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New England Transportation Consortium (NETC)

NETC 20-3

Investigating Thermal Imaging Technologies and Unmanned Aerial Vehicles to Improve Bridge Inspections

Task 1 Interim Report

Desk Scan of Infrared Thermal Imaging and Drone Technologies

6/4/2021

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The overall research objective is to focus on developing UAV-based inspection and analysis protocols using infrared (IR) thermal imaging to determine the existence and extent of concrete delamination, with emphasis on the underside of bridge decks.

The first phase of this research, reflected in this Task 1 report, is to conduct a desk scan to identify infrared thermal imaging (IRTI) and unmanned aerial vehicle (UAV) technologies that are best suited for use in bridge underside inspections. These technologies will be evaluated to identify select models for field demonstration as part of Task 2 of this research project.</td></tr>
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APPROXIMATE CONVERSIONS TO SI UNITS				
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		LENGTH		
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mi	miles	1.61	kilometers	km
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ac	acres	0.405	hectares	ha
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yd^3	cubic yard	0.765	cubic meters	m^3
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lb	pounds	0.454	kilograms	kg
T	short ton (2000 lb)	0.907	megagrams ("metric ton")	Mg ("t")
		TEMPERATURE (EXACT DEGREES)		
°F	Fahrenheit	5 (F-32) / 9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE AND PRESSURE OR STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPA
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m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
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		FORCE AND PRESSURE OR STRESS		
N	newtons	0.225	poundforce	lbf
kPA	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380

(Revised March 2003)

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LIST OF ABBREVIATIONS

ASTM = American Society for Testing Materials
CFR = Code of Federal Regulations
DOT = Department of Transportation
EFL = Equivalent Focal Length
EMI = Electromagnetic Interference
FAA = Federal Aviation Administration
FHWA = Federal Highway Administration
FOV = Field of View
GPS = Global Positioning System
HFOV = Horizontal Field of View
IEC = International Electrotechnical Commission
IR = Infrared
IRTI = Infrared Thermal Imaging
LiDAR = Light Detection and Ranging
LWIR = Long Wave Infrared
NETC = New England Transportation Consortium
NETD = Noise Equivalent Temperature Difference
NBIS = National Bridge Inspection Standards
RPIC = Remote Pilot in Command
SLR = Single-Lens Reflex
SWOT = Strengths, Weaknesses, Opportunities, Threats
TC = Technical Committee
UAV = Unmanned Aerial Vehicle
UAS = Unmanned Aircraft System
UBIT = Under Bridge Inspection Truck
VLOS = Visual Line of Sight
VO = Visual Observer

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Introduction

Bridge inspection is central to any transportation facility's maintenance program. The National Bridge Inspection Standards (NBIS) were established in 1971 following the collapse of the Silver Bridge in West Virginia. The NBIS is governed by Title 23 CFR 650 Subpart C, which defines the NBIS regulation, establishes requirements for inspection procedures, inspection frequency, qualifications of personnel, and implementation of a state bridge inventory. The primary goal of the NBIS bridge inspection program is to accurately identify bridge deficiencies, particularly critical deficiencies that could lead to structural failure or other safety hazards to ensure that bridges are safe for the traveling public [1].

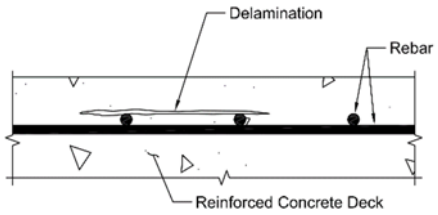


Figure 1 – Concrete Delamination

One critical safety hazard is concrete delamination along the underside of bridge decks, especially on overpass bridges and on bridges that see pedestrian or boat traffic underneath. Delamination occurs when layers of concrete separate at or near the level of the outermost layer of reinforcing steel (rebar). The major cause of delamination is expansion of corroding reinforcing steel causing a subsurface fracture plane. This is commonly caused by intrusion of chlorides or salt. Another potential cause is severe overstress in a member [2]. Freeze and thaw cycles can cause this condition to worsen as water freezes within cracks during the winter and expands, causing the crack to widen and allowing more water to enter. Over time, the delaminated concrete will completely separate and create what is known as a spall. Spalling from an overhead concrete element creates a fall hazard that can injure pedestrians or motorists. When located over a highway, spalling concrete is a critical safety concern. Falling concrete can directly cause injury to motorists or create a distraction to drivers resulting in accidents with other vehicles. The roadway is often protected from these areas of delamination through the installation of timber shielding or metal grating between girder bottom flanges. Some agencies, like MassDOT for example, will perform additional inspections of bridges over roadways in the beginning of spring in order to identify and remove any areas of concrete that are at risk of spalling due to the freeze-thaw cycles over the winter.

The traditional methods for inspecting the underside of overpass bridge decks include visual observations and/or manual sounding from underneath by maintenance personnel. This may be done on foot or with the use of access equipment such as a bucket truck or aerial lift. The ability to visually identify delaminations will depend on the size and severity of each individual delamination. Less severe delaminations are commonly referred to as hollow sounding areas and may be indicated by the presences of narrow cracks, efflorescence, and/or rust staining. In the early stages, there may be no visual indication of delamination but limited risk of spalling. Delaminations that are nearing the point of spalling are sometimes referred to as incipient spalls and can be identified by wide cracks, sagging, heavy rust staining, and/or bulging of the concrete. Sometimes visual observations can miss deteriorated areas, especially if the inspection is performed on foot.

Figure 2 – Severe Delamination

Historically, bridge inspectors identify delaminated concrete by manual acoustic methods, commonly referred to as sounding. Sounding uses tools and is based on the when the sound from impact changes from a clear ringing sound (sound deck) to a somewhat mute, dull, and hollow sound (delaminated deck)

[3]. The delamination has an air pocket which causes a change in the acoustic response. The primary tools for manual sounding that are typically used by bridge inspectors are as follows:

Chain drag – A chain or series of short medium weight chains attached to a handle. Inspectors drag the chain(s) along the top of the bridge deck to identify delaminations [2]. The chain drag is limited to the top face of horizontal surfaces.

Hammer – A tool with a metal head mounted at the end of a handle. Inspectors tap concrete surfaces to identify delaminations [2]. Steel rods or pieces of rebar can be utilized in a similar manner. A hammer can be used on horizontal, overhead, and vertical surfaces.

Rotary Percussion tool – Inspectors utilize a rotary percussion tool which consists of two gear-toothed wheels attached to an extension pole and handle. The wheels produce a uniform tapping sound as it rolls over the surface [2]. The rotary percussion tool can be used on horizontal, overhead, and vertical surfaces.

These sounding methods are effective at identifying concrete delamination but include several draw backs and challenges. These methods require hands-on access and significant time for proper assessment resulting in additional costs for traffic control and potentially access equipment. The documentation of delamination can also be subjective and varies as delaminated areas are generally irregularly shaped and approximated into more regular rectangular shapes by inspectors. The sound of traffic passing may also cause delays or inaccuracies if the inspector cannot adequately hear the sound produced by the sounding method. This can especially be challenging on heavily traveled roadways, like interstate highways. It is also possible that the bridge geometry or sloped terrain beneath the bridge may limit hands-on access to some areas of the bridge deck for sounding.

Figure 3 - Traffic Closure along Bridge

Infrared (IR) thermography is one method of non-destructive evaluation that can be used for identifying concrete delamination. The delamination contains an air pocket which causes a surface temperature variation and can be detected by infrared thermal imaging (IRTI). While infrared thermography has been used to detect delaminations along the top of bridge decks since the 1980s, the application along the underside of bridges is a relatively new endeavor [3]. Additional discussion on infrared thermography is included in the “Thermal Imaging for Concrete Delamination Detection” section of this report.

Unmanned aircraft systems (UAS), which are commonly referred to as unmanned aerial vehicles (UAV) or drones, are an emerging technology that is receiving a lot of attention for potential application in bridge inspection. Various public agencies, consulting firms, universities, and private drone manufacturers are performing pilot studies and exploring potential bridge inspection use cases [1]. Drones, equipped with thermal sensors, may provide a practical and inexpensive alternative to traditional manual inspections for the purpose of concrete delamination detection. Additional discussion on the use of UAV for bridge inspection is included in the “Unmanned Aircraft System (UAS) for Bridge Inspection” section of this report.

Purpose and Scope

Research Objectives

The overall research objective is to focus on developing UAV-based inspection and analysis protocols using IRTI to determine the existence and extent of concrete delamination, with emphasis on the underside of bridge decks. This objective will be realized by answering the specific questions:

1. **Can IRTI technology be used effectively** to identify concrete delamination, especially on the underside of bridge decks where the concrete surface thermal differences may be only subtle due to very little exposure to direct sunlight. What type of thermal resolution is required? Sensor images will need to be "ground-truthed" with actual measured delamination from tried and true methods. Also is there sensor equipment that can be used in handheld operation and attached to drones for flight operations?

2. **What type of drone hardware,** Camera Specifications, Camera Mountings and Testing Attachments would provide the most cost-effective benefit for each type of data capture? This question will be answered through surveys and test trials of different UAVs. For optimal information gathering, it is envisioned that several technologies will be concurrently employed, and a significant outcome of the work will be an assessment of the relative value and optimum combination of technologies. (e.g. drone and infrared imaging systems).

3. **What data storage and retrieval systems** and hardware are required for managing and easily re-using the potentially enormous volume of digitized information captured? Data storage and data transfer technologies make this a relatively simple problem. However, universal data sharing formats will need to be established early on.

