LeafScan Data Collection Plan

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00 – Scope and Objectives

Audience: Researchers, Field Adjusters, Project Managers, and Reviewers
Purpose: Define the boundaries, goals, and expected outcomes of the LeafScan data collection project.

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1. Project Scope

Purpose

To clearly define what the LeafScan system is intended to measure, the constraints under which data is collected, and the expected uses of the resulting data.

Description

LeafScan is designed to provide a **repeatable, objective, and scalable** method for estimating corn leaf defoliation. It encompasses:

1. **Physical tools** – specialized LeafScan device for standardized leaf capture.
2. **Data capture workflow** – videos of leaves slid across the tool.
3. **Mobile and cloud software** – OpenMobile for data entry, annotation, and cloud synchronization.
4. **Reconstruction models** – algorithms to estimate original leaf area and defoliation percentage.

Data collected will be used to:

- Quantify **post-defoliation leaf area**
- Train and validate **pre-defoliation reconstruction models**
- Benchmark system performance under varied environmental and leaf conditions

- Provide operational guidance for insurance, research, or precision agriculture applications

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System Connection

Establishing scope ensures that all personnel, from field adjusters to data scientists, have a shared understanding of the system boundaries.
This reduces inadvertent protocol violations and aligns expectations across teams.

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2. Objectives

Objective 1 – Operational Data Collection

Purpose: Enable adjusters to collect consistent, high-quality data under real-world field conditions.

Approach:

- Collect post-defoliation leaf videos using the LeafScan tool
- Record base widths and remaining leaf length
- Annotate field, plant, and leaf IDs in OpenMobile
- Ensure videos pass on-device validation before upload

System Connection:
This objective ensures that operational users contribute data usable for routine inference while minimizing the risk of invalid captures.

Objective 2 – Validation and Benchmarking

Purpose: Generate ground-truth datasets to assess LeafScan system accuracy and robustness.

Approach:

- Measure pre- and post-defoliation leaf area using calibrated leaf area meters
- Apply controlled simulated defoliation patterns
- Capture video and measurements for benchmarking edge cases
- Record detailed metadata for system evaluation (lighting, background, leaf type, damage patterns)

System Connection:
Provides a high-fidelity reference to quantify model error and system reliability across real-world and extreme conditions.

Objective 3 – Standardization and Auditing

Purpose: Ensure that all collected data is traceable, comparable, and auditable.

Approach:

- Use structured multilevel annotations: Field → Plant → Leaf → Measurements & Videos
- Record metadata for collector identity, tool version, and capture conditions
- Implement on-device and cloud-based validation checks
- Maintain revision-controlled protocols and checklists

System Connection:
Enables reproducibility and external review while preserving dataset integrity for long-term research and operational use.

Objective 4 – Scalability and Usability

Purpose: Collect large volumes of data efficiently without sacrificing quality.

Approach:

- Optimize workflow for field adjusters with minimal training
- Standardize tool design and video capture procedure
- Provide mobile app guidance and automated validation
- Prioritize low-complexity, repeatable tasks

System Connection:
Supports deployment across multiple regions and users while keeping cognitive load low and minimizing operator-induced errors.

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3. Key Deliverables

- **Operational Dataset:** Post-defoliation leaf measurements and videos, ready for model inference.
- **Validation Dataset:** Pre- and post-defoliation ground truth for benchmarking and model training.
- **Protocols and Checklists:** Formalized procedures for operational and validation data collection.
- **Training Materials:** Step-by-step guidance for field personnel, including video capture and app workflow.

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4. Out of Scope

- Analysis beyond corn leaf defoliation (other crops are not supported)
- Defining standard adjustment procedures (LeafScan **augments**, but does not replace, NCIS adjuster training and existing guidance)

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5. Summary

This document establishes **the boundaries, goals, and expected outputs** of the LeafScan data collection system.
It serves as a reference for all subsequent materials, ensuring clarity and consistency for both field and validation workflows.

01 – Materials and Preparation

This document defines **all preparation requirements** that must be satisfied *before* LeafScan data collection begins.

Preparation requirements are divided into: - **Operational Protocols** – required for all field use
- **Validation Protocols** – extensions applied only during system validation and benchmarking

If any required preparation step is not met, **data collection must not proceed**.

