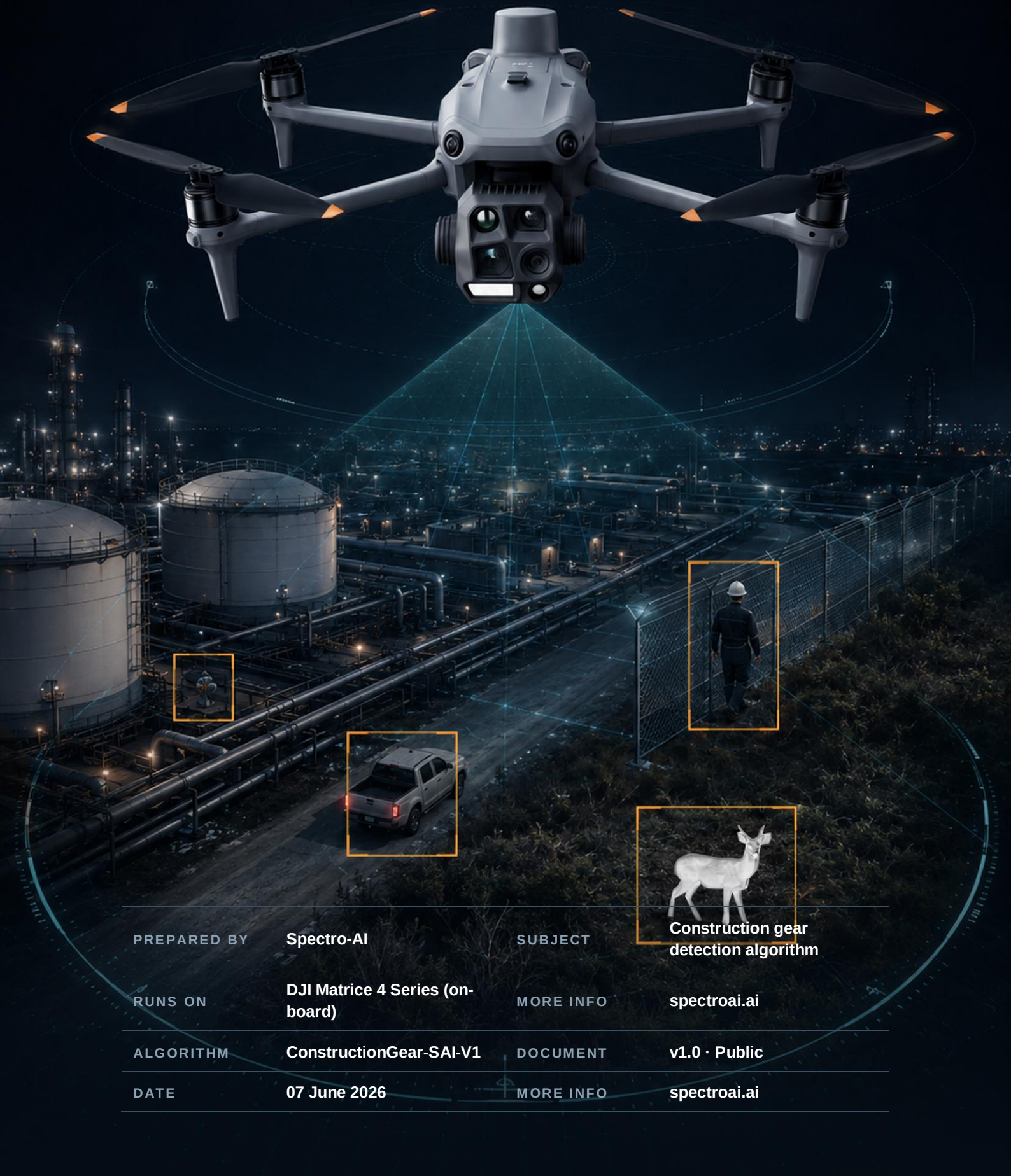
SPECTRO AI

Construction Gear Detection

Performance & Operating Guide



PREPARED BY	Spectro-AI	SUBJECT	Construction gear detection algorithm
RUNS ON	DJI Matrice 4 Series (on-board)	MORE INFO	spectroai.ai
ALGORITHM	ConstructionGear-SAI-V1	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.

A SAFETY-OBSERVATION AID, NOT A COMPLIANCE RECORD Several classes report whether a person appears to be wearing personal protective equipment. These detections are an aid to site safety observation. They are not a compliance record, not evidence, and not a basis for action against any individual. Before deploying the algorithm over a workforce, confirm your obligations on workplace monitoring, notification and data protection, and agree with the site how the output may and may not be used.