4. **What software** is available or will require development to efficiently process the captured data for human inspection and evaluation? Many generic systems of machine learning (including computer vision) are available and as such it is relatively easy to develop and train prototype systems. Once prototypes are tested, they can be turned into application-specific codes with an interface appropriate for field use.

Overview of Tasks

The overall research objective will be achieved by completing five tasks as follows:

- **Task 1:** Conduct a desk scan to identify IRTI and drone technologies that are best suited for use in bridge underside inspections and other needs expressed by the TC. Include a Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis of each model using a table to display comparative information. Also include any software requirements and compatibility issues. User needs may include concrete delamination determination, cost-effectiveness, data ease-of-use, ease of generating results, etc. Make recommendations on which model(s) would be best suited for inspection needs expressed by TC.
- **Task 2:** Field demonstration of recommended sensor and drone technologies from Task 1. Demonstration will be conducted on [a set number] bridge site(s) coordinated through the TC and will also include data analysis, reporting, and delamination (the existence and extent) cross check with traditional methods. Purchase of equipment will not be allowed as part of this study. Equipment may be leased or rented.

- **Task 3:** Develop UAV-based inspection and analysis protocols using IRTI to determine concrete delamination, with emphasis on the underside of bridge decks. Provide specifications for models selected. Address data storage protocols, identify specific required software, model specific training considerations for pilots and inspectors on software use, cost estimates for selected technology, etc.
- **Task 4:** Draft Final Report and Technology Transfer Strategy and Toolbox includes an Implementation Plan, a Technology Transfer Strategy and Toolbox.
- **Task 5:** Final Report

Expected Benefits

Based on existing research and implementation of both infrared thermography and UAV, the following benefits are expected to be realized through the implementation of these technologies:

- **Advancing State of Practice**: The use of innovative technologies is continually evaluated and researched by the Federal Highway Administration (FHWA) and other agencies to determine effectiveness and develop guidelines for implementation [1]. This research project will advance the state of the practice by providing guidance for the application of UAV and thermal imaging for use in bridge inspections.
- **Increased Productivity**: The use of infrared thermography for concrete delamination detection will allow quicker identification of these areas in lieu of requiring traditional sounding by bridge inspectors. This process also reduces the reliance on the inspector's judgement for determining limits and documentation. It is anticipated that IR findings overlaid onto plans of the bridge deck will provide easily understood documentation to assist in decision making by state agencies.
- **Greater Accuracy**: Infrared thermography can identify areas of delamination that may not be detected by traditional sounding methods depending on the severity and depth of the delamination within the bridge deck. This will also be dependent on the capabilities of the thermal sensor. The reduction of the inspector's judgement for documentation will also increase accuracy as the delaminations are generally documented as generalized shapes in the field.
- **Increased Safety**: The use of UAV will increase safety for bridge inspectors. Bridge inspectors typically utilize access equipment such as under bridge inspection trucks (UBITs), aerial lifts, and bucket trucks. The use of these types of access equipment, as well as working within traffic closures along roadways, while standard practice, does carry inherent risk. The use of UAV for inspections will reduce or minimize the amount of time within traffic closures and the amount of time required for access equipment.
- **Reduced Cost for Inspections**: There are several direct expense costs that are incurred during a typical bridge inspection. These include costs for traffic control, truck mounted attenuator(s), police detail(s), and access equipment. There are also indirect costs associated with traffic closures, based on delays to the traveling public. While the extent of UAV use will depend on the bridge structure type and condition, the use of UAV could reduce the amount of time required for traffic closures and access equipment reducing both direct and indirect costs for the overall inspection.
- **Repeatability**: The use of the same data collection parameters and guidelines can be repeated over time allowing for direct comparison of the delaminated areas and the identification of deterioration over that time period, which provides more information for agencies to make decisions regarding repair and rehabilitation.

Thermal Imaging for Concrete Delamination Detection

Overview of Basic Thermography Principals

Infrared thermography is the collection and analysis of infrared electromagnetic radiation emitted by objects which is translated to temperature readings through software allowing the inspector to detect variations in temperature. Generally, infrared thermography only captures surface measurements. The infrared spectrum is divided into short wave, mid wave, and long wave, based on the wavelength. Infrared cameras are only capable of detecting infrared radiation within one of the subdivided bands. Long wave infrared (LWIR), which spans between 7.5 micrometers (µm) and 14 µm, is the most common wavelength band utilized for concrete delamination detection.

In the specific application of concrete delamination detection, differences in the surface temperatures of the concrete allows the inference of subsurface delaminations or defects. An infrared sensor can be used to locate delaminated areas by observing the surface temperature difference between delaminated areas and solid concrete which exists when the bridge deck is warmed. The basic theory is that heat conduction through the concrete is altered if a delamination is present. Trapped air in a delamination acts as an insulator, permitting the concrete above the delamination to become warmer than the surrounding, more massive concrete. Temperature differences in the concrete can reach 10° F on sunny days. When there are no internal defects, heat flow through the deck is relatively uniform [2].

Thermal Imaging for Topside of Bridge Decks

Figure 4 - Van Equipped with IR Sensor

Generally, infrared surveys of the topside of bridge decks are performed in accordance with ASTM-D-4788 “Standard Test Method for Detecting Delamination in Bridge Decks Using Infrared Thermography” [4] These topside infrared surveys consist of a scan of the entire roadway (lanes and shoulders). Frequently this survey is performed with IR sensors mounted to vehicles although they may also be performed with handheld IR sensors. While not included in the standard, UAV mounted IR sensors could also be a possibility for data collection. The survey provides the size and location of existing delaminations, debonding of overlays (if present), patches (both concrete and asphalt), and spalls in the deck. The IR survey is only able to locate these deficiencies along the top half of the deck. An underside survey is also required to obtain a complete picture of the deck condition.

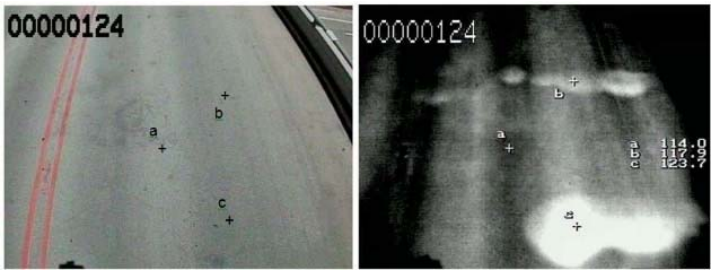


Figure 5 – Top of Deck Visual and IR Imagery

The topside IR survey involves scanning the bridge deck with an infrared camera and recording the video signal on digital media for detailed analysis later. A single pass, traveling between a walking pace and posted speed, is made for each lane of the bridge deck. At the same time, a real-life control image of the bridge deck surface is also recorded to identify anything on the surface of the deck which could cause an anomaly in the IR picture and be mistakenly identified as a delamination during the analysis. Distance footage is super-imposed on to both images to locate defects.

Field confirmation of the infrared data generally consists of two methods. The first method is to sound several suspect deteriorated areas in order to measure surface temperatures of both the suspect and sound areas during the data collection to confirm that a sufficient temperature differential is established in accordance with the ASTM standard. The second method of confirming the infrared data is to take cores if required by the project. In this scenario, several representative core locations are marked at the time of the inspection. The cores are used to confirm the infrared data and can identify the depth of reinforcing steel.

During the analysis of the infrared data, the recorded temperature variations are interpreted to identify specific, delaminated areas. Each delamination is identified and plotted onto plan view drawings of the bridge deck. Square footage and the percentage of the delaminated deck are calculated. The real-life control data is examined to make sure that temperature variations were not caused by concrete spalling, discoloration, patching, tar, debris, or other anomalies. The plan view shows located defects and any other distinguishable characteristics along with a quantities block.

The advantages of the infrared system are that it provides complete coverage of the bridge deck from parapet to parapet, the data is highly accurate and repeatable when appropriate guidelines are followed, traffic disruption is minimized when using vehicle mounted sensors, and the data collection is rapid. Infrared thermography is the one technology that will yield the same results as a chain drag survey since they both utilize air pockets within the deck delamination for identification of these areas. Infrared surveys give an area and location of existing defects. The disadvantages of the infrared system are that it is weather-dependent, does not provide a depth of the defects, and requires experienced staff to identify false positives.

There are a number of factors that affect thermal imagery and must be accounted for during project planning and execution. The thermal data can capture irregularities which can be misinterpreted by inexperienced staff. These irregularities can include shadows on the bridge deck from adjacent features such as buildings and trees, uneven heating due to traffic, an accumulation of sand/debris, surface defects from vehicles such as oil stains and skid marks, and/or environmental factors such as water, snow, and ice. To confirm accurate identification of delamination, the real-life control data (visual record) needs to be captured and reviewed to cross-check for these surface irregularities.

Generally, for the topside IR survey, the temperature difference between the delaminated and sound areas of the deck is established by the sun's rays and relies upon sunny days with minimal cloud cover. The temperature difference is primarily related to the amount of sun, not the ambient air temperature, so infrared surveys can be performed during various temperatures. Infrared surveys should generally take place between the hours of 9:00 am and 3:00 pm in order to allow enough time for the sun to heat the deck and to avoid/minimize shadows from adjacent features. The deck must be dry for this process and winds should be less than 30 mph.