Part I – Operational Protocols

(Applies to all LeafScan data collection)

Section A – Operational Materials

Purpose To ensure all physical and digital tools required for LeafScan data collection are present and functional before entering the field.

Description LeafScan relies on a constrained physical capture environment and standardized measurements.
Missing, substituted, or malfunctioning equipment can invalidate an entire collection session.

Protocol **Required Equipment** - LeafScan physical tool
- Mobile device with OpenMobile installed
- Precision ruler (>= 1/16 inch or 1 mm resolution)
- Leaf-safe marking method (fine-tip marker or tape)

Device Readiness 1. Confirm mobile device battery >= 50%.
2. Confirm sufficient local storage for video capture.
3. Confirm camera lens is clean and unobstructed.

System Connection Equipment gaps introduce systematic bias by selectively dropping difficult or time-constrained samples.
This check protects dataset completeness, repeatability, and downstream inference integrity.

Section B – Operational Operator Training

Purpose To ensure data collectors can correctly execute LeafScan procedures and recognize unusable data *before* submission.

Description LeafScan assumes baseline competency prior to field deployment. This section confirms readiness rather than providing in-field instruction.

Protocol

1. Confirm the operator has completed LeafScan tool training.

2. Confirm the operator understands:
   - Proper LeafScan tool handling
   - What constitutes a valid LeafScan video
   - Common failure modes requiring re-capture

3. Confirm completion of OpenMobile training.

4. Confirm the operator can:
   - Create Plant and Leaf Annotations
   - Assign Leaf ID, Plant ID, and Field ID
   - Record leaf length and base widths
   - Attach LeafScan videos to annotations

System Connection Operator variability is the dominant source of field data failure.
Ensuring minimum competency reduces invalid captures, prevents unnecessary cloud inference, and improves cross-adjuster consistency.

Part II – Validation Protocols

(Extension of Operational Protocols)

All operational preparation requirements apply unless explicitly extended below.

Section C – Validation Materials

Purpose To ensure validation data includes accurate, repeatable ground-truth measurements and controlled defoliation capability.

Description Validation mode introduces additional measurement and manipulation steps that are not required during normal operation.

Protocol Ground Truth Measurement - Commercial leaf area meter
- Calibration reference (if applicable)

Simulated Defoliation - Scissors
- Standard hole punch (optional)

Documentation and Handling - Notebook or CSV file for recording measurements
- Cleaning materials for measurement equipment

1. Verify calibration status of the leaf area meter.

2. Confirm measurement device settings are known and reproducible.

System Connection Validation benchmarks are only as reliable as their reference measurements.
Uncalibrated instruments or inconsistent settings invalidate error analysis and model evaluation.

Section D – Validation Operator Training

Purpose To ensure validation personnel can reliably generate ground-truth data and controlled failure cases.

Description Validation data collection requires additional technical skill beyond operational use.
Personnel must be capable of producing **repeatable measurements**, not just valid LeafScan captures.

Protocol

1. Confirm certification for LeafScan validation protocol.

2. Confirm training on:
   - Commercial leaf area meter operation
   - Measurement repeatability and stability checks

3. Confirm training on:
   - Controlled, intentional defoliation methods
   - Avoiding accidental tearing or distortion

4. Confirm understanding of:
   - Validation metadata requirements
   - CSV or notebook recording standards

System Connection Ground-truth error propagates directly into model evaluation metrics.
Trained validation personnel ensure observed system error reflects algorithmic performance rather than human inconsistency.

Section E – Task Assignments and Edge-Case Quotas

(Validation Mode Only)

Purpose To ensure systematic coverage of edge cases, stress conditions, and known failure modes during validation.

Description Task assignments define **quotas**, not sequential steps.
They are applied opportunistically during normal per-leaf processing and recorded for later analysis.

Detailed definitions, rationale, and expected outcomes for each task are documented in a **separate Task Assignment file**.

Protocol

1. Review the task assignment sheet prior to entering the field.

2. During leaf-level data collection:
   - Apply assigned transformations when appropriate
   - Do not alter the core data collection sequence

3. For each transformed leaf, record:
   - Leaf ID
   - Transformation applied
   - System outcome (pass / fail / ran)
   - Adjuster assessment of acceptability

4. Ensure all assigned quotas are met before concluding collection.

System Connection Edge cases rarely occur naturally and are underrepresented in field data.
Explicit task assignments ensure validation datasets adequately probe system limits and failure boundaries.

