# Executive Summary — PV Thermography (IEC 62446-3)

Client / Site

Project / Asset

Inspection Date & Window

Standards                                    IEC TS 62446-3:2017

UAS & Payload                         Autel EVO II Dual 640T RTK V3 — 640×512
                                               radiometric; thermal FOV 33°×26° (13 mm);
                                               50 MP stills / 4K video; RTK ±1 cm + 1 ppm (H),
                                               ±1.5 cm + 1 ppm (V).

Radiometric Settings               Mode: ON (R-JPEG + IRG); Emissivity: ____;

                                               Trefl: ____°C; Gain: [High/Low];

                                               Palette: _____.

Key Environmental Gates        Wind ≤ spec; standoff 2–20 m for quantitative
                                               temps; record ambient, humidity,
                                               ΔT/irradiance/load (per service).

Team & Contacts                      Lead: _____   Thermographer Level: [I/II/III]

                                               Part 107 Cert#: _____

## Key Findings (top 3)

- 
- 
- 

## Options & Recommendation

A) _____   B) _____   C) _____   Recommended: _____

## Risks & Mitigations

- 
- 

## Approval / Next Steps

Approve _____ by _____ ; follow-up scan date _____ ; point of contact _____.

## QC Worksheet — PV Thermography (IEC 62446-3)

| | | |
|---|---|---|
| Radiometric Mode | R-JPEG + IRG saved | [ ] Yes  [ ] No |
| Emissivity (ε) | Material-specific | Value: _____ |
| Reflected App. Temp (Trefl) | Per environment | ____ °C |
| Measurement Distance | 2–20 m required for quantitative temps | Min: ___ m  Max: ___ m  % within band: ___% |
| Altitude Above Roof/Target (ARL) | Service-specific (see below) | Level 1: ___ ft  L2: ___ ft  L3: ___ ft |
| RTK FIX Quality | Target ≥ 95% images FIX; PPK fallback if needed | FIX %: ___%   PPK: [ ] Used |
| Overlap Achieved | Thermal ≥ 80/80 (or per service) | Front: ___%  Side: ___% |
| Focus/Blur Check | Random sample ≥ 20 images | [ ] Pass  [ ] Re-fly segments |
| Coverage Audit | 100% or exceptions noted | Coverage: ___%  Exceptions: _____ |
| Processing Integrity | No-blending for quantitative mosaics | [ ] No-blend  [ ] Avg-blend (viz only) |
| Deliverables | Exec summary, orthos, CSV/KML, imagery, logs | [ ] All included |
| Sign-off | QC by | Name: _____   Date: _____ |

### IEC 62446-3-Specific Gates

| | | |
|---|---|---|
| Irradiance (POA) | ≥ 600 W/m²; stable <10%/min | Measured: ____ W/m²  Var: ____%/min |
| Viewing Angle | ≤ 60° from perpendicular | [ ] Verified |
| Wind | ≤ 17 mph | Measured: ____ mph |
| Resolution | ≥ 5×5 px/cell (detailed) / ≥ 3×3 (simpl.) | Achieved: ____ px/cell |
| Normalization | ΔT normalized to 1000 W/m² or 100% load | [ ] Done |
| Soiling/Glint | Low/consistent; avoid glint angles | Notes: _____ |

# IEC 62446-3:2017 Enhanced Edition
## PV Outdoor Infrared Thermography Checklist

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**KEY INSPECTION REQUIREMENTS**
Daylight only; POA irradiance ≥ 600 W/m² (modules) or ≥ 30% rated current (BOS)
Wind ≤ 17 mph (28 km/h); cloud ≤ 2 okta
If variability > 10%/min: PAUSE 15 min for steady state
Flight Pattern: E-W for fixed-tilt, N-S for trackers
Overlap: 65% front, 35% side minimum

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*This enhanced edition integrates standards from:*
• IEC TS 62446-3:2017
• Solar Best Practices Aerial Thermography
• NFPA 70B Electrical Maintenance