Thermal Imaging for Underside of Bridges

The use of infrared thermography along the underside of bridges is based upon the same premise of locating delamination along the topside of bridge decks. The biggest difference is the source of heat; rather than the sun heating up the deck as in topside surveys, the ambient temperature provides the temperature change. Because of this, underside surveys won't be dependent on sunny days but rather on large temperature swings. It is anticipated that the largest temperature change will occur in the morning, providing the best time for data collection although there will be some variations based on the weather and season. The data collection should also avoid rain events, including prior day rain events, as the water may seep through the deck affecting the IR data. The anticipated wind speed along the underside of the bridge should be limited to either 30 mph for handheld sensors or 20 mph for UAV mounted sensors. The lower wind rating for UAV mounted sensors is needed based on wind resistance factors for many UAVs. Depending on the selected UAV model, the anticipated wind limit may be adjusted based on the UAV's capabilities. This research project will evaluate both atmospheric weather conditions and technical specifications of thermal sensors to develop guidelines for future implementation of the technology.

Figure 6 - Underside of Deck IR Imagery

Control images of the underside will be necessary for the analysis of the IR data similar to the topside analysis. Consideration of image quality of the control images should be considered during the planning phase. If the IR sensor does not capture quality visual images, a separate camera may be needed for that purpose. Similar to topside IR surveys, the underside defects can be overlaid on plan views or elevations and quantified.

The analysis of thermal data is typically performed with computer software provided by the infrared camera manufacturers. Some software can aid in the analysis process by stitching IR images together based on photogrammetry. This process can be hampered if there aren't enough distinct features in each image to stitch together, so proper planning is important for data collection.

Unmanned Aircraft Systems (UAS) for Bridge Inspection

UAS Regulations

Commercial drone operations are regulated by 14 CFR Part 107 which was established in 2016 [5]. These regulations govern all commercial operations but can be waived for specific operations by the FAA if it can be shown that the operation can be safely completed. All Federal Aviation Administration (FAA) regulations will need to be followed while performing any UAS bridge inspection unless a waiver has been received from the FAA. It is critical that all UAS pilots involved in bridge inspection are familiar with these regulations. The FAA is continually reviewing and reflecting on current regulations based on changes in drone technology and usage, UAS waiver and authorization requests, and feedback from operators and agencies. It is anticipated that the regulations for Part 107 will continue to change over time. A discussion on the UAS regulations and the impact on UAS bridge inspection will be included as part of Task 3 of this research project.

UAS and Thermal Imaging for Bridge Inspections

It is important to note that drones have different operating parameters and capabilities which means that each type will have different strengths and weaknesses. No single drone will fit all situations. It is important that the limitations of each drone are understood by the staff involved in any UAS operation. The biggest constraint for the use of any drone for bridge inspection is the need for the drone sensor to look upwards. Many consumer and commercial drones are primarily limited to downward or forward-facing views, limiting their effectiveness for bridge inspection. The ideal drone for bridge inspection would be able to look fully upwards to easily view the underside of the bridge deck. Another constraint for this research project is that a thermal sensor is required for the scope of concrete delamination detection. Drones without thermal sensors can be useful bridge inspection tools but were not included for consideration as part of this project. Refer to the "Equipment Desk Scan" section of this report for additional discussion of drone criteria considered for evaluation of drone models.

Figure 7 - UAS Bridge Inspection

UAS Bridge Inspection Challenges

The use of UAS for bridge inspection is one of the more challenging applications of this innovative technology. Drones present a few challenges related to flight underneath and around bridges. The first challenge is flight stability. The majority of commercially available drones are manufactured to rely on the global positioning system (GPS) for flight stability. Bridge inspections require flight directly underneath bridges which can hinder GPS connectivity and require direct manual flight of the drone, which also removes safety features like return-to-home functionality in the event of a lost link between the drone and controller. The stability can also be worsened by strong and varying wind currents and eddies forming along the bridge. Steel bridges can create electromagnetic interference (EMI) which needs to be a consideration for flight operations as well.

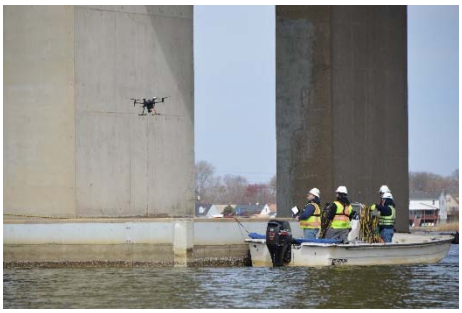


Figure 8 - UAS Operation from Boat

Another challenge is the requirement to maintain visual line of sight (VLOS) of the UAV unless an FAA waiver has previously been granted. Obstructions to maintaining VLOS include the bridge piers as well as portions of the bridge superstructure. Depending on the bridge configuration and adjacent ground features, the flight crew may need to include multiple visual observers (VO's) at different locations, the flight crew may need to change launch positions multiple times, or the drone may need to launch from a boat if the bridge is over water.

Equipment Desk Scan

The equipment desk scan primarily focused on UAV mounted IR sensor combinations. Handheld IR sensors are also being included as part of the field demonstration but due to limited differences between models, a detailed comparison was not performed for handheld sensors. Both handheld and UAV mounted scenarios need to be evaluated for the research project as the use of UAV may not be practical or economical for many bridge sites. It is important to realize that many of the bridges in the New England area are typically standard low height multi-girder overpass bridges. For many of the currently available commercial drones, this is not the ideal operating environment and a handheld sensor could be more practical for implementation. The use of a handheld IR sensor may prove to be more economical for DOT's as well.

Figure 9 - Typical Overpass Bridge

There are numerous factors to consider as part of the equipment desk scan of this research project. While some of the factors are relatively straight forward (i.e. flight time and wind resistance) some need additional definition to understand the context of these factors. Generally, the evaluation criteria are divided into two categories: aircraft traits and sensor/gimbal traits. An overview of the evaluation criteria follows:

Aircraft Traits:

- Order of Magnitude Base Cost: The analysis of the potential drone models includes an order of magnitude cost estimate. This order of magnitude cost estimate is based upon the manufacturer's initial drone purchase package and the purchase of one IR sensor, if not already integrated into the drone. This cost estimate includes only the batteries included by the manufacturer with the purchase of the drone. The purchase of additional batteries to increase flight time is not included within the estimate. A more detailed cost estimate for selected UAV model(s) that can successfully identify concrete delamination based on the field demonstration will be prepared as part of Task 3 of this research project.
- Weight and Size: The dimensions of each drone vary in terms of type and location of measurements by manufacturer, so a direct size comparison is not possible for all of the models. For example, some manufacturers provide the diagonal dimension of the props while others provide the width and length. However, the dimensions provide a relative size comparison. The size and weight will provide an indication of how easily the drone can be transported and set up by the inspection team.
- Ingress Protection: The ingress protection code classifies the degrees of protection from intrusion of dust, accidental contact, and water by casings and enclosures. The code is based on the International Electrotechnical Commission (IEC) Standard 60592. The number consists of two digits with the first digit representing solid particle protection and the second digit representing liquid ingress protection [6]. The ingress protection definitions are included in Appendix A. While better protection from particles and liquid is desired, flight operations need to avoid rainfall for optimal data collection, so ingress protection is not a significant evaluation factor for this research project.
- Maximum Payload Weight: The maximum payload is the amount of weight that the drone can safely carry. This primarily applies to drones that can be mounted with different sensors/gimbals. It does not apply to the drones with integrated sensors. Generally, the larger

the payload weight, the less available flight time. While thermal sensor payloads are relatively minimal, the capabilities of the drone to carry a heavier payload, such as a Light Detection and Ranging (LiDAR) sensor potentially provides the benefit of multiple drone applications.

- Max Wind Speed Resistance: The maximum wind speed that the drone can safely resist to maintain position.
- Advertised Max Flight Time: Generally, the advertised max flight time is based upon ideal conditions with no wind and no payloads. In reality, flight times will be less than that advertised.
- Operating Temperature Range: The operating temperature range is the limits of safe operation for the drone system. Flights outside of this range increase the likelihood of issues during operation related to the drone, control systems, and batteries.
- Obstacle Avoidance System: Drones can be outfitted with obstacle avoidance systems which are prevalent in consumer and commercial drones. Generally, these systems will consist of either visual or infrared sensors around the perimeter of the drone which enable it to detect nearby objects. This system may cause the drone to stop in place to avoid collisions or automatically adjust drone movement. There are some drones that do not have any obstacle avoidance system.
- Launch Capabilities: The evaluation also considered the ability of a drone to launch and recover by hand and the potential need to launch from a relatively flat surface. The ability to hand launch and recover the drone allows for drone use when the terrain may be steep or rocky.

Figure 10 - Hand Recovery of UAV

Sensor & Gimbal Traits:

- Resolution: The resolution is the number of pixels that the camera sensor has and can capture imagery for. The higher the resolution, the better the quality of the image and the more detail that can be captured. The resolution applies to both visual and IR sensors, however, visual sensors are able to contain many more pixels than their IR counterparts. The research project will look at multiple IR resolution ranges in an attempt to identify the minimum resolution needed to detect concrete delamination.
- Zoom: Optical zoom will utilize a mechanical assembly of lens elements in order to adjust the focal length and reduce the field of view while maintaining the same sensor resolution. Digital zoom crops the existing image so that the individual pixels get larger and are scaled up to the original image dimensions. It is important to note that digital zoom decreases of overall image quality.

- Field of View (FOV): The field of view is the angular extent of the scene that is captured by the camera. Since sensors are usually constructed with two different dimensions (i.e. 640x512), references can also include H, V, or D for horizontal, vertical, or diagonal respectively. The field of view corresponds to an equivalent focal length. In traditional single-lens reflex (SLR) cameras, the focal length is typically the distance between the lens and the image sensor and is measured in millimeters. The equivalent focal length is the focal length that corresponds to the field of view that the sensor replicates. A larger field of view indicates that a larger area will be captured by the sensor compared to a smaller field of view when taken at the same distance. Typical focal lengths for IR cameras include 9 mm (wide angle), 13 mm (wide angle), 19 mm (telephoto), and 25 mm (telephoto). A wider field of view is desirable for this project in order to capture as much of the deck in one image as possible.

