Solar Panel Hotspot Detection

Performance & Operating Guide

PREPARED BY	Spectro-AI	SUBJECT	Solar panel hotspot detection algorithm
RUNS ON	DJI Matrice 4T / 4TD (on-board)	MORE INFO	spectroai.ai
ALGORITHM	SolarHot-IronBow-SAI-V2	DOCUMENT	v1.0 · Public
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Contents

OPERATIONAL SAFETY The algorithm is an operator-assistance tool and does not replace the pilot's responsibility to maintain safe flight or comply with applicable aviation regulations. All detections should be verified before operational decisions are made.

INTENDED USE This algorithm is designed to assist operators in locating thermal anomalies on photovoltaic arrays during aerial inspection. It can highlight areas requiring further investigation, but should not be used as a replacement for radiometric measurement, physical inspection or any engineering assessment.

DETECTIONS ARE INDICATIONS, NOT DIAGNOSES A detection marks a thermal anomaly on the live image. It does not establish the cause, the severity, or whether the panel is faulty at all. Every detection must be confirmed by a radiometric measurement or a physical inspection before any maintenance decision is taken.

1 About this guide

This guide explains how the Spectro-AI solar panel hotspot detection algorithm performs when running on-board DJI Matrice 4 Series thermal aircraft, and how to fly and configure the payload to obtain the most reliable results.

The algorithm runs directly on the aircraft and reports detections in real time during the flight through the DJI Pilot 2 application. It detects a single class, Hotspot, from IronBow thermal imagery. It is intended for photovoltaic inspection: flagging overheating cells, modules and connections during a survey so that they can be prioritised for measurement and repair.

Performance figures presented in this guide were established under validated operating conditions and should be used as operational guidance rather than guaranteed performance. Detection accuracy varies with thermal contrast, vegetation, weather, flight height, gimbal angle and image stability.

2 Supported aircraft

The algorithm is trained on thermal imagery. It requires a thermal camera and therefore runs only on the thermal variants of the Matrice 4 Series.

Table 2.1 *Aircraft compatibility*

Aircraft	Status	Reason
DJI Matrice 4T	**Supported**	Thermal camera fitted
DJI Matrice 4TD	**Supported**	Thermal camera fitted (dock variant)
DJI Matrice 4E	**Not supported**	No thermal camera: visual payload only
DJI Matrice 4D	**Not supported**	No thermal camera: visual payload only

THERMAL PAYLOAD REQUIRED The Matrice 4E and Matrice 4D carry visual cameras only (RGB) and cannot run this algorithm. Use a Matrice 4T or Matrice 4TD.

3 What the algorithm recognises

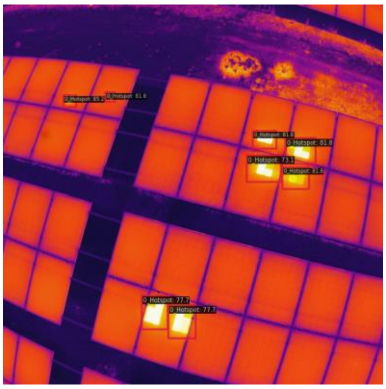
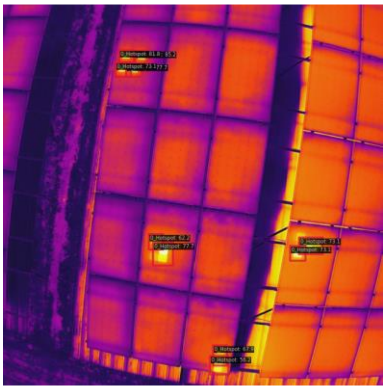
The algorithm detects a single class, Hotspot, and displays each detection as a bounding box with an associated confidence score on the live thermal image in DJI Pilot 2. Each hotspot in an image is boxed individually.