# 1. Pre-Flight Planning & Preparation

## 1.1 Site Layout Review

**As-built drawings reviewed:**

[ ] Yes   [ ] No   [ ] N/A

Date reviewed: _____

**Site access points identified:**
[ ] Yes   [ ] No

**Hazards/obstacles documented:**
[ ] Yes   [ ] No   Details: _____

## 1.2 Weather & Environmental Check

**5-day weather forecast reviewed:**

[ ] Yes   Date: _____

**Irradiance meter calibration confirmed:**

[ ] Yes   Model: _____ Calibration date: _____

**Current irradiance reading (must be ≥ 600 W/m²):**

_____ W/m²   Time: _____

## 1.3 Flight Path Planning

**Array configuration:**
[ ] Fixed-tilt   [ ] Single-axis tracker   [ ] Dual-axis tracker

**Selected flight pattern:**
[ ] E-W (for fixed-tilt)   [ ] N-S (for trackers)   [ ] Custom: _____

**Planned overlap:**
Front: _____ % (min 65%; increase to 80/70 in low-contrast conditions)   Side: _____ % (min 35%)

## 1.4 Self-Evaluation (Solar Best Practices)

**PV system experience:**
[ ] 2+ years field experience   [ ] Certified PV technician   [ ] Other: _____

**Thermography certification:**
Level: [ ] I  [ ] II  [ ] III   Cert #: _____   Exp: _____

**Drone piloting experience:**
[ ] 100+ hours   [ ] Part 107 certified   Certificate #: _____

# 2. Site & Inspection Information

**Client Name:**
_____

**Site/Project Name:**
_____

**Site Address:**
_____

**GPS Coordinates (decimal degrees):**
Lat: _____ Long: _____

**PV System Capacity:**
DC: _____ kW   AC: _____ kW   DC/AC Ratio: _____

**System Age:**
COD: _____   Years in operation: _____

**Inspection Date & Time:**

Date: _____   Start: _____   End: _____

# 3. Inspection Type & Scope
## 3.1 Inspection Level

| Level | Description | Selected |
|---|---|---|
| Overview | Quick assessment, major issues only | [ ] |
| Standard | Full coverage, all anomalies documented | [ ] |
| Comprehensive | Detailed + close-ups, individual string analysis | [ ] |

**Purpose: [ ] Commissioning   [ ] Annual O&M   [ ] Post-event   [ ] Warranty   [ ] Due diligence**

# 4. Environmental Conditions Compliance
**CRITICAL: If any condition varies > 10%/min, PAUSE and wait 15 minutes for steady state**

| Parameter | Requirement | Measured | Compliant? |
|---|---|---|---|
| Irradiance (POA) | ≥ 600 W/m² (modules) | _____ W/m² | [ ] Y  [ ] N |
| Irradiance Stability | < 10% variance/min | _____ %/min | [ ] Y  [ ] N |
| Wait Time (if needed) | 15 min after variance | _____ min | [ ] N/A |
| Wind Speed | ≤ 17 mph (28 km/h) | _____ mph | [ ] Y  [ ] N |
| Cloud Cover | ≤ 2 okta | _____ okta | [ ] Y  [ ] N |
| Module Soiling | Low/consistent | _____ | [ ] Y  [ ] N |
| System Load (BOS) | ≥ 30% rated current | _____ % | [ ] Y  [ ] N |

# 5. Equipment & Aerial Parameters: 5.1 Thermal Camera Specs

| | |
|---|---|
| **Camera Model** | Autel EVO II Dual 640T RTK V3 |
| **Detector Resolution** | 640 x 512 pixels |
| **Spectral Range** | LWIR 8-14 µm |
| **Thermal Sensitivity (NETD)** | ≤ 50 mK @ 30°C |
| **Calibration Date** | _____ |