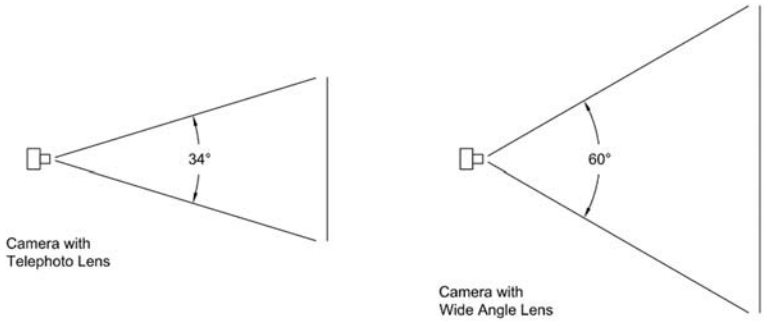


Figure 11 - FOV Illustration

- IR Frame Rate / Frequency: The frequency is the rate at which the thermal sensor can create thermal images. For example, a 9 Hz camera will create 9 images per second. A higher frame frate is desirable if the thermal images are taken while the sensor is in motion.
- Thermal Sensitivity: Thermal sensitivity, also known as Noise Equivalent Temperature Difference (NETD) is the smallest temperature difference that can be seen with the thermal camera. This is frequently measured in millikelvin. A Kelvin is the SI base unit for thermodynamic temperature with 1 mK equivalent to 0.001 K. A lower value means the camera has better sensitivity and can detect smaller temperature changes.
- Gimbal Pitch Range: A gimbal is a mechanism designed to hold an object level and stable in place while carried by another moving object. In the terms of this research project, the gimbal supports the sensor that is carried by a drone. The pitch range is the vertical range of motion of the sensor. The straight-ahead position is typically considered 0 degrees with the straight down view at -90 degrees and the straight upward view at +90 degrees. The gimbal pitch range is a critical factor as the sensor must be able to look upwards to detect delamination along the underside of the concrete bridge deck.

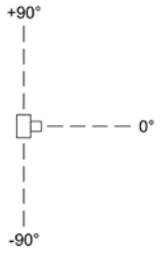


Figure 12 - Pitch Illustration

There are many other considerations for the application of infrared technology for the purpose of concrete delamination detection which are not easily evaluated through a desk scan. Software and data requirements will need to be considered. Each thermal camera manufacturer will typically provide their own thermal data analysis software. For this reason, the research project will review and evaluate these considerations during Task 2.

UAV Mounted Thermal Sensors

The desk scan identified several options for drones with either integrated infrared cameras or swappable gimbal/sensor combinations that were capable of upward views. The desk scan excluded drones that are only equipped with a visual sensor and those that have limited upward viewing capacities. An overall Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis was performed for several identified UAV and IR combination models. The SWOT analysis tables can be found in Appendix B. The UAV product specifications can be found in Appendix C. The following UAV models were evaluated:

- Digital Aerolus Aertos 130 IR
- DJI Matrice 300 with Zenmuse H20T sensor
- DJI Matrice 210 with Zenmuse XT2 sensor
- DJI Matrice 210 with Flir TZ20 sensor
- Flir Ion M440
- Flyability Elios 2
- Parrot Anafi Thermal
- Parrot Anafi USA
- Skydio X2D
- Teal Golden Eagle

Several drones were identified during the desk scan that did not meet the criteria required for this research project or were discounted for other reasons. A SWOT analysis was not performed for these drones. The specific UAV and the rationale for not including follow:

- Intel Falcon 8+ with Inspection Payload: Production of this UAV model has been discontinued by the manufacturer.
- DJI Mavic Enterprise Advanced: The gimbal for this drone is limited to +30° limiting its effectiveness for the scope of this research project.
- Autel Robotics EVO II Dual: The gimbal for this drone is limited to +0° limiting its effectiveness for the scope of this research project.
- Vantage Robotics Vesper: The gimbal for this drone is limited to +30° limiting its effectiveness for the scope of this research project.
- Freefly Alta 8+: This UAV is a “heavy lift” drone designed to carry up to 20 pounds of payload. While the drone can be outfitted with an upward facing thermal camera, the size of the drone will likely not be practical for bridges with shorter vertical clearances. The customizable nature of this specific drone also lends itself to be less beginner friendly than other drones included within this research project.

Several of the key traits evaluated as part of the SWOT analysis are summarized in Table 1.

Table 1 - Summary Comparison of UAV/IR Models

Drone	Summary of Evaluation Factors											
	Order of Magnitude Base Cost	Weight (lb)	Size	Max Wind Speed Resistance (mph)	Max Flight Time (minutes)	Launch Capabilities	IR Sensor Resolution (pixels)	IR Field of View (degrees)	Visual Sensor Resolution (megapixels)	Frame Rate (Hz)	Thermal Sensitivity (mK)	Gimbal Pitch Range
Aertos 130 IR	$38,000	5.95	21" (diag.)	10	10	Hand Launch Capable	320 x 256	34°	15.3	60	60	-90° to +90°
Matrice 300 & H20T	$27,300	13.89	31.89" x 26.38" x 16.93"	33.55	55	Ground Launch Only	640 x 512	40.6°	Wide: 12 Tele: 20	30	<50	-30° to +120°
Matrice 210 & XT2	$27,000	10.82	25.32" (diag.)	26.86	33	Ground Launch Only	640 x 512	45°	12	30	<50	-45° to +130°
Matrice 210 & TZ20	$26,500	10.82	25.32" (diag.)	26.86	33	Ground Launch Only	640 x 512	Wide: 95° Tele: 18°	n/a	30	85	-30° to +120°
Ion M440	$16,500	3.99	22.5" x 22"x 4.9"	23	35	Hand Launch Capable	320 x 256	34°	12	60	<60	Not Provided
Elios 2	$42,500	3.20	15.75" diam.	14.54	10	Hand Launch Capable	160 x 120	56°	12.3	8.7	<50	-90° to +90°
Anafi Thermal	$2,000	0.69	9.53" x 12.40" x 2.52"	31.07	26	Hand Launch Capable	160 x 120	57°	21	8.7	<50	-90° to +90°
Anafi USA	$7,500	1.00	11.10" x 14.69" x 3.30"	32.88	32	Hand Launch Capable	320 x 256	50°	Wide: 21 Tele: 16	60	<60	-140° to +110
X2D	$16,000	2.92	26.1" x 22.4"	25	35	Hand Launch Capable	320 x 256	24°	12	60	<60	-90° to +90°
Golden Eagle	$15,000	2.30	13.9" (diag.)	25	30	Hand Launch Capable	320 x 256	34°	12.3	60	<60	-135° to +45°

Based on the results of the desk scan, AECOM recommends the following UAV be tested as part of the field demonstration:

1. Parrot Anafi USA
2. DJI Matrice 210 with Zenmuse XT2 sensor
3. Skydio X2

Some rationale for these selections based on the SWOT tables are included in Table 2.

Table 2 - Rationale for Selection of UAV/IR Models

Drone	Rational for Selection
Parrot Anafi USA	Relatively low purchase cost
	Compact and lightweight
	Capable of hand launch and recovery
	IR sensor resolution (320x256) is average for evaluated models
	Visual sensor has most megapixels compared to other evaluated models
	Gimbal has largest pitch range
DJI Matrice 210 with Zenmuse XT2 Sensor	Proven commercial UAV
	Drone has master and slave capabilities for controllers so the pilot can focus on flying with the sensor operator controlling the sensor
	IR sensor has the highest resolution (640x512) of evaluated models
Skydio X2	Compact and lightweight
	Capable of hand launch and recovery
	IR sensor resolution (320x256) is average for evaluated models
	Collision avoidance system provides greater safety and reduces risk beneath bridges

It should be noted that the field demonstration for handheld thermal sensors will be performed prior to field demonstration of UAV mounted sensor combinations. Based on the results of the handheld thermal sensor field testing, the actual UAV and IR combinations may be adjusted if limits for the IR resolution are identified.

The final equipment will also be subject to rental availability by vendors. Any variations in equipment will be communicated with the Technical Committee prior to any field demonstrations.

Handheld Thermal Sensors

There are numerous handheld IR cameras that are commercially available for a variety of applications. Since many of these IR cameras have similar features and limited variations in their technical specifications, a SWOT analysis was not performed for the handheld IR sensors. AECOM reviewed commercially available cameras and identified several cameras of varying manufacturers and resolutions for field testing. Several models manufactured by Teledyne FLIR, LLC of varying resolution were selected provide comparable data and determine the required resolution for concrete delamination detection. Two models produced by other manufacturers (Seek Thermal and Fluke Corporation) were included to provide comparisons for ease of use and data quality. The traits considered for selection of the handheld sensors are similar to that for the UAV mounted IR sensors. The recommended handheld IR sensors are listed in Table 3. The rationale for the selection of these cameras is included in Table 4.