1 About this guide

This guide describes how the Spectro-AI construction gear detection algorithm performs when running on-board a DJI Matrice 4 Series aircraft, and how to fly and configure the camera to obtain the most reliable results. It is written for drone pilots, site inspectors and site safety staff.

The algorithm runs directly on the aircraft and reports detections in real time during the flight through the DJI Pilot 2 application. It works from the visible-light (RGB) camera and recognises ten categories covering construction equipment and vehicles, traffic cones, people, and the protective equipment those people are or are not wearing.

Its purpose is to give an operator a faster read of a site than scanning a video feed unaided: which equipment is where, where people are working, and where protective equipment appears to be missing, so that attention can be directed to the right part of the site.

INTENDED USE This algorithm is designed to assist operators in locating construction equipment, vehicles, people and protective equipment during aerial site inspections. It can highlight areas requiring further investigation, but should not be used as a replacement for visual inspection, site supervision or any safety procedure. It does not make judgements. Every detection is a prompt for a person to look, never a conclusion in itself.

Performance figures presented in this guide were established under validated conditions and should be used as operational guidance rather than guaranteed performance. Detection accuracy varies with viewing angle, distance, lighting, weather, dust and how much of an object is visible.

2 Supported drone and camera configuration

This is a visible-light algorithm. It uses the RGB camera, not a thermal payload, and therefore runs on every aircraft in the Matrice 4 Series: the Matrice 4E, 4T, 4D and 4TD. On the thermal variants it still works from the visible camera and does not read the thermal feed.

Camera configuration

The settings below are recommended starting points. They describe the way the algorithm is designed to be flown and should be adjusted to suit the site, the task and the conditions on the day.

Table 2.1 *Recommended camera configuration*

Parameter	Setting	Notes
Camera type	**Visible light (RGB)**	The algorithm reads the visible feed only. It does not use the thermal camera, even where one is fitted.

Parameter	Setting	Notes
Viewing direction	**Forward-looking**	Look forward and slightly down across the site rather than straight down at it.
Camera pitch	**Approx. −10° to −30° from horizontal**	A recommended starting point rather than a fixed specification. Adjust within this band to suit the site.
Field of view	**Wide, unless zoomed for detail**	A wide view covers more of the site in a single pass. Narrow it only when detail on a specific object is needed.
Zoom	**As the task requires**	Use the lowest practical optical zoom when surveying large areas. Increase optical zoom when people or protective equipment appear too small, or when confirming a detection.
Lighting	**Good daylight**	Night and low light are not validated and should not be relied upon.

3 What the algorithm detects

The algorithm reports ten classes. Each detection appears on the live image as a box, a label and a confidence score. Everything visible in the frame is boxed separately, so a single view of a busy site will typically produce many detections at once.

Table 3.1 *Detection classes*

Group	Classes	Size, and how easily they are found
Equipment and vehicles	**Machinery · Vehicle**	Metres across. The easiest objects to detect: large, distinctive and visible from well back. These typically carry the highest confidence scores.
People	**Person**	Around 1.7 m tall. Detected reliably at working distances, but a person far across a site becomes small in the frame and will start to be missed.
Protective equipment	**Helmet · Vest · Mask · No-helmet · No-vest · No-mask**	Tens of centimetres, and only ever a small part of an already small person. These are the hardest classes and need the closest approach or the most zoom. Treat them as the limiting factor when planning a flight.
Site markers	**Cone**	Roughly half a metre. Detected at moderate range; scores fall away with distance faster than for machinery and vehicles.

The PPE classes work in pairs

Six of the ten classes describe protective equipment, in matched pairs: helmet and no-helmet, vest and no-vest, mask and no-mask. The algorithm reports what is visible on each person in the image.

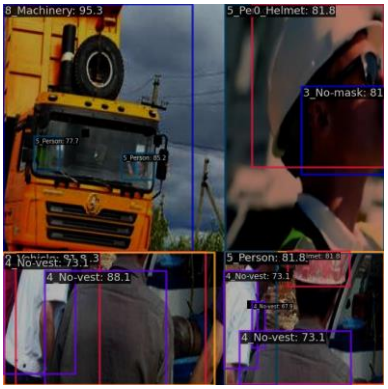
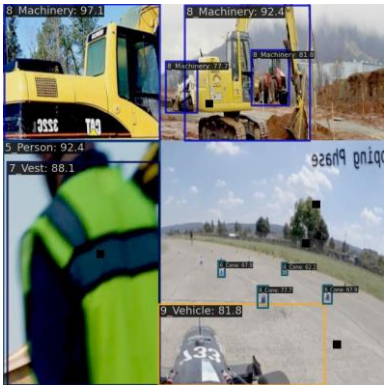
The distinction matters. A no-helmet detection means no helmet was visible. It does not establish that no helmet was worn: the person may be turned away, partly hidden behind machinery, too far off, or