## 5.2 Drone & Flight Parameters
**Controller/Computer:**
[ ] Smart Controller Enterprise   [ ] Other: _____
**UHR Mode Status (must be OFF for thermography): [ ] Confirmed OFF   [ ] N/A**
**Flight altitude AGL: _____ ft (_____ m)  Ground speed: _____ mph (_____ m/s)**
**Positioning system:**
[ ] RTK (centimeter-level; record FIX %)  [ ] PPK  [ ] Standard GPS  Accuracy: ± _____ cm
**Geometric resolution achieved:**
Detailed: _____ px/cell (req ≥ 5x5)   Simplified: _____ px/cell (req ≥ 3x3)
**Ground Sample Distance (GSD): _____ cm/pixel**

# 6. PV System Details

**Module Manufacturer & Model:**_____

**Module Technology:**
[ ] Mono c-Si   [ ] Poly c-Si   [ ] CdTe   [ ] CIGS   [ ] a-Si   [ ] Other: _____

**Module Power Rating:**

_____ Wp @ STC   Voc: _____ V   Isc: _____ A

**System Configuration:**

Total modules: _____   Strings: _____   Modules/string: _____

**Inverter Details:**
Make/Model: _____   Type: [ ] String  [ ] Central  [ ] Micro

Quantity: _____   Total capacity: _____ MW

**Array Orientation:**

Azimuth: _____°   Tilt: _____°   Row spacing: _____ m

# 7. Enhanced Procedure Checklist: 7.1 Pre-Inspection Setup

| Step | Status | Notes |
|---|---|---|
| Review SLD, layout drawings, datasheets | [ ] | _____ |
| Verify system in steady state (> 15 min operation) | [ ] | _____ |
| Set camera emissivity (glass: 0.85-0.94) | [ ] | Value: ____ |
| Set reflected apparent temperature (Trefl) | [ ] | _____ °C |
| Confirm viewing angle ≤ 60° from perpendicular | [ ] | _____ |
| Verify geometric resolution requirements met | [ ] | _____ |
| Capture both radiometric thermal AND RGB | [ ] | _____ |
| Record RTK GPS coordinates for all anomalies | [ ] | _____ |

## 7.2 During Inspection

**Irradiance monitoring frequency:[ ] Continuous   [ ] Every 5 min   [ ] Every 10 min**

**Pause for irradiance drops (if < 600 W/m²):**
[ ] Yes, paused _____ times for _____ min each   [ ] Not needed

**BOS inspection load verification (≥ 30% rated):[ ] Confirmed   Current reading: ____ A (__ %)**

**Full PV plant coverage achieved: [ ] 100%   [ ] Partial: _____ %   Reason: _____**

## 8. Anomaly Classification Reference (Delta T at 1000 W/m²)

| Class | ΔT @ 1000 W/m² | Description | Action |
|---|---|---|---|
| A (Minor) | < 10°C | Small or no temperature difference | Monitor |
| B (Moderate) | 10-20°C | Moderate temperature difference | Next O&M |
| C (Significant) | 20-40°C | Significant temperature difference | < 3 months |
| D (Critical) | > 40°C | Major difference; safety risk | Immediate |

## 9. Abnormality Summary (Modules & BOS)

| Pattern/Component | Total | Class A | Class B | Class C | Class D |
|---|---|---|---|---|---|
| **MODULES** | | | | | |
| Hot spot - single cell | _____ | _____ | _____ | _____ | _____ |
| Hot spot - multiple cells | _____ | _____ | _____ | _____ | _____ |
| Bypass diode issue | _____ | _____ | _____ | _____ | _____ |
| Module heating (whole) | _____ | _____ | _____ | _____ | _____ |
| String/row mismatch | _____ | _____ | _____ | _____ | _____ |
| PID effect | _____ | _____ | _____ | _____ | _____ |
| Junction box heating | _____ | _____ | _____ | _____ | _____ |
| **BOS COMPONENTS** | | | | | |
| Combiner connection/fuse | _____ | _____ | _____ | _____ | _____ |
| String connector (MC4) | _____ | _____ | _____ | _____ | _____ |
| DC disconnect/switch | _____ | _____ | _____ | _____ | _____ |
| Inverter connection/internal | _____ | _____ | _____ | _____ | _____ |
| AC connection/switchgear | _____ | _____ | _____ | _____ | _____ |