Table 3 - Recommended Handheld Thermal Sensors

Manufacturer	Model	Resolution	FOV (degrees)	Frame Rate (Hz)	Thermal Sensitivity (mK)	Purchase Cost
Flir	C5	160 x 120	54°	8.7 Hz	<70 mK	$700
Seek	Shot Pro	320 x 240	57°	<9 Hz	<70 mK	$700
Flir	E8	320 x 240	45°x34°	9	<60 mK	$2,999*
Flir	E86	464 x 348	42°	30	<30 mK	$10,999
Flir	E96	640 x 480	42°	30	<30 mK	$11,999
Fluke	Ti480 Pro	640 x 480	34°H x 24°V	60	50 mK	$10,350

** The Flir E8 is discontinued. The cost included in the table is for the new version of this sensor, the E8-XT. A vendor that rented the E8-XT was not able to be located.*

Table 4 - Rationale for Selection of Handheld Thermal Sensors

Thermal Sensor	Rationale for Selection
Flir C5	Rugged handheld camera that is compact and easy to carry
	Easy implementation for bridge inspection staff
	Low cost
	Lowest IR resolution (160x120) which serves as lower boundary for identifying the required resolution for detection
Seek Shot Pro	Alternative manufacturer and software for comparison
	Rugged handheld camera that is compact and easy to carry
	Easy implementation for bridge inspection staff
	Low cost
	Lower IR resolution (320x240)
Flir E8	Relatively low cost
	Lower IR resolution (320x240)
Flir E86	High performance thermal sensor
	Higher IR resolution (464x348)
Flir E96	High performance thermal sensor
	Highest IR resolution (640x480)
Fluke Ti480 Pro	Alternative manufacturer and software for comparison
	Highest IR resolution (640x480)
	Capable of stitching images to create 1280x960 images

References

[1] 23 CFR Part 650, Subpart C – National Bridge Inspection Standards, Federal Highway Administration, Proposed Update dated 11/12/2019 https://www.federalregister.gov/documents/2019/11/12/2019-23929/national-bridge-inspection-standards

[2] Bridge Inspectors' Reference Manual, Federal Highway Administration, December 2012 https://www.fhwa.dot.gov/bridge/nbis.cfm

[3] Federal Highway Administration Nondestructive Evaluation (NDE) Web Manual, Version 1.0, University of Nebraska-Lincoln https://fhwaapps.fhwa.dot.gov/ndep/Default.aspx

[4] ASTM D4788-88: Standard Test Method for Detecting Delaminations in Bridge Decks Using Infrared Thermography, ASTM International, 1988

[5] 14 CFR Part 107 – Operation and Certification of Small Unmanned Aircraft Systems, Federal Aviation Administration (FAA) and Office of the Secretary of Transportation (OST), Department of Transportation (DOT), 8/29/2016 https://www.federalregister.gov/documents/2016/06/28/2016-15079/operation-and-certification-of-small-unmanned-aircraft-systems

[6] International Electrotechnical Commission (IEC) 60529, "Degrees of Protection Provided by Enclosures (IP Codes)," ed. 2.1 (Geneva: International Electrotechnical Commission, 2001).

Appendix A

Ingress Protection Standard Definitions

Table 1 – First Numeral*

Numeral	Characterization of Ingress Limit	Approximate Equivalent Inches
X	Not evaluated	-
0	None	-
1	≥ 50.0 mm diameter object	1.97 in
2	≥ 12.5 mm diameter object	0.50 in
3	≥ 2.5 mm diameter object	0.10 in
4	≥ 1.0 mm diameter object	0.04 in
5	Dust-protected	-
6	Dust-tight	-

** The first numeral in an IP code indicates the degree of protection from solid foreign objects*

Table 2 – Second Numeral**

Numeral	Characterization of Ingress Limit
X	Not evaluated
0	None
1	Dripping water – vertical
2	Dripping water - 15° tilt
3	Spraying water
4	Splashing water
5	Jetting water
6	Powerful jetting water
7	Temporary immersion
8	Continuous immersion

*** The second numeral in an IP code indicates the degree of protection from liquids or moisture*

Appendix B
UAV & IR SWOT Tables

MANUFACTURER: Digital Aerolus **MODEL:** Aertos 130IR

SENSOR: Visual Camera with Flir Boson

Order of Magnitude Cost

Drone	$38,000
Sensor/Gimbal	-
Total	**$38,000**

Image from Digital Aerolus product page

Aircraft Summary

Weight	5.95 lb
Approximate Size (excluding props)	21 inches (diagonal)
Color	Black
Environmental Sealing	Not provided by manufacturer
Max Payload Weight	n/a
Max Wind Speed Resistance	10 mph
Advertised Max. Flight Time	10 minutes
Operating Temperature Range	-4°F to 110°F
Obstacle Avoidance System	Yes, Folded Geometry Framework AI system
Launch Capabilities	Can be hand launched and recovered
Controller Screen	Aertos Controller
Control App	Aertos Flight Software

Integrated Sensor & Gimbal

IR Resolution	320x256
IR Zoom	2x digital
IR Spectral Band	Long Wave
IR Focal Length / FOV	6.3 mm EFL; 34 degree HFOV
IR Frame Rate	60 Hz
IR Thermal Sensitivity	<60 mK (0.060°C)
Visual Sensor Resolution	15.3 MP
Visual Sensor Focal Length / FOV	Not provided by manufacturer
Environmental Sealing	Not provided by manufacturer
Gimbal Pitch Range	-90° to +90°

Additional Comments

Drone outfitted with synthetic LiDAR sensors which capture the surroundings and can be used for data analysis post-flights

MANUFACTURER: Digital Aerolus **MODEL:** Aertos 130IR
SENSOR: Visual Camera with Flir Boson

STRENGTHS

- Designed and manufactured in the US
- Rugged drone that can impact objects. Ducted props (props mounted within an encasement) are protected from impacts
- Drone has two controller system -> sensor operator controls sensor while pilot focuses on flying
- Drone outfitted with illuminators to brighten subjects
- Drone has FPV camera so pilot and sensor operator can both operate simultaneously while viewing different subjects
- Folded Geometry Framework (propriety software) flight system collects information from all internal and external sensors and can self-correct disturbances during flight.

WEAKNESSES

- Short battery life / flight time
- Low wind resistance rating
- One of the more expensive drone options

OPPORTUNITIES

- LiDAR data captured by drone can help with developing 3d models and other data products
- Confined space drone offers different applications than other traditional commercial drones
- Hand launch and landing capabilities offer more opportunities for use in difficult terrains
- Drone is modular allowing quick replacement of damaged components
- Potential to upgrade IR sensor to 640x512 resolution with additional cost

THREATS

- Short battery life may be too limiting for efficient inspection
- Low wind rating may limit the number of bridges where the drone can be used
- 320x256 IR sensor may not be adequate for consistent concrete delamination detection
- If utilized in confined area, wind disturbance may cause loose sand/dust to become airborne and obstruct the sensors

MANUFACTURER: DJI **MODEL:** Matrice 300 RTK
SENSOR: Zenmuse H20T

Order of Magnitude Cost

Drone	$16,000
Sensor/Gimbal	$11,300
Total	**$27,300**

Image from DJI product page

Aircraft Summary

Weight	13.89 lb
Approximate Size (excluding props)	31.89" x 26.38" x 16.93"
Color	Black
Environmental Sealing	IP45
Max Payload Weight	5.95 lb
Max Wind Speed Resistance	33.55 mph
Advertised Max. Flight Time	55 minutes
Operating Temperature Range	-4°F to 122°F
Obstacle Avoidance System	Yes
Launch Capabilities	Must launch from relatively flat surface
Controller Screen	DJI Smart Controller Enterprise
Control App	DJI Pilot

Integrated Sensor & Gimbal

No integrated sensors beyond FPV camera

Interchangeable Sensor & Gimbal

IR Resolution	640x512
IR Zoom	8x digital zoom
IR Spectral Band	Long Wave
IR Focal Length / FOV	13.5 mm; 40.6 degree DFOV
IR Frame Rate	30 Hz
IR Thermal Sensitivity	<50 mK (0.050°C)
Visual Sensor Resolution	Wide: 12 MP / Tele: 20 MP
Visual Sensor Focal Length / FOV	Wide: 4.5 mm (82.9 degree DFOV) Tele: 6.83-119.94mm (66.6 degrees DFOV)
Environmental Sealing	IP44
Gimbal Pitch Range	-120° to +30° (downward gimbal) -30° to +120° (upward gimbal)

MANUFACTURER:	DJI	**MODEL:**	Matrice 300 RTK
		SENSOR:	Zenmuse H20T

STRENGTHS

- One of the highest wind resistances of evaluated drones
- M300 has built in ADS-B receiver for monitoring planes and helicopters increasing safety
- M300 utilizes swappable sensors -> greater flexiblity to purchase what is needed
- M300 has two controller system -> sensor operator controls sensor while pilot focuses on flying
- M300 has FPV camera so pilot and sensor operator can both operate simultaneously while viewing different subjects
- Sensors can be mounted upwards and downwards at the same time.