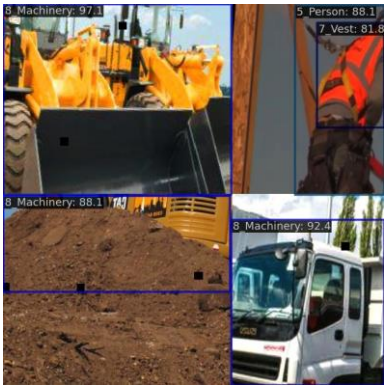
too small in the frame for the equipment to be made out. Treat these classes as a prompt to look, never as a finding.

SMALL THINGS ON SMALL PEOPLE Protective equipment is the smallest thing the algorithm looks for, and it is attached to something already small in the frame. If the site is being surveyed from a distance that suits machinery and vehicles, the PPE classes will be working at the very edge of what is possible. Decide before the flight whether PPE observation is the objective, because if it is, it dictates how close you fly.

IMPORTANT: DETECTIONS ARE NOT COMPLIANCE FIGURES The algorithm identifies where objects appear in the picture. It does not produce counts. Do not read the number of boxes as a headcount, an equipment inventory, or a compliance rate: people and equipment hidden behind machinery or each other will not appear at all, closely grouped objects may be merged into a single box, and a no-vest detection means only that no vest was visible. Totals will generally understate what is present, and must not be used as a site record or a compliance statistic.

Table 3.2 *Example detections*

Detection (with bounding boxes)	What it shows
	**Equipment at close range** Machinery boxed at high confidence, filling a large part of the frame, alongside smaller detections further back. Large equipment close to the camera is the algorithm's strongest case.
	**Cones, vehicle and machinery together** Several cones detected across the scene alongside a vehicle and machinery. Note that the cones score lower than the machinery; smaller objects consistently do.

Detection (with bounding boxes)	What it shows
	**People and protective equipment** Person and vest detections alongside machinery. People appear as tall, upright shapes in the frame, a direct consequence of the forward-oblique view, and the reason this algorithm is not flown looking straight down.
	**A missing-vest detection** A no-vest detection among people at varying distances. Detections like this are the ones that most need confirming by eye before anything is said or done about them.

4 Detection performance

Validation was performed on an independent dataset that was held out from training and evaluated separately. The results below describe performance under the validated conditions and should be regarded as estimates of expected performance rather than guarantees.

0.826	0.604
mAP@0.50	mAP@0.50–0.95

What these numbers mean

The validation scores indicate how consistently the algorithm identified and located objects in the tested images. Higher scores indicate stronger performance under those conditions.

- **mAP@0.50 (0.826).** The measure of whether objects were found and placed in roughly the right position. The validation results indicate strong detection performance under the tested conditions. For most operators, this is the figure that reflects the question that matters: was it spotted?
- **mAP@0.50–0.95 (0.604).** A stricter measure that also rewards how tightly the box is drawn. It says little about whether an object was seen.

These scores do not directly represent guaranteed field success. Actual performance depends on viewing angle, distance, lighting, weather, dust and how much of an object is visible, and will vary from one flight to the next. The figures also average everything together, which hides the thing an operator most needs to know: broken down by how large objects appear in the frame, performance changes considerably.

Table 4.1 *How reliability changes with apparent size*

How it appears in frame	Reliability	What this means on site
Large, fills much of the view	**Strong**	Equipment and vehicles at working range. Found consistently and scored highly.
Medium, clearly visible	**Good**	People at moderate distance, nearby cones. Generally found, with occasional misses.
Small, a minor part of the view	**Weak**	Distant people, cones far off, and protective equipment at any real distance. Expect misses. This is where the algorithm is least dependable, and no confidence setting fixes it.

Detection reliability decreases significantly as objects occupy fewer pixels in the image. Per-class figures were not measured for this build, so these results should not be read as applying equally to every class. In particular, the protective-equipment classes are inherently small-object cases and should be assumed to sit at the weaker end.

CONFIDENCE-THRESHOLD SLIDER A confidence threshold around 0.50 is recommended as a starting point. Lower thresholds may improve sensitivity but will increase false alarms; this is often the right trade when looking for people or missing protective equipment. Higher thresholds reduce false alarms but risk missing smaller objects, and suit cluttered sites where too much is being flagged. The recommended setting may vary depending on the site, lighting, weather and mission objectives. If small objects are being missed, fly closer or zoom in before touching the threshold: no confidence setting can recover something the camera never resolved.