## 10. Detailed Findings (Complete for Each Anomaly)

**FINDING ID: PV-001**

**Location (string/module/cell or BOS ID):**

_____

**RTK GPS Coordinates:**

Lat: _____     Long: _____     Accuracy: ± _____ cm

**Component Type:**

[ ] Module   [ ] Combiner   [ ] Connector   [ ] Inverter   [ ] Other: _____

**Pattern/Defect Type:**

_____

**Image References:**

Thermal: #_____     Visual: #_____     Close-up: #_____

| Thot (°C) | Tref (°C) | Tamb (°C) | Irradiance (W/m²) |
|---|---|---|---|
| _____ | _____ | _____ | _____ |

| ΔT (Thot - Tref) | ΔT Normalized @ 1000W/m² | Classification |
|---|---|---|
| _____ °C | _____ °C | [ ] A [ ] B [ ] C [ ] D |

**Probable Cause(s):**

[ ] Cell defect/crack   [ ] Diode failure   [ ] PID   [ ] Shading/soiling

[ ] Loose connection   [ ] High resistance   [ ] Corrosion   [ ] Overload

[ ] Other: _____

**Recommended Action:** _____

**Priority: [ ] Immediate   [ ] Short-term (<1 month)   [ ] Next maintenance   [ ] Monitor**

# 11. Data Processing & Reporting (Solar Best Practices)

## 11.1 Post-Flight Data Processing

**Orthomosaic Creation:**

[ ] Completed   Software used: _____   Processing time: _____ hrs

**Anomaly Detection Method:**

[ ] Manual review   [ ] AI-assisted   Tool: _____

**Temperature Normalization:**

[ ] Normalized to 1000 W/m²   [ ] Normalized to 100% load   Method: _____

**Georeferencing Accuracy:**

± _____ cm   [ ] RTK corrected   [ ] GCP corrected

## 11.2 Client Deliverables

**Report Contents (check all included):**

[ ] Executive summary

[ ] Geotagged thermal orthomosaic

[ ] RGB orthomosaic

[ ] Anomaly location maps

[ ] Detailed findings database

[ ] Prioritized action plan

[ ] Cost-benefit analysis

[ ] Historical comparison (if applicable)

**Data Format:**

[ ] PDF report   [ ] GIS layers   [ ] CSV database   [ ] KML/KMZ

[ ] Cloud portal access   URL: _____

# 12. Wind/Utility Infrastructure Crossover

*Complete this section for hybrid sites with wind turbines or utility infrastructure*

## 12.1 Wind Turbine Integration

**Wind turbines present on site:**

[ ] Yes   [ ] No   If yes, quantity: _____

**Blade defect inspection performed:**

[ ] Yes (per Flyability guide)   [ ] No   [ ] N/A

**Findings:**

Leading edge erosion: [ ] Yes  [ ] No   Count: _____

Surface cracks: [ ] Yes  [ ] No   Count: _____

Lightning damage: [ ] Yes  [ ] No   Count: _____

## 12.2 Utility Infrastructure

**Utility equipment inspected:**

[ ] Substation   [ ] Transmission lines   [ ] Distribution lines

[ ] Switchgear   [ ] Transformers   [ ] Other: _____

**NFPA 70B compliance verified:**

[ ] Yes   [ ] Partial   [ ] N/A

# 13. Quality Assurance & Certification

## 13.1 QA Checklist

[ ] All environmental conditions met or documented
[ ] 100% site coverage achieved or exceptions noted
*[ ] All anomalies classified and georeferenced*
[ ] Temperature normalization calculations verified
[ ] Report reviewed by Level II/III thermographer
[ ] Client-specific requirements addressed

## 13.2 Certification

I certify this inspection complies with IEC TS 62446-3:2017and accurately represents all findings.