WEAKNESSES

- M300 batteries take multiple hours to charge
- M300 is large and bulky, making it more difficult to transport
- M300 sensors can be mounted upward and/or downward but payloads need to be reconfigured in between flights for desired viewing direction
- M300 has DJI Geofencing which prohibit flights in some areas and requires approval by DJI which can prevent quick response times

OPPORTUNITIES

- DJI D-RTK 2 GNSS mobile station can be utilized to relay GPS signal
- In regards to other types of sensors, Zenmuse L1 (synthetic LiDAR) sensor may be beneficial tool for inspections. This is the only drone model that can support the L1 sensor

THREATS

- M300 may not be effective for low clearance bridges due to size
- Concerns over security of Chinese manufactured drones
- US Government is working on American Securities Drone Act which would ban this drone for federal agencies. While it would not apply to state and local agencies; the ban would apply to grants

MANUFACTURER: DJI **MODEL:** Matrice 210 RTK V.2
SENSOR: Zenmuse XT2

Order of Magnitude Cost

Drone	$16,000
Sensor/Gimbal	$11,000
Total	**$27,000**

Image from DJI product page

Aircraft Summary

Weight	10.82 lb
Approximate Size (excluding props)	25.32" diagonal
Color	Black
Environmental Sealing	IP43
Max Payload Weight	2.71 lb
Max Wind Speed Resistance	26.86 mph
Advertised Max. Flight Time	33 minutes
Operating Temperature Range	-4°F to 122°F
Obstacle Avoidance System	Yes
Launch Capabilities	Must launch from relatively flat surface
Controller Screen	DJI Crystal Sky tablet
Control App	DJI Pilot

Integrated Sensor & Gimbal

No integrated sensors beyond FPV camera

Interchangeable Sensor & Gimbal

IR Resolution	640x512 or 336x256
IR Zoom	Up to 4x (8x for 336x256 version)
IR Spectral Band	Long Wave: 7.5 - 13.5 um
IR Focal Length / FOV	9mm, 13mm, 19mm, 25mm versions available 45° x 37° for 13mm, 640x512 sensor
IR Frame Rate	30 Hz
IR Thermal Sensitivity	<50 mK (0.050°C)
Visual Sensor Resolution	12 MP
Visual Sensor Focal Length / FOV	8 mm / 57.12° FOV
Environmental Sealing	IP44
Gimbal Pitch Range	-130° to +45° (downward gimbal) -45° to +130° (upward gimbal)

Additional Comments

XT2 sensor considered for this project is 640x512 resolution with 13mm lens focal range

MANUFACTURER:	DJI	**MODEL:**	Matrice 210 RTK V.2
		SENSOR:	Zenmuse XT2

STRENGTHS

- M210 has built in ADS-B receiver for monitoring planes and helicopters increasing safety
- M210 utilizes swappable sensors -> can purchase only what is needed; options for other sensor types allows flexiblity for drone use
- M210 has two controller system -> sensor operator controls sensor while pilot focuses on flying
- M210 has FPV camera so pilot and sensor operator can both operate simultaneously while viewing different subjects

WEAKNESSES

- M210 batteries take multiple hours to charge
- M210 is large and bulky making it more difficult to transport
- M210 sensors can be mounted upward or downward but payloads need to be reconfigured in between flights for desired viewing direction
- M210 has DJI Geofencing which prohibit flights in some areas and requires approval by DJI which can prevent quick response times

OPPORTUNITIES

- DJI D-RTK 2 GNSS mobile station can be utilized to relay GPS signal
- XT2 is available in multiple focal lengths and resolutions and can be tailored to agency needs
- Some agencies have some prior experience with the DJI M200/210 series and may require less training and familiarization for DOT staff

THREATS

- M210 may not be effective for low clearance bridges due to size
- DJI Zenmuse XT2 sensor is nearing the end of its product life cycle
- New DJI Zenmuse sensors are not compatible with the M210
- Concerns over security of Chinese manufactured drones
- US Government is working on American Securities Drone Act which would ban this drone for federal agencies. While it would not apply to state and local agencies; the ban would apply to grants

MANUFACTURER: DJI **MODEL:** Matrice 210 RTK V.2

SENSOR: Flir Vue TZ20

Order of Magnitude Cost

Drone	$19,000
Sensor/Gimbal	$7,500
Total	**$26,500**

Image from DJI product page

Aircraft Summary

Weight	10.82 lb
Approximate Size (excluding props)	25.32" diagonal
Color	Black
Environmental Sealing	IP43
Max Payload Weight	2.71 lb
Max Wind Speed Resistance	26.86 mph
Advertised Max. Flight Time	33 minutes
Operating Temperature Range	-4°F to 122°F
Obstacle Avoidance System	Yes
Launch Capabilities	Must launch from relatively flat surface
Controller Screen	DJI Crystal Sky tablet
Control App	DJI Pilot

Integrated Sensor & Gimbal

No integrated sensors beyond FPV camera

Interchangeable Sensor & Gimbal

IR Resolution	640x512
IR Zoom	5x optical; up to 20x digital
IR Spectral Band	Long Wave: 12 um
IR Focal Length	Wide Angle: 4.9mm EFL; 95 degree FOV Narrow Angle: 24 mm EFL; 18 degree FOV
IR Frame Rate	30 Hz
IR Thermal Sensitivity	85 mK (0.085°C)
Visual Sensor Resolution	None
Visual Sensor Focal Length	N/A
Environmental Sealing	IP44
Gimbal Pitch Range	-120° to 30° (downward gimbal) -30° to +120° (upward gimbal)

MANUFACTURER:	DJI	**MODEL:**	Matrice 210 RTK V.2
		SENSOR:	Flir Vue TZ20

STRENGTHS

- M210 has built in ADS-B receiver for monitoring planes and helicopters increasing safety
- M210 utilizes swappable sensors -> can purchase only what is needed; options for other sensor types allows flexiblity for drone use
- M210 has two controller system -> sensor operator controls sensor while pilot focuses on flying
- M210 has FPV camera so pilot and sensor operator can both operate simultaneously while viewing different subjects
- TZ20 has wide-angle view and narrow view sensors for thermal zoom capabilities

WEAKNESSES

- M210 batteries take multiple hours to charge
- M210 is large and bulky, making it more difficult to transport
- M210 sensors can be mounted upward or downward but payloads need to be reconfigured in between flights for desired viewing direction
- M210 has DJI Geofencing which prohibit flights in some areas and requires approval by DJI which can prevent quick response times
- TZ20 does not have a visual sensor -> no visual image to verify no anamolies affecting IR image
- TZ20 does not record radiometric data for adjustments of data in office

OPPORTUNITIES

- DJI D-RTK 2 GNSS mobile station can be utilized to relay GPS signal
- Some agencies have some prior experience with the DJI M200/210 series and may require less training and familiarization for DOT staff

THREATS

- M210 may not be effective for low clearance bridges due to size
- New DJI Zenmuse sensors are not compatible with the M210
- Concerns over security of Chinese manufactured drones
- US Government is working on American Securities Drone Act which would ban this drone for federal agencies. While it would not apply to state and local agencies; the ban would apply to grants

MANUFACTURER: Flir

MODEL: Ion M440

SENSOR: Visual camera with Flir Boson

Order of Magnitude Cost

Drone	$16,500
Sensor/Gimbal	-
Total	**$16,500**

Image from Flir product page

Aircraft Summary

Weight	3.99 lb
Approximate Size (excluding props)	22.5" x 22" x 4.9"
Color	Black / Gray
Environmental Sealing	Not provided by manufacturer
Max Payload Weight	n/a
Max Wind Speed Resistance	23 mph
Advertised Max. Flight Time	35 minutes
Operating Temperature Range	-4°F to 122°F
Obstacle Avoidance System	Forward collision avoidance
Launch Capabilities	Can be hand launched and recovered
Controller Screen	Ground Control Station with Samsung Galaxy S9 or T9
Control App	QGroundControl

Integrated Sensor & Gimbal

IR Resolution	320x256
IR Zoom	2x digital
IR Spectral Band	Long Wave
IR Focal Length / FOV	6.3mm EFL; 34 degrees FOV
IR Frame Rate	60 Hz
IR Thermal Sensitivity	<60 mK (0.060°C)
Visual Sensor Resolution	12 MP
Visual Sensor Focal Length / FOV	Wide: 3.37mm (82 degree FOV) Tele: 3.37mm (28 degree FOV)
Environmental Sealing	Not provided by manufacturer
Gimbal Pitch Range	Not provided by manufacturer

MANUFACTURER: Flir **MODEL:** Ion M440
SENSOR: Visual camera with Flir Boson

STRENGTHS

- "Blue" UAS - Designed for US military and government contracts
- Compact drone allows for easy transportation

WEAKNESSES

- Less flexibility if sensors other than those integrated are desired.
- Limited obstacle avoidance system (forward only)

OPPORTUNITIES

- Hand launch and landing capabilities offer more opportunities for use in difficult terrains

THREATS

- Gimbal pitch range not provided in any product specifications. May not meet project needs in order to adequately view the underside of bridge decks
- 320x256 IR sensor may not be adequate for consistent concrete delamination detection

MANUFACTURER: Flyability

MODEL: Elios 2
Visual camera with Lepton 3.5

SENSOR: Flir

Order of Magnitude Cost

Drone	$42,500
Sensor/Gimbal	-
Total	**$42,500**

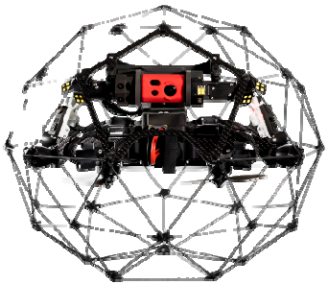


Image from Flyability product page

Aircraft Summary

Weight	3.20 lb
Approximate Size (excluding props)	15.75 inch diameter
Color	Black
Environmental Sealing	Splash and dust resistant
Max Payload Weight	n/a
Max Wind Speed Resistance	14.54 mph
Advertised Max. Flight Time	10 minutes
Operating Temperature Range	32°F to 122°F
Obstacle Avoidance System	None
Launch Capabilities	Can be hand launched and recovered
Controller Screen	Samsung Galaxy Tab Active 2
Control App	Cockpit Software