What a hotspot looks like in IronBow

IronBow renders temperature as colour: the coldest parts of the scene appear as deep purple and blue, warm areas as red and orange, and the hottest as yellow and white. A hotspot is a small, locally hot region, a cell, a module, a string or a connection running hotter than the panels around it, and appears as a bright yellow-white core standing out against the cooler body of the array.

The algorithm is trained on that appearance. It does not measure temperature and it does not classify the fault: it reports where the image is locally hot, and it is the operator's job to establish what that means.

Table 3.1 *Example detections on IronBow thermal imagery*

Detection (with bounding box)	What it shows
	**Single hotspot** One anomaly boxed and scored. The hotspot occupies a small part of the image: this is typical, and it is why the algorithm is flown low and looking straight down.
	**Several hotspots in one image** Multiple anomalies detected in a single pass, each boxed separately with its own confidence score. Detections are reported independently; the algorithm does not group them or relate them to a particular module or string.

4 Detection performance

Validation was performed on an independent dataset that was held out from training and evaluated separately. The results presented below describe the algorithm's performance under the validated operating conditions and should be regarded as estimates of expected performance. Actual performance may vary with thermal contrast, environmental conditions and operating practices.

0.838	0.456
mAP@0.50	mAP@0.50–0.95

What these numbers mean

- **mAP@0.50 (0.838).** The algorithm achieves strong overall detection performance when moderate localisation accuracy is required. For most operational users, this is the metric that best reflects the algorithm's operational performance.
- **mAP@0.50–0.95 (0.456).** This applies progressively stricter requirements on how tightly the bounding box must fit the hotspot. The lower value primarily reflects the difficulty of drawing pixel-tight boxes around small, diffuse thermal signatures with no hard edges. It does not materially affect whether a hotspot is detected.

Precision and recall at a single fixed confidence threshold were not measured in this validation. Use the threshold guidance below as a starting point and tune it against your own site.

> **CONFIDENCE-THRESHOLD SLIDER** Start at approximately 0.75. This is higher than the other thermal algorithms, and deliberately so: a solar site is full of hot objects that are not faults, and a low threshold will bury genuine anomalies in false alarms. Lower it only where you are actively hunting for marginal, early-stage anomalies and are prepared to sift the results. Raise it where the array is surrounded by hot ground or hardware.

5 Operating recommendations

Thermal palette

> **IRONBOW ONLY** The algorithm is trained exclusively on the IronBow palette and must only be used with IronBow selected in DJI Pilot 2. White Hot, Black Hot and all other palettes render the same heat as entirely different colours, and the algorithm has never seen them: detection performance on them is not validated and should not be relied upon.

Flight height and gimbal angle

Table 5.1 *Recommended operating envelope*

Parameter	Setting	Notes
Flight height	**10 – 15 m above ground level (AGL)**	Low enough that a single overheating cell still covers a usable number of pixels.
Gimbal pitch	**−90° (nadir)**	Straight down. Oblique views introduce reflections off the panel glass and are not validated.
Thermal palette	**IronBow**	Mandatory. No other palette is supported.
Confidence threshold	**0.75 to start**	Adjustable in DJI Pilot 2. Set high by default: see the note below on hot surroundings.

> **HOW TO USE THIS** Select IronBow, point the gimbal straight down, fly at 10–15 m AGL, and start with the confidence threshold at 0.75. Survey when the array is generating under strong, steady sunlight: a panel that is not producing power has no fault heat to find.

Hot surroundings and false positives

This is the single biggest source of error in solar inspection, and it is worth understanding before the first flight. The algorithm finds regions that are locally hot in the image. It has no way of knowing whether the heat it has found is a defect or simply part of the environment.

A solar site on a sunny day is full of hot things that are not faults. Bare ground, gravel, roofing membrane, access tracks, mounting rails, junction boxes, inverters, cabling, vehicles and people all absorb heat and can read as hot as, or hotter than, a genuinely defective cell. Detections that land at the edge of an array, on the ground between rows, or on hardware rather than on panel glass should be treated with suspicion.