Section F – Pre-Field Readiness Confirmation

Purpose To provide a final go/no-go checkpoint before data collection begins.

Description This confirmation prevents partially prepared sessions from entering the dataset.

Protocol

☐ Operational materials confirmed

☐ Operational training confirmed

☐ Validation materials confirmed (if applicable)

☐ Validation training confirmed (if applicable)

☐ Task assignments reviewed (if applicable)

System Connection Clear readiness gates improve auditability, reduce protocol drift, and protect downstream trust in collected data.

03 – Data Collection Steps

This document defines the **in-field execution steps** for LeafScan data collection. It is designed to remove ambiguity during field work while also serving as a formal, auditable protocol for system validation, benchmarking, and external review. All preparation steps are assumed complete per **01 – Materials and Preparation**.

Two data collection modes are defined:

- **Operational Mode** – standard field use by trained adjusters
- **Validation Mode** – extended protocol for system testing and benchmarking

  Note on Audience
  This document is written primarily for adjusters performing data collection.
  Sections labeled **System Connection** provide additional technical context for researchers, engineers, and reviewers.
  These sections may be skipped during routine data collection without affecting protocol compliance.

Part I – Operational Data Collection Protocol

(LeafScan – Intended Use)

LeafScan is designed to **augment existing adjusting procedures**, not replace them.
All plant and field selection decisions should follow standard adjusting guidance unless explicitly stated otherwise.

Step 1: Select a Representative Plant

Purpose
To select a plant that accurately reflects field-level defoliation and is suitable for LeafScan measurement.

Description
The adjuster selects a representative corn plant following standard adjusting procedures.

During selection, the adjuster verifies that the plant contains leaves suitable for LeafScan data collection.

If no representative plants meet minimum requirements, the field is flagged and standard visual estimation procedures are used.

Procedure
1. Select a corn plant representative of surrounding field conditions, following standard adjusting guidance.
2. Inspect leaves on the plant **without removing them**.
3. Confirm the plant contains leaves that:
- Fit within the LeafScan tool channel
- Can be held taut without tearing
- Do not show extensive damage across the first **X inches** from the leaf collar
4. If determining growth stage requires plant removal:
- Select a nearby equivalent plant
- Determine growth stage following standard adjusting guidance
5. If the plant does not meet LeafScan requirements:
- Select a different representative plant
6. If no suitable representative plants are available:
- Flag the field for extensive damage in the app
- Defer to standard visual estimation procedures

System Connection
Representative plant selection underpins all scaling from leaf-level measurements to plant- and field-level estimates.
Allowing a formal fallback to visual estimation prevents biased datasets caused by forcing LeafScan on unsuitable material.

Step 2: Per-Leaf Processing

The following steps are performed for each leaf on the selected plant.
LeafScan is designed to operate **non-destructively**, with leaves remaining intact and attached to the plant during video capture.

Step 2.1: Environment Check (Immediately Before Capture)

Purpose
To ensure environmental conditions will not interfere with LeafScan video quality.

Description
Environmental checks are performed immediately before each video capture.
Lighting, background color, and glare directly affect tool detection.

Procedure
1. Confirm lighting is even and sufficient.

2. Ensure no strong glare appears on the LeafScan tool.
3. Confirm background elements contain **no pink, red, or similar colors**.

System Connection
Environmental variability directly impacts contour detection and tool localization.
Performing this check immediately before capture reduces silent failures caused by changing conditions.

Step 2.2: LeafScan Video Capture

Purpose
To digitally capture the defoliated leaf in a controlled and repeatable manner while the leaf remains intact and attached to the plant.

Description
The leaf is slid through the LeafScan tool while a video is recorded.
Capture is performed with the **frontside of the leaf facing forward**.

Procedure
1. Position the LeafScan tool around the leaf while it remains attached to the plant.
2. Ensure the **entire tool** is visible in the frame.
3. Start recording in OpenMobile.
4. Slide the leaf smoothly through the tool:
- No pauses
- No reversals
- No folding
5. Continue until the entire leaf length is scanned.
6. Stop recording.