Integrated Sensor & Gimbal

IR Resolution	160x120
IR Zoom	Information not provided by manufacturer
IR Spectral Band	Long Wave
IR Focal Length / FOV	Focal Length not provided by manufacturer 56° x 42° FOV
IR Frame Rate	8.7 Hz
IR Thermal Sensitivity	<50 mK (0.050°C)
Visual Sensor Resolution	12.3 MP
Visual Sensor Focal Length / FOV	Focal Length not provided by manufacturer 118.8° HFOV
Environmental Sealing	Splash and dust resistant
Gimbal Pitch Range	-90° to +90°

MANUFACTURER: Flyability **MODEL:** Elios 2
SENSOR: Visual camera with Lepton 3.5

STRENGTHS

- Rugged drone that can impact objects. Fiberglass cage protects the drone
- Drone has two controller system -> sensor operator controls sensor while pilot focuses on flying
- Drone outfitted with illuminators to brighten subjects which includes oblique lighting

WEAKNESSES

- Less flexibility if sensors other than those integrated are desired.
- Short battery life / flight time
- Low wind resistance rating
- One of the more expensive drone options

OPPORTUNITIES

- Confined space drone offers different applications than other traditional commercial drones
- Drone is modular allowing quick replacement of damaged components
- A range extender can be purchased allowing for farther flights in confined spaces
- Inspector 3.0 software allows user to measure within the software and create points of interest within software. Subscription fee of ($3338/year) to develop 3d models/maps from flight data

THREATS

- 160x120 IR sensor likely not adequate for consistent concrete delamination detection
- Drone includes auto-landing if signal is lost which could result in the loss of the drone if the flight is located over a body of water

MANUFACTURER: Parrot

MODEL: Anafi Thermal
Visual camera with FLIR LEPTON

SENSOR: 3.5

Order of Magnitude Cost

Drone	$2,000
Sensor/Gimbal	-
Total	**$2,000**

Image from Parrot product page

Aircraft Summary

Weight	0.69 lb
Approximate Size (excluding props)	9.53" x 12.40" x 2.52"
Color	Black
Environmental Sealing	Not provided by manufacturer
Max Payload Weight	n/a
Max Wind Speed Resistance	31.07 mph
Advertised Max. Flight Time	26 minutes
Operating Temperature Range	14°F to 104°F
Obstacle Avoidance System	No
Launch Capabilities	Can be hand launched and recovered
Controller Screen	Parrot Skycontroller 3
Control App	FreeFlight 6

Integrated Sensor & Gimbal

IR Resolution	160x120
IR Zoom	3x digital
IR Spectral Band	Long Wave
IR Focal Length / FOV	Focal Length not provided by manufacturer; 57 degrees HFOV
IR Frame Rate	8.7 Hz
IR Thermal Sensitivity	<50 mK (0.050°C)
Visual Sensor Resolution	21 MP
Visual Sensor Focal Length / FOV	26 mm EFL, 84 degrees HFOV
Environmental Sealing	Not provided by manufacturer
Gimbal Pitch Range	-90° to +90°

MANUFACTURER:	Parrot	**MODEL:**	Anafi Thermal
			Visual camera with FLIR LEPTON
		SENSOR:	3.5

STRENGTHS

- Compact drone allows for easy transportation
- Gimbal/sensor can look 180 degrees up and down

WEAKNESSES

- Less flexibility if sensors other than those integrated are desired.
- No obstacle avoidance system

OPPORTUNITIES

- Compatibility with industry fleet management and operation software provides easier record keeping and more options for autonomous flights
- Hand launch and landing capabilities offer more opportunities for use in difficult terrains
- Potentially cost effective implementation of both technologies

THREATS

- 160x120 IR sensor likely not adequate for consistent concrete delamination detection

MANUFACTURER: Parrot

MODEL: Anafi USA
Wide Angle EO, Telephoto EO,

SENSOR: Flir Boson

Order of Magnitude Cost

Drone	$7,500
Sensor/Gimbal	-
Total	**$7,500**

Image from Parrot product page

Aircraft Summary

Weight	1 lb
Approximate Size (excluding props)	11.10" x 14.69" x 3.30"
Color	Black
Environmental Sealing	IP53
Max Payload Weight	n/a
Max Wind Speed Resistance	32.88 mph
Advertised Max. Flight Time	32 minutes
Operating Temperature Range	-32°F to 110°F
Obstacle Avoidance System	No
Launch Capabilities	Can be hand launched and recovered
Controller Screen	Parrot Skycontroller 3
Control App	FreeFlight 6

Integrated Sensor & Gimbal

IR Resolution	320x256
IR Zoom	8x digital
IR Spectral Band	Long Wave
IR Focal Length / FOV	4.3mm EFL; 50 degrees HFOV
IR Frame Rate	60 Hz
IR Thermal Sensitivity	<60 mK (0.060°C)
Visual Sensor Resolution	Wide: 21 MP / Tele: up to 16 MP
Visual Sensor Focal Length / FOV	Wide: 84 degree FOV / Tele: up to 75.5 degree FOV
Environmental Sealing	IP53
Gimbal Pitch Range	-140° to +110°

MANUFACTURER:	Parrot	**MODEL:**	Anafi USA
		SENSOR:	Wide Angle EO, Telephoto EO, Flir Boson

STRENGTHS

- "Blue" UAS - Designed for US military and government contracts
- Compact drone allows for easy transportation
- Designed for GPS denied navigation
- Gimbal/sensor exceeds 180° providing the largest range for gimbal pitch of evaluated drones
- Visual sensor has highest megapixels of evaluated drones
- Highest wind resistance of evaluated drones

WEAKNESSES

- Less flexibility if sensors other than those integrated are desired.
- No obstacle avoidance system

OPPORTUNITIES

- Compatibility with industry fleet management and operation software provides easier record keeping and more options for autonomous flights
- Hand launch and landing capabilities offer more opportunities for use in difficult terrains
- Multiple versions of drone available including GOV edition with controller that has built in tablet and screen for greater data security (higher purchase cost)
- One of the lower costs of evaluated models

THREATS

- 320x256 IR sensor may not be adequate for consistent concrete delamination detection

MANUFACTURER: Skydio **MODEL:** X2D

SENSOR: Visual camera with Flir Boson

Order of Magnitude Cost

Drone	$16,000
Sensor/Gimbal	-
Total	**$16,000**

Image from Skydio product page

Aircraft Summary

Weight	2.92 lb
Approximate Size (excluding props)	26.1" x 22.4"
Color	Black
Environmental Sealing	No IP rating provided by manufacturer Manufacturer indicates not to fly in rain
Max Payload Weight	n/a
Max Wind Speed Resistance	25 mph
Advertised Max. Flight Time	35 minutes
Operating Temperature Range	14°F to 110°F
Obstacle Avoidance System	Yes
Launch Capabilities	Can be hand launched and recovered
Controller Screen	Skydio Enterprise Control
Control App	Skydio Control Software, QGroundControl

Integrated Sensor & Gimbal

IR Resolution	320x256
IR Zoom	8x digital
IR Spectral Band	Long Wave
IR Focal Length / FOV	9.1mm EFL; 24 degrees FOV
IR Frame Rate	60 Hz
IR Thermal Sensitivity	<60 mK (0.060°C)
Visual Sensor Resolution	12 MP
Visual Sensor Focal Length / FOV	7.4 mm EFL; 46 degrees FOV
Environmental Sealing	No IP rating provided by manufacturer
Gimbal Pitch Range	-90° to +90°

Additional Comments

Skydio offers autonomous enterprise software for yearly subscription fee of $2000. This is not required to manually fly the drone. The Autonomy Data Sheet describing features is included as part of the appendix.

MANUFACTURER: Skydio **MODEL:** X2D
SENSOR: Visual camera with Flir Boson

STRENGTHS

- "Blue" UAS - American made
- Compact drone allows for easy transportation
- Designed for GPS denied navigation
- Obstacle avoidance system includes infrared sensors and will function in the dark
- Gimbal/sensor can look 180 degrees up and down

WEAKNESSES

- Less flexibility if sensors other than those integrated are desired.
- Drone is just starting to enter manufacturing stage. Not readily available for purchase or leasing/rental at present.

OPPORTUNITIES

- Hand launch and landing capabilities offer more opportunities for use in difficult terrains
- Skydio has assisted NCDOT in obtaining waivers from the FAA for beyond visual line of sight (BVLOS) operations for bridge inspections. There is a possiblity similar assistance can be provided for similar waivers in New England states
- Skydio is developing "3D Scan" autonomous photogrammetry data capture software which has included bridges as part of its development.

