001.

EPA. *Environmental Technology Verification Program, Quality Management Plan.* EPA Publication No. EPA/600/R-03/021. Office of Research and Development, U.S. Environmental Protection Agency. Cincinnati, OH. December 2002.

EPA. *EPA Requirements for Quality Assurance Project Plans. EPA QA/R-5*, EPA Publication No. EPA/240/B-01/003. Office of Environmental Information, U.S. Environmental Protection Agency. March 2001.

EPA. *Guidance for Quality Assurance Project Plans. EPA QA/G-5*, EPA Publication No. EPA/600/R-98/018. Office of Environmental Information, U.S. Environmental Protection Agency. February 1998.

EPA. *Guidance on Technical Audits and Related Assessments for Environmental Data Operations. EPA QA/G-7*, EPA Publication No. EPA/600/R-99/080. Office of Environmental Information, U.S. Environmental Protection Agency. January 2000.

2. RTI Documents

RTI International. Verification Testing of Air Pollution Control Technology - Quality Management Plan, Revision 2.2. RTI International. Research Triangle Park, NC. February 2005. http://www.epa.gov/nrmrl/std/etv/pubs/600etv10011.pdf.

3. USDA-ARS Documents[2]

USDA SOP-4.1: Personnel Records, Training Logs, and Laser Safety. September 2007.

USDA SOP-4.2: Measurement of Physical Properties of Liquids. September 2007.

USDA SOP-4.3: Reception, Storage, and Distribution of Active Chemicals. September 2007.

USDA SOP-4.4: Determining Cross-Section Average Drop-Size Distributions of Sprays. September 2007.

USDA SOP-4.5: Corrective and Preventive Actions. September 2007.

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[2] The USDA SOPs can be obtained from Bradley Fritz of USDA-ARS in College Station, TX, at brad.fritz@ars.usda.gov.

Appendix B: Organizational Charts for Testing the High Speed Pesticide Spray DRT Protocol

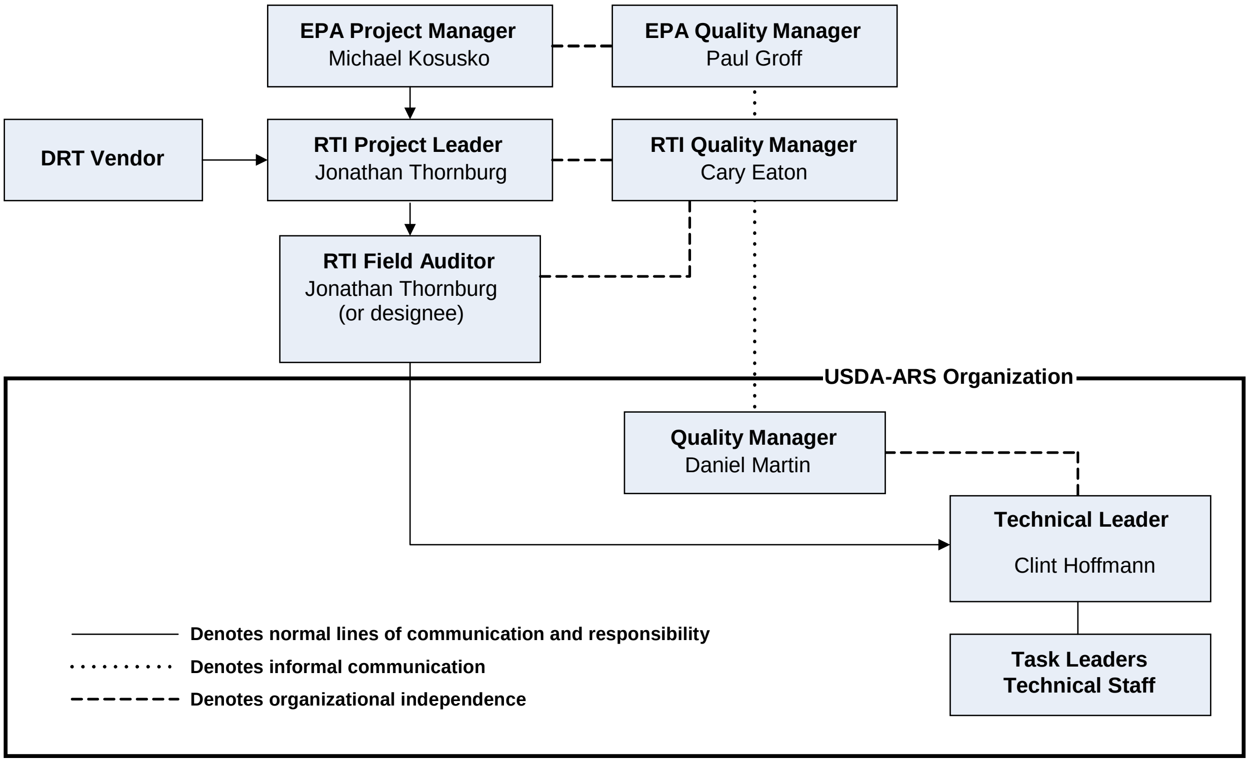

Figure 4. Organizational chart for the high speed pesticide spray DRT protocol validation.