5 Camera angle and operating recommendations

Why the forward-oblique view matters

The algorithm performs best when flown using a forward-oblique view: looking forward and slightly down across a site, rather than straight down at it. This is unusual among on-board detection algorithms and it drives every recommendation in this section.

The reason is simple. Seen from a forward-oblique angle, a person is an upright figure, a vehicle shows its side and a machine shows its working face. Those are the shapes the algorithm recognises. Seen from directly overhead, the same objects present only their roofs and shoulders, which look nothing alike, and detection suffers accordingly.

RECOMMENDED CAMERA PITCH Set the gimbal to approximately −10° to −30° from horizontal. This gives a forward-oblique inspection view suited to identifying equipment faces, vehicle outlines and the upright shape of a person. Treat it as a starting point and adjust within the band to suit the site rather than holding a fixed figure.

Recommended drone positioning

Table 5.1 *Recommended set-up*

Parameter	Recommendation	Why
Gimbal pitch	**Approx. −10° to −30°**	Gives the forward-oblique view the algorithm is designed for. Steeply downward or fully level views fall outside it.

Parameter	Recommendation	Why
Drone orientation	**Nose towards the area of interest**	Fly the aircraft as though it were walking the site and looking ahead.
Height	**Only as high as the task requires**	Fly high enough to see over obstructions and cover the area, but no higher, while maintaining safe separation from people and equipment. The greater the height, the more the camera must tilt down to keep the subject in frame, which moves you away from the forward-oblique view.
Flight speed	**Slow and steady**	Fly slowly enough that people and protective equipment remain clear in the live image. Excessive speed reduces image quality and leaves less time to verify detections.
Distance: equipment and vehicles	**Comfortable standoff**	Large objects are detected from well back, so there is no need to close in.
Distance: people and cones	**Closer**	They must remain clearly resolvable rather than becoming specks in the frame.
Distance: protective equipment	**Closest, or well zoomed in**	The limiting case. If protective equipment is the objective, it sets your working distance.
Detection range	**Establish on site**	Ranges vary with camera settings, lighting and object size, so no single figure applies. Establish your own working distances using the method in Section 7.

OBJECTS HIDE BEHIND OTHER OBJECTS Because the algorithm works from a forward-oblique view rather than looking straight down, anything behind machinery, stacked material, site huts or vehicles is simply not visible to the camera. A single pass therefore covers less of a site than it appears to. Where practical, fly additional passes from different directions so that objects hidden on one approach come into view on another.

How viewing angle affects detection

- **Match the trained view.** An object seen from an angle the algorithm has not been trained on is a different shape to it. Machinery viewed from directly overhead presents its roof, an outline that shares little with the side-on view in the training imagery, and detection suffers accordingly.
- **Expect near objects to detect better than distant ones.** In a forward-oblique view, objects higher up the image are further away and much smaller than those near the bottom. Focus on keeping the area of interest in the lower half of the image, where objects appear larger, and reposition the aircraft rather than relying on what is visible at the top.
- **Very steep or very oblique angles both hurt.** Tilting far down loses the recognisable side profile; going fully level fills the frame with sky and background and reduces the ground area covered.
- **Move rather than zoom where you can.** Optical zoom genuinely resolves more detail on a distant object. Digital zoom only enlarges what has already been captured. Where the site allows it, flying closer is better than magnifying from far off.

6 Limitations

Each limitation below is paired with what the operator should actually do about it.

Table 6.1 *Limitations and operator response*

Limitation	What to do
Objects hidden behind other objects	Machinery, spoil heaps and site huts hide whatever is behind them, and people working close to machinery are often partly obscured. Fly a second pass from a different bearing rather than assuming one view has covered the area.
Poor lighting and shadow	Detection may be reduced when equipment or people are heavily shadowed, under structures, inside excavations, or on the shaded side of large machinery. Fly with the sun behind the aircraft where possible, and avoid the hour after sunrise and before sunset when shadows are longest. Night and low light are not validated.
Dust and airborne debris	Active earthworks, haul roads and demolition raise dust that softens the image and hides objects. Wait for it to settle, approach from upwind, or accept that the pass will need repeating.
Weather	Rain, mist and spray reduce contrast and put droplets on the lens. Wet high-visibility clothing and wet machinery also look different from the dry examples in the training imagery. Check the lens after any wet flight.
Similar-looking objects	Machinery and vehicles can be confused with one another, and orange or red site objects can read as cones or vests. The label may be wrong while the detection is still useful; confirm what it actually is before acting on the class name.
Unusual viewing angles	Detection may be reduced when objects are viewed from an angle not represented in the training imagery, particularly from directly overhead. Keep the camera in the forward-oblique range given in Section 5.
Objects too small or too far away	This is the single largest source of missed detections, and it affects protective equipment most. Fly closer or use optical zoom; do not attempt to compensate by lowering the confidence threshold.
Sites unlike the training conditions	Unusual equipment, non-standard protective clothing, unfamiliar site layouts and different seasons or ground colours all move real operations away from the validated conditions. Run a short familiarisation flight on a new site and see how the algorithm behaves before relying on it.
It reports appearance, not fact	A no-helmet or no-vest detection means no helmet or vest was visible, not that none was worn. Never treat these as findings about a person. An absence of detections is likewise not evidence that a site is clear or compliant.