**Inspector Signature:**

_____

**Printed Name & Qualification:**

_____

**Date:**

_____

**QA Review By:**

Name: _____   Level: _____   Date: _____

## Accuracy, Safety & Liability Notes

• Radiometric temperature accuracy is ±3 °C or ±3% of reading (whichever is greater) when the camera is used within the manufacturer's specified environment (−20 °C to +60 °C). Measurements outside this environment have unspecified accuracy.

• The thermal camera's accurate measurement distance is 2–20 m (≈6.5–65 ft). Temperature readings taken beyond 20 m should be treated as qualitative unless otherwise validated.

• Thermal sensitivity (NETD) is specified at 30 °C; apparent ΔT detection will vary with target temperature, wind, and atmosphere. Small temperature differences on very hot or very cold scenes may be harder to resolve.

• Wind limits in these templates are set to protect radiometric integrity (convective cooling, plume effects), not to reflect the drone's maximum wind resistance rating.

• RTK-enabled positioning: Horizontal ±1 cm + 1 ppm (RMS); Vertical ±1.5 cm + 1 ppm (RMS) when FIX is maintained. If RTK is lost, positions revert to standard GNSS (≈±1–1.5 m). Report RTK FIX percentage with deliverables.

• Operating range of the aircraft is −10 °C to +40 °C (14–104 °F). Operations may be postponed if ambient or surface conditions exceed equipment limits.

• All findings represent conditions at the time of inspection only. Thermal anomalies indicate areas for further investigation; they are not a guarantee of defect, remaining life, or performance. Verification by qualified professionals (e.g., roof cores per ASTM, IV-curve/electrical testing per IEC/NFPA) is recommended before remediation.

• IEC TS 62446-3 classifications assume ≥600 W/m² POA irradiance and stable conditions. Targeted troubleshooting below this threshold can be performed, but anomaly classes will be marked as non-IEC-classifiable.

• For temperature normalization, record Thot/Tref/Tamb and normalize ΔT to 1000 W/m² (or to 100% load for BOS), noting method used.

• For quantitative reads, maintain 2–20 m standoff and document emissivity and Trefl. Avoid sun-glint angles; keep viewing angle ≤60° from perpendicular.

# Aerial Accuracy – IEC 62446-3 Enhanced Defaults & Forms (Effective 2025-10-29)

## 1) Anomaly Classes (ΔT normalized to 1000 W/m²)

*We are retaining IEC-aligned class bands for consistency with O&M and warranty expectations. These are conservative enough to avoid over-calling in cold/windy winter conditions, while still surfacing material defects.*

| Class | ΔT_NORM threshold |
|---|---|
| C0 – Investigate | 3 – <10 °C above local reference (flagged; not counted as failure) |
| C1 – Minor | 10 – <20 °C |
| C2 – Moderate | 20 – <40 °C |
| C3 – Severe | ≥ 40 °C |

**Notes:**
• ΔT must be normalized to 1000 W/m² (or 100% load for BOS).
• For winter cold-start campaigns (optional), you may temporarily lower the investigate flag to 8 °C, but keep C1/C2/C3 at 10/20/40 °C for reporting and KPIs.

## 2) Units Policy (Metric primary; Imperial in parentheses)

*Primary units are SI/metric per IEC: W/m², °C, m/s, m. Provide imperial in parentheses for field readability: mph, ft, °F.*

| Parameter | Default |
|---|---|
| Wind | ≤ 17 mph (≤ 7.6 m/s) recommendation for radiometric integrity |
| Standoff (quantitative reads) | 2–20 m (≈ 6.5–65 ft) |
| Operating ambient | −10 °C to +40 °C (14–104 °F), per aircraft limits |

## 3) SCADA / I-String Time-Sync on Confirm Passes

**Policy: ENABLED. Capture SCADA I-string current snapshots for confirm passes time-aligned to thermal frames within ±1 minute. This materially improves root-cause confidence on string-level anomalies.**