System Connection
LeafScan processes video as a sequence of fixed-height segments.
Capturing the leaf while attached preserves natural tension and alignment, reducing deformation-related errors.

Step 2.3: Video Validation (Required Before Measurement)

Purpose
To ensure the captured video is acceptable before any further handling of the leaf.

Description
Validation occurs immediately after capture and consists of **two independent checks**: automated system validation and adjuster visual review.
Both must pass for the video to be accepted.

Procedure
1. Allow on-device validation to complete.
2. Confirm automated checks pass:
- Tool presence validation
- Leaf motion validation
3. Visually review the video to confirm:
- Entire tool remains in frame
- Leaf motion is continuous
- No folding, reversal, or obstruction occurs
4. If **either** the system or the adjuster rejects the video:
- Discard the capture
- Re-capture the video before proceeding
5. Only proceed once the video is accepted by **both** checks.

System Connection
This two-factor validation prevents false positives where automated checks pass but subtle issues remain.
Early rejection protects downstream inference and dataset integrity.

Step 2.4: Leaf Identification and Physical Measurements

Purpose
To record the physical measurements required to interpret the LeafScan video and estimate the leaf's original area.

Description
For each leaf, the adjuster records:
- **Leaf number**
- **Post-defoliation leaf length**
- **Base width measurements** across the first X inches

Measurements may be performed with the leaf still attached or removed for convenience.
Leaf removal is optional and does not affect LeafScan operation.

Procedure
1. Identify and record the **leaf number**.
2. Measure and record the **remaining leaf length** from collar to tip.
3. Identify the **leaf collar**, where the blade meets the plant.
4. Hold the leaf taut with the **backside facing upward**.
5. Measure and record the width at the collar.
6. Mark a line **1 inch above the previous measurement**, perpendicular to the leaf.
7. Measure and record the width at each marked interval.
8. Flag any base width that is damaged or unmeasurable.
9. Repeat until all **X base widths** are attempted.

Notes on Damaged Base Widths
- Damaged base widths may be extrapolated from remaining measurements.
- If too many base widths are missing or damaged, the system will prevent completion of the leaf record.
- In this case, the adjuster must select a different representative plant.

System Connection
Leaf length calibrates the number of segments extracted from the video.
Leaf number and base widths anchor reconstruction models used to predict original leaf area.
Explicit damage flags allow the system to distinguish missing data from true geometry.

Step 5: Repeat Across Leaves and Plants

Purpose
To collect sufficient data for reliable field-level estimates.

Description
The adjuster repeats per-leaf processing for each leaf on the selected plant, then repeats plant selection across **X representative plants** in key field locations.

Procedure
1. Repeat Step 4 for each leaf on the plant.
2. Select the next representative plant.
3. Repeat Steps 3–4 until the required number of plants is reached.

Step 6: Data Synchronization and Results Retrieval

Purpose
To securely upload collected data, complete inference, and retrieve results.

Description
After field collection, the adjuster must reach a location with reliable internet to synchronize all data with the cloud system.

Procedure
1. Navigate to a location with reliable internet access.
2. Open OpenMobile and initiate data synchronization.
3. Confirm all:
- Leaf annotations
- Measurements
- LeafScan videos
have uploaded successfully.

4. Wait for cloud inference to complete.
5. Download and review results as required.

System Connection
Explicit synchronization ensures data integrity, traceability, and consistent linkage between field data and inference results.

Part II – Validation Data Collection Protocol

(System Validation and Benchmarking)

> **Note:**
> This protocol is an extension of the **Operational Mode**. All operational steps apply unless explicitly modified below.
> Validation steps are interleaved **within Step 4: Per-Leaf Processing** of the operational protocol.
> Timing for each validation substep is explicitly noted.

Task Assignment / Edge Case Quotas

Purpose
Ensure systematic coverage of edge and failure cases for benchmarking.

Description
Before fieldwork, each adjuster receives a **task assignment sheet**:
- Specifies quotas for extreme or unusual scenarios (e.g., severe defoliation, damaged base widths, partial scans, suboptimal lighting)
- Adjusters may apply these transformations **at any point** during Step 4 per-leaf processing
- Transformations are recorded in the CSV along with system pass/fail status

Protocol
- Review task sheet before starting leaf collection.
- During data capture, mark any leaves where a transformation was applied:
- Leaf ID
- Transformation type
- Observed system behavior (pass/fail)
- Ensure all quotas are met before concluding fieldwork.