- **Keep the array filling the image.** The less non-panel surface is in view, the fewer opportunities there are for the surroundings to be flagged. Nadir framing at 10–15 m does most of this work.
- **Raise the threshold before lowering it.** 0.75 is the starting point. Where the array sits on hot ground or is dense with hardware, raise it further rather than accepting the noise.
- **Judge every detection by where it sits.** A hotspot on panel glass is worth investigating. A hotspot on a rail, a cable tray or the ground between rows almost certainly is not.

> **REFLECTIONS ARE THE OTHER TRAP** Panel glass is highly reflective in the infrared. Sun glint and reflected sky can appear as bright regions that have nothing to do with the temperature of the cell beneath. Flying at nadir minimises this; oblique angles make it substantially worse.

Sunlight, load and time of day

Unlike the other thermal algorithms, this one does not benefit from cool conditions: it depends on them being warm. A hotspot only exists while the panel is generating: the defect dissipates energy as heat because current is flowing through it. On an array that is not producing, there is no fault heat to find, and the algorithm will return nothing however carefully the site is flown.

- **Best conditions.** Clear skies, strong and steady irradiance, and the array on-line and generating. Anomalies are then at their hottest relative to the healthy panels around them.
- **Degraded conditions.** Overcast skies, low sun, intermittent cloud, and early morning or late afternoon. Defects run cooler and the contrast that separates them from healthy cells narrows or disappears.
- **Not usable.** Night, and any period when the array is disconnected, curtailed or otherwise not generating.
- **Passing cloud.** A cloud shadow crossing the array during a pass changes panel temperature mid-survey and can produce inconsistent results between adjacent images. Wait for stable conditions rather than flying through them.

Thermal lens cleanliness

Dirt, water droplets or condensation on the thermal lens reduce image contrast and may degrade detection performance. Inspect the lens before each flight and clean it as required, and allow time for condensation to clear when a cold aircraft is brought into warmer, more humid air.

6 Limitations

- **Thermal aircraft only.** The algorithm cannot run on the Matrice 4E or Matrice 4D.
- **IronBow only.** Any other palette places the algorithm outside its validated envelope.

- **Hot surroundings produce false positives.** Sun-heated ground, gravel, roofing, mounting rails, junction boxes, cabling, inverters and vehicles can all be detected as Hotspot. This is the dominant failure mode: see Section 5.
- **Reflections can be detected as heat.** Sun glint and reflected sky on panel glass may be flagged even where the cell beneath is at normal temperature.
- **No temperature, no severity, no cause.** The algorithm reports that a region is locally hot. It does not measure temperature, does not grade severity, and does not distinguish a cell hotspot from a failed bypass diode, a string fault, soiling or shading. Radiometric measurement or physical inspection is required.
- **No fault means no heat.** An array that is not generating produces no fault heat. An absence of detections is not evidence of a healthy array.
- **Small, soft signatures.** Hotspots occupy a small part of the image and have diffuse edges, which is why precise box placement is harder than detection itself.
- **Detections are independent.** Each box is reported on its own. The algorithm does not count modules, group detections by string, or georeference them.
- **Performance figures are intended for operational planning and should not be interpreted as guaranteed performance under all conditions.**

7 Deployment

The algorithm is licensed to the individual aircraft serial number and delivered through DJI Pilot 2. Once activated, it runs entirely on-board and does not require a network connection during operation.

> **VALIDATED VERSION** The validated performance described in this guide applies to the released algorithm version identified on the cover of this document, SolarHot-IronBow-SAI-V2. Later algorithm updates, aircraft firmware changes and different camera configurations may perform differently, and the figures here should not be assumed to carry over to them. Check the algorithm version shown in DJI Pilot 2 against the cover of this guide, and record it alongside any results you keep.

Questions, or results in conditions not covered here? Visit spectroai.ai.