7 Operator workflow

Before flight

- ▢ **Camera set to visible (RGB).** The algorithm does not read a thermal feed.
- ▢ **Gimbal pitch set forward-oblique.** Approximately −10° to −30° from horizontal.

- **Lens inspected and clean.** Dust, fingerprints and dried spray all cost small detections first.
- **Lighting checked.** Good daylight. Note where the sun is and plan passes with it behind the aircraft.
- **Confidence threshold set for the task.** Lower when looking for people and protective equipment; higher on cluttered sites.
- **Objective agreed.** Decide what you are looking for. Protective equipment sets the closest working distance; machinery and vehicles allow the widest.
- **Permissions confirmed.** Where the flight will observe people, confirm site notification and monitoring obligations have been met.

During the inspection

- **Approach with the nose towards the area of interest.** Fly it like a walk-round at height, looking ahead rather than down.
- **Hold the oblique view.** If you climb, you will be tempted to tilt further down; resist the temptation, or descend again.
- **Work the site in overlapping passes.** Cover from more than one bearing so that objects hidden on one pass are visible on another.
- **Move closer for the small things.** Where protective equipment matters, close the distance or apply optical zoom rather than relying on the threshold.
- **Act on consistently low scores.** If scores stay low across a whole pass, adjust the flight before continuing: move closer, bring the gimbal back towards the recommended band, or reposition so the light is behind you. Repeating the same pass will give the same result.
- **Let dust settle.** A pass flown through a dust cloud is a pass wasted.

After a detection

- **Confirm visually.** Zoom in on the live image and look at what is actually inside the box.
- **Inspect the area around it.** Where one object has been found, look for what the algorithm may have missed nearby, particularly small objects and partly hidden people.
- **Do not rely on the label alone.** The class name may be imprecise while the detection is still correct. What matters is what you can see.
- **Treat protective-equipment detections with particular care.** Confirm before anything is recorded, reported or raised with anyone. These detections describe what was visible from the air at one moment, from one angle.
- **Record the conditions.** Note distance, angle, light and weather alongside anything you keep. It explains the result later.

> **BUILD YOUR OWN RANGE CARD** No validated detection distances are available. On an early flight at a new site, place or identify a known object, such as a cone, a parked vehicle or a colleague in a vest, and note the distance at which detections become reliable and the distance at which they stop. Half an hour spent doing this gives you numbers that apply to your site, your aircraft and your conditions, which is worth more than any general figure.

8 Deployment and maintenance

The algorithm is licensed to the individual aircraft serial number and delivered through DJI Pilot 2. Once activated it runs entirely on-board: all processing happens on the aircraft, and no network connection is required during operation.

Table 8.1 *Deployment summary*

Item	Detail
Where it runs	On-board the aircraft, in real time, from the visible camera feed.
Network connection	Not required in flight. Imagery is not sent off the aircraft for processing.
Licensing	Tied to the aircraft serial number.
Version identification	The algorithm name and version are shown in the DJI Pilot 2 interface. The algorithm version and the version of this guide are numbered separately. Record the algorithm version shown on the aircraft alongside any results you keep, so that findings can be matched to the build that produced them.
Firmware compatibility	Keep aircraft firmware and DJI Pilot 2 at compatible versions, as published by DJI. Mismatched firmware and DJI Pilot 2 versions are a common reason why an algorithm may fail to load.
If it does not load	Confirm the licence is active for that airframe, check that firmware and DJI Pilot 2 versions are compatible, and restart the aircraft and controller. If it still does not appear, fly the inspection visually and report the fault. Do not delay a safety-critical inspection waiting for the algorithm.

VALIDATED VERSION The validated performance described in this guide applies to the released algorithm version identified on the cover of this document, ConstructionGear-SAI-V1. 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.