System Connection
This ensures validation datasets adequately stress-test the system across predefined extreme conditions.
A separate file will describe the purpose and expected outcome for each transformation.

Step 2: Per-Leaf Processing

The following steps are are interleaved extensions to the **Per-Leaf Processing Operational Protocols**.
All 3 steps must be completed before proceding to **Step 2.1 (Environment Check)**

Step 2.a: Pre-Defoliation Leaf Area Measurement

Purpose
Record baseline leaf area to quantify LeafScan prediction error.

Description
Use a commercial leaf area meter to measure the intact leaf before any simulated or natural defoliation.

Timing
Before Step 2.1 (Environment Check)

Protocol
1. Assign Leaf ID, Plant ID, and Field ID (record in CSV or notebook).
2. Measure full leaf area with the leaf area meter.
3. Record pre-defoliation area.
4. Repeat measurement if device reports instability.

System Connection
Provides ground-truth reference for evaluating LeafScan's post-defoliation predictions.

Step 2.b: Simulated Defoliation

Purpose
Create controlled, repeatable leaf damage for benchmarking reconstruction under varied conditions.

Description
Defoliation is applied intentionally, following patterns from the task assignment sheet.

Timing
Immediately **after Step 2.a (Pre-defoliation area)** and **before Step 2.1 (Environment Check)**.

Protocol
1. Select defoliation pattern according to the assignment sheet.

2. Apply defoliation carefully to avoid accidental tearing or crushing.
3. Record defoliation details and approximate severity in CSV.

System Connection
Controlled defoliation allows systematic evaluation of LeafScan accuracy across different severities and leaf types.

Step 2.c: Post-Defoliation Leaf Area Measurement

Purpose
Record remaining leaf area after defoliation to enable accurate defoliation benchmarking.

Description
Use the same leaf area meter as pre-defoliation measurement.

Timing
Immediately **after Step 2.b (Simulated Defoliation)** and **before Step 2.1 (Environment Check)**.

Protocol
1. Measure leaf area with the meter.
2. Record post-defoliation area in CSV.
3. Ensure measurement settings match pre-defoliation measurement.
4. Repeat if device instability occurs.

System Connection
Together with pre-defoliation area, establishes true defoliation percentage for benchmarking.

Step 3: Post-Collection Review

- Verify all validation data (pre/post area, defoliation, base widths, leaf number, leaf length, task assignments) are complete.
- Flag anomalies.

Step 4: Data Synchronization

- Upload all videos, annotations, and CSV records to cloud.
- Wait for inference to finish.
- Download and review results.

LeafScan Video Capture Protocol

(Operational and Validation Use)

Purpose

This document defines the **authoritative procedure** for capturing a valid LeafScan video. A LeafScan video is the primary input to the digitization pipeline and must meet strict physical and visual constraints to ensure reliable downstream processing.

This protocol defines **what constitutes a valid capture**. Companion training videos illustrate correct and incorrect execution but do not supersede this document.

Description

A LeafScan video records a leaf sliding continuously through the LeafScan tool's constrained view window. Each frame represents a fixed-scale cross-section of the leaf, allowing the system to reconstruct post-defoliation leaf area from unique observed segments.

LeafScan is designed to be run **non-destructively**. The leaf must remain attached to the plant during capture and sufficiently intact to allow a continuous scan.

Preconditions

- LeafScan tool is available and clean
- Mobile device has sufficient battery and storage
- Leaf meets eligibility requirements:
  - Accessible without damaging the plant
  - Fits fully within the tool channel
  - Can be held taut and flat
  - Sufficiently intact to allow continuous motion

Capture Protocol

1. Tool and Camera Setup

- Entire LeafScan tool **must be visible** in the camera frame
- View window must be fully unobstructed

- Camera must remain stationary during capture
- Lighting must be sufficient to clearly distinguish leaf tissue

2. Leaf Positioning

- Leaf is inserted into the tool channel correctly
- Leaf is held taut and flat
- No twisting, folding, or bending is permitted

3. Leaf Motion

- Leaf must slide **continuously** through the view window
- Motion must be:
  - Single-directional
  - Smooth and uninterrupted
- No pauses, reversals, or backtracking
- Entire remaining leaf length must be scanned in one pass

4. Recording Constraints

- Recording starts before leaf enters the view window
- Recording ends only after leaf fully exits the view window
- No mid-scan stopping or restarting

On-Device Validation

Captured videos are automatically evaluated by on-device validation services:

- Tool presence validation
- Leaf motion validation

Videos that fail validation **must not** be uploaded.