*Add the following mini-form to each Detailed Finding where string-level confirmation is desired.*

| Field | Value / Notes |
|---|---|
| Finding ID | _____ |
| Thermal capture time (local) | ____----- (CST/CDT) |
| Thermal capture time (UTC) | ____-----Z |
| SCADA source | Site SCADA / DAS / Inverter API |
| SCADA parameter | I_string (A) / P_string (kW) |
| SCADA time stamp | ____----- (local) ±1 min tolerance |
| Nearest string(s) | Row __ String __ Inverter __ |
| Match quality | [ ] Exact  [ ] ±30 s  [ ] ±60 s  [ ] >±60 s (note) |
| Observations | _____ |

## 4) Export CRS & Time Defaults

**Default CRS for geospatial deliverables:**

| Layer | Coordinate Reference System |
|---|---|
| GeoTIFF orthos (thermal/RGB) | WGS 84 / UTM Zone 14N – EPSG:32614 |
| Anomaly CSV/KML | WGS 84 latitude/longitude – EPSG:4326 |
| Optional client CRS | NAD83 / UTM 14N – EPSG:26914 (on request) |

**Timestamp policy:**
• All timestamps recorded in site local time (CST/CDT) and UTC (Zulu) in the CSV export.
• File-level metadata includes timezone and daylight-saving flag.

## 5) CSV Data Dictionary (Minimum Fields)

| Field | Type | Description |
|---|---|---|
| panel_id | string | Panel or block identifier (if available) |
| utm_e | float | Easting (EPSG:32614) |
| utm_n | float | Northing (EPSG:32614) |
| lat | float | Latitude (EPSG:4326) |
| lon | float | Longitude (EPSG:4326) |
| dt_local | string | Local time ISO-8601 (CST/CDT) |
| dt_utc | string | UTC time ISO-8601 (Z) |
| dT_norm_C | float | ΔT normalized to 1000 W/m² (°C) |
| class | string | C0/C1/C2/C3 per thresholds |
| fault_hint | string | Hot-cell / String-out / Diode / Soiling / Shadow etc. |
| standoff_m | float | Median measurement distance (m) |
| rtk_fix_pct | float | % images with RTK FIX in segment |
| scada_I_A | float | I-string (A) if confirm pass collected |
| scada_ts_local | string | SCADA timestamp (local) |

## 6) QC Worksheet Possible Add-Ons

| Check | Setting |
|---|---|
| ΔT class thresholds set | 10/20/40 °C (C1/C2/C3); C0=3–<10 °C investigate |
| Units policy | Metric primary; imperial in parentheses |
| SCADA confirm sync captured | [ ] Yes  [ ] No  (±1 min) |
| Export CRS applied | EPSG:32614 UTM 14N + EPSG:4326 lat/lon |

## 7) Standard Report Language

**Anomaly Classes**
"Thermal anomalies are normalized to 1000 W/m² and classified as C1 (10–<20 °C), C2 (20–<40 °C), and C3 (≥40 °C). Values 3–<10 °C are flagged as C0 'investigate' but not counted as failures."

**Units**
"All measurements are reported in SI units with imperial equivalents in parentheses (e.g., 7.6 m/s (17 mph))."

**SCADA Sync**
"Confirmation passes include SCADA I-string snapshots time-aligned within ±1 minute of thermal capture; mismatches are noted per finding."

**CRS**
"GeoTIFFs are exported in WGS 84 / UTM 14N (EPSG:32614); CSVs include both UTM and WGS 84 (EPSG:4326) coordinates."

## 8) Payload Constraint to Protect Radiometric Accuracy

*Use 2–20 m standoff for quantitative temperatures (beyond 20 m treat as qualitative). Maintain −10 °C to +40 °C ambient operating range. Record emissivity and reflected apparent temperature (Trefl) per target material.*