Failure Modes (Non-Exhaustive)

- Tool partially out of frame
- Leaf motion stops or reverses
- Leaf folds or twists during scan
- View window obstructed
- Background color interference
- Insufficient lighting

System Connection

This protocol enforces assumptions required by: - Leaf segment uniqueness detection - Fixed-scale area reconstruction - Robust post-defoliation area estimation

Violations of this protocol directly degrade reconstruction accuracy and invalidate defoliation estimates.

OpenMobile Data Collection Workflow

(Operational and Validation Use)

Purpose

This document defines the **canonical workflow** for using the OpenMobile application to capture, validate, and submit LeafScan data.

Correct app usage ensures: - Proper metadata association - Traceability across field, plant, and leaf levels - Reliable downstream inference and reporting

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Description

OpenMobile acts as the interface between field data collection and cloud-based processing. It enforces structural constraints on data entry while enabling on-device validation of captured media.

Workflow Overview

The OpenMobile workflow follows a strict hierarchy:

1. Field
2. Plant
3. Leaf
4. Measurements and Media

This hierarchy must be respected to preserve data integrity.

Operational Workflow

1. Field Initialization

- Create or select the correct Field
- Verify field identifier and location metadata

2. **Plant Registration**

- Create or select the correct Plant within the Field
- Verify plant identifier consistency

3. **Leaf Registration**

- Assign a unique Leaf ID
- Confirm leaf orientation and eligibility
- Leaf ID must be assigned **before** measurements or video capture

4. **Base Width Entry**

- Enter required base width measurements
- Verify units and measurement count
- Confirm values before proceeding

5. **Video Capture**

- Capture LeafScan video following the Video Capture Protocol
- Review playback immediately after capture

6. **On-Device Validation**

- Confirm tool presence validation passes
- Confirm leaf motion validation passes
- Videos failing validation must be recaptured

7. **Submission**

- Verify all required metadata fields are populated
- Submit data for upload when connectivity permits

Common Errors

- Incorrect Leaf ID assignment
- Missing or incomplete base width measurements
- Submitting videos before validation passes
- Misassociation of leaf data to the wrong plant or field

System Connection

OpenMobile enforces structural assumptions required by: - Cloud inference scheduling - Dataset consistency across collectors - Auditability and post-hoc validation

Incorrect app usage can result in irrecoverable data loss or invalid inference results.

Task Assignments and Edge Case Definitions

(System Validation and Benchmarking)

Purpose

This document defines the **task types and edge cases** used to evaluate and stress-test the LeafScan system.

Task assignments ensure that validation data covers: - Expected operational conditions - Known failure modes - Structural and environmental extremes

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Description

Each task represents a controlled deviation or targeted scenario designed to test specific system assumptions. Tasks are assigned to certified validation operators and executed according to defined constraints.

Detailed task execution procedures are expanded in dedicated task-specific documents.

Task Categories

1. Standard Operational Tasks

Baseline captures following all operational protocols. Used to establish expected system performance.

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2. Capture-Level Edge Cases

Designed to probe robustness of video validation and reconstruction.

Examples: - Partial scans - Non-continuous motion - Tool partially out of frame - Leaf folding or twisting

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3. Environmental Stress Tasks

Evaluate sensitivity to real-world field conditions.

Examples: - Suboptimal lighting - Background color interference - Mild wind-induced motion

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4. Structural Extremes

Test assumptions about leaf morphology and damage patterns.

Examples: - Severe defoliation - Irregular or damaged base widths - Narrow or atypical leaf shapes

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Assignment Rules

- Tasks are assigned explicitly per leaf
- Task type must be recorded in metadata
- Deviations from protocol must be documented
- Failed or ambiguous outcomes must be flagged

System Connection

Task assignments enable: - Quantification of system failure boundaries - Model robustness evaluation - Justification of operational constraints

They are essential for interpreting performance metrics and defining acceptable operating conditions.

04 – Quality Control

This document defines procedures to verify the quality of collected data.
Two modes are defined:

1. **Operational Mode QC** – standard checks for all operational data.
2. **Validation Mode QC** – additional checks on top of operational QC.

Part 1 – Operational Mode QC

Video Quality

☐ Entire LeafScan tool visible

- ☐ Leaf slides continuously through view window
- ☐ No folding, twisting, or reversals
- ☐ Full leaf length captured

Metadata Consistency

- ☐ Leaf ID, Plant ID, Field ID present
- ☐ Base width measurements recorded
- ☐ Timestamps and device info consistent

Environment

- ☐ Background free from red/pink/tool-colored objects
- ☐ Lighting adequate
- ☐ Leaf held taut and flat

Part 2 – Validation Mode QC

Only apply if running validation mode.

Ground Truth Verification

- ☐ Pre- and post-defoliation leaf areas measured
- ☐ Measurements repeatable (no device errors)
- ☐ Baseline segment widths recorded correctly

Defoliation Verification

- ☐ Applied defoliation matches recorded method and location
- ☐ Estimated defoliation percentage present
- ☐ Edge cases tested as assigned

Data Integrity

- ☐ Video and ground truth measurements internally consistent
- ☐ Metadata matches physical measurements
- ☐ Any deviation flagged

System Components

The LeafScan ecosystem consists of the following interdependent systems. Each system imposes specific constraints and requirements on data collection, which are explicitly addressed in this plan.

1. LeafScan Digitization Pipeline

A leaf-agnostic, low-cost, and scalable digitization workflow

LeafScan is a set of scripts and procedures that process short videos of a leaf being slid across a specialized tool. From these videos, the system reconstructs and measures the **post-defoliation leaf area** by aggregating unique leaf segments observed through a constrained viewing window.

Key properties: - Leaf-agnostic (applicable to long-leaf crops) - Low computational complexity - Designed for field conditions - Robust to partial defoliation and fragmentation

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2. LeafScan Defoliation Reconstruction Model

A lightweight regression model for pre-defoliation area estimation

This model predicts the **original pre-defoliation leaf area** using post-defoliation measurements produced by the LeafScan pipeline. It enables estimation of defoliation percentage without requiring pre-damage imagery in operational settings.

Key properties: - Parsimonious and interpretable - Trained on physically meaningful measurements - Designed to generalize across damage patterns

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3. LeafScan Physical Tool

A constrained capture environment for reliable digitization

The LeafScan tool consists of: - A **pink rectangular frontpiece** with a rectangular cut-out (the *view window*) - A **blue rectangular backpiece**, offset to create a sliding channel

A leaf is manually slid across the tool, exposing successive leaf segments through the view window. The tool enforces: - Fixed scale - Controlled background - Consistent orientation - Simplified computer vision assumptions

This physical constraint is foundational to the performance of all downstream systems.

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4. OpenMobile Application

A mobile bridge between field collection and cloud inference

OpenMobile is a mobile application that enables trained adjusters to: - Capture standardized *LeafScan videos* - Run **on-device validation** to determine video

usability - Upload validated data to cloud servers - Retrieve inference results and finalized defoliation reports

The application is designed to function in **low-connectivity field environments**, deferring heavy computation until connectivity is available.

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5. On-Device Validation Services

Lightweight quality assurance for field-captured data

Validation services run locally on mobile devices to determine whether a captured video is suitable for inference. These services are enabled by the constrained physical design of the LeafScan tool and include:

1. **Tool Presence Validation**
   - Detects the LeafScan tool using a PCA-based classifier (*eigen-tool detection*)
2. **Leaf Motion Validation**
   - Confirms that a leaf is actively sliding across the view window
   - Uses changes in contour area, perimeter, and compactness across key frames

These checks prevent unusable data from entering the cloud pipeline.

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6. Cloud Inference and Data Management Servers

A centralized source of truth

Cloud servers: - Receive validated videos from all adjusters - Automatically schedule inference jobs - Store raw data, metadata, and results - Generate defoliation reports across plants, fields, and time

These servers function as the **authoritative database** for all operational and analytical outputs.