THREATS

- Commercial UAS is a new venture for the company and has not been a proven provider in the market
- 320x256 IR sensor may not be adequate for consistent concrete delamination detection
- Autonomous software subscription fee presents an additional recurring cost for the owner

MANUFACTURER: Teal

MODEL: Golden Eagle

SENSOR: Flir Hadron Dual Camera

Order of Magnitude Cost

Drone	$15,000
Sensor/Gimbal	-
Total	**$15,000**

Image from Teal Golden Eagle product page

Aircraft Summary

Weight	2.3 lb
Approximate Size (excluding props)	13.9" diagonal
Color	White/gray
Environmental Sealing	IP53
Max Payload Weight	n/a
Max Wind Speed Resistance	25 mph
Advertised Max. Flight Time	30 minutes
Operating Temperature Range	-32°F to 110°F
Obstacle Avoidance System	Yes
Launch Capabilities	Can be hand launched and recovered
Controller Screen	Teal Air Control
Control App	Teal Air Control

Integrated Sensor & Gimbal

IR Resolution	320x256
IR Zoom	2x digital
IR Spectral Band	Long Wave
IR Focal Length / FOV	6.3mm EFL; 34 degrees FOV
IR Frame Rate	60 Hz
IR Thermal Sensitivity	<60 mK (0.060°C)
Visual Sensor Resolution	12.3 MP
Visual Sensor Focal Length / FOV	3.7mm EFL; 80 degrees FOV
Environmental Sealing	IP53
Gimbal Pitch Range	-135° to +45°

MANUFACTURER: Teal **MODEL:** Golden Eagle
SENSOR: Flir Hadron Dual Camera

STRENGTHS

- "Blue" UAS - American made
- Compact drone allows for easy transportation
- Designed for GPS denied navigation
- Drone designed to be rugged and can bump against objects above and below the drone
- Drone and controller both use the same battery reducing different components needed

WEAKNESSES

- Less flexibility if sensors other than those integrated are desired.
- Integrated gimbal/sensor does not look straight upwards (+45° upward limit)

OPPORTUNITIES

- Modular design allows for upgrading of parts/components as new ones are developed and released over time. Manufacturer is planning upgraded gimbal/sensors in the future
- Hand launch and landing capabilities offer more opportunities for use in difficult terrains
- Extended flight kit with larger arms and props available which extends flight times
- Purchase of drone includes Teal training courses which includes of 93 hours of material. Course includes FAA regulations, safety, general industry, and Teal equipment. Course syllabus is included as part of spec sheet

THREATS

- Relatively new company, originally created for government applications. Commercial UAS support has not been a proven provider in the market
- 320x256 IR sensor may not be adequate for consistent concrete delamination detection

Appendix C

UAV & IR Product Data Sheets

Aertos 130IR

The Next Generation in Autonomous Stability for Confined Space and GPS-Denied Environments

RUGGED. AUTONOMOUS. AMERICAN.

The world's best workforces require the world's best tools. Tools designed to get the job done. Tools that can be used in any environment and that survive the rough-and-ready demands of the men and women who use them. Specialized tools that fill voids and solve problems, and make your work more successful, not more complicated.

No one wants second-rate tools on the jobsite. And while drones may seem unique and promising, they don't exactly thrive in challenging environments. Your demanding task deserves Rugged and Durable – not Fragile, or Vulnerable, or Risky.

You want a tough tool, not an expensive toy.

Your tools should work just as hard as you do and come back in one piece, and Aertos UAVs from Digital Aerolus change the game. Gone are the days of shattered plastic and flimsy frames. Aertos UAVs feature a tough carbon fiber body built for the toughest tasks, and a cutting-edge flight framework that keeps you in the air through the tightest, trickiest paths. It's a flying supercomputer with a breathtaking set of imagers and sensors, and it's the smartest tool in the shed.

We design and manufacture every Aertos UAV and controller right here in the USA. We understand your job - and we know what tools you need to do your job better.

Experience the Aertos difference – it's a rugged, smart, autonomous, American UAV for industrial inspections. It's a tool, not a toy.

THE NEXT GENERATION

Our original Aertos UAVs delivered many firsts: a unique groundbreaking FGF® flight framework that reacts to environmental factors and self-corrects the vehicle during flight; ultra-rugged construction designed for confined space operations without external sensors or GPS reference; and the first industrial UAV truly capable of replacing a human during dangerous or costly in-field inspections.

Building squarely on that success, the all-new Aertos 130IR now takes flight. With the latest AI technology wrapped in a rugged frame that meets the challenge of real-world confined spaces, it's a serious tool ready to tackle the harshest places and toughest jobs. No other UAV matches the 130IR's combination of stability, autonomy, advanced technology, omnidirectional sensors, and mapping and tracking capabilities -- all designed and built in America.

The engineers and scientists at Digital Aerolus spent years perfecting the 130IR's unique technology. This revolutionary tool for industrial inspections represents another milestone in our history of creating transformative technologies with far-reaching impacts across a variety of industries.

AUTONOMOUS STABILITY

Every Aertos UAV contains our patented Folded Geometry Framework (FGF®). This unique AI system equips Aertos UAVs to self-correct during flight, delivering unparalleled stability in confined spaces and GPS-denied environments.

The FGF® navigation code intelligently fuses information from all its internal and external sensors in real time based on the quality of the signal. If any external sensor fails, becomes ineffective, or is obscured, the 130IR remains stable. If the platform's flight is disturbed in any way, the UAV immediately knows the source of the disturbance, the impact the disruption will have on flight, and how to respond, correct, and stay airborne and stable.

In addition, the latest aerodynamic ducted fan designs significantly improve performance and flight times.

RUGGED CONSTRUCTION

Aertos commercial UAVs fly in harsh situations every day - and return for more. The Aertos 130IR's cutting-edge technology and rugged frame make it the ideal choice in treacherous environments. We built the 130IR for rough-and-tumble real world applications - it powers up quickly where other platforms can't, and remains stable in all conditions as it flies under bridges, through pipes, inside power plants, mines, and chimneys, and more. The Aertos design pushes the UAV performance envelope to a new level, and redefines how and where inspectors approach critical missions when the conditions are challenging.

The 130IR remains exceptionally stable in GPS-denied environments that are impossible for other drones to navigate. The artificial intelligence FGF® senses walls, wind, and ceilings, and reacts instantly to changes in the flight environment. The ducted blades and durable construction equip Aertos drones to complete missions in confined spaces, around obstacles, and in locations where the aircraft might be bumped or pushed, or must maneuver through tight spaces while contacting surfaces.

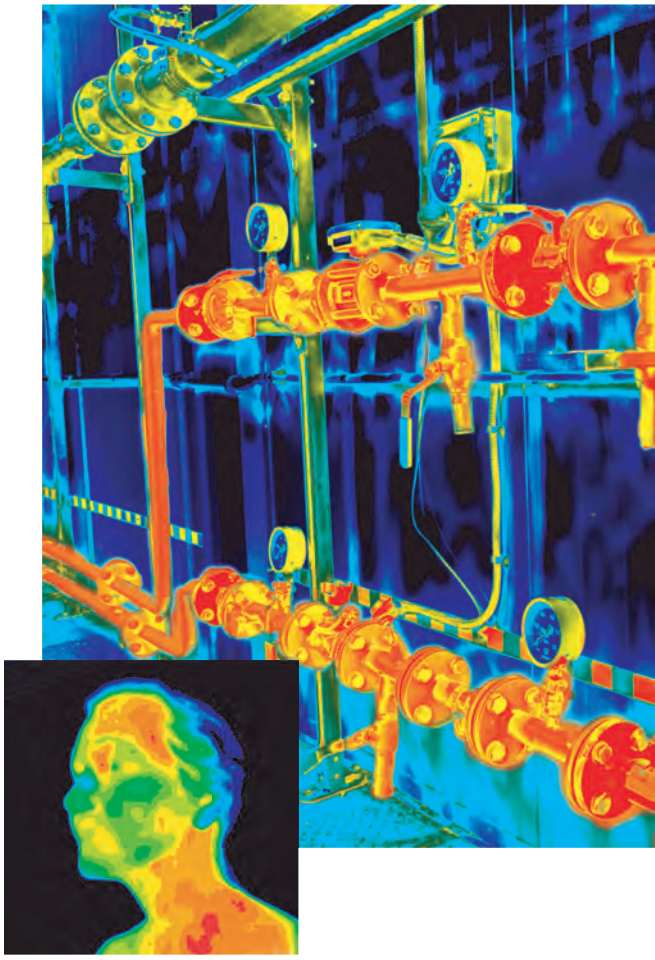
TRACKING & 3D MAPPING

We don't map to fly stably. We fly stably to map.

Conventional drones rely on sensors, LIDAR, GPS, or map building techniques just to remain stable. We engineered Aertos UAVs to be inherently stable without the external sensors or complicated maps required by typical drones.

We added nine state-of-the-art sensing elements that track the environment, measure distances, and produce point clouds and 3D maps useful for engineering or architectural applications. The Aertos FGF® integrates data from these omnidirectional scene sensors in real time to further improve the UAV's inherent stability and awareness of its space. Maintaining an ultra-stable platform for the onboard imagers is mission-critical, and Aertos UAVs fly predictably and continue to collect accurate, clear images even if a changing environment blocks the sensors, interrupts the data stream, or disrupts the maps.

Rock-solid stability and advanced tracking and mapping capabilities plus precise awareness of position combine to deliver unmatched utility when real pilots are doing real work in confined indoor spaces. Tracking and distance measuring enables the Aertos 130IR to navigate complicated paths like sewer pipes or mine shafts with incredible precision. Operators can point the 130IR to an indoor destination hundreds of meters distant and arrive within centimeters of accuracy. This highly precise environmental awareness greatly reduces the possibility of operator error or an unnecessary collision when flying in a confined space, and eliminates the possibility of losing the vehicle among the twists and turns of pipes or corridors.



INSPECTION IMAGING

Imagine a fighter pilot's cockpit view...

The 130IR's high-resolution Sony optical camera features a state-of-the-art CMOS sensor with wide ISO dynamic range, and a low-light capable low-distortion ZEISS® Tessar lens. It's durable and dustproof, and the controllable gimbal tilts 180 degrees to capture ultra-quality 15.3 mp RAW photos and 4K video wherever the Aertos can fly. And, we've added enhanced illuminators to give operators every opportunity for clean, high-quality photos, videos, and data.

The Aertos gimbal also supports a FLIR® Boson infrared imager. FLIR's best-in-class IR technology delivers accurate thermal images in the harshest environmental conditions with little or no image degradation.

To help pilots navigate easily via FPV, a high-resolution camera provides continuous flight path video.

The drone's onboard Nvidia processing array overlays data from these imagers and integrates data from all sensing elements to provide tracking, mapping, and an omnidirectional view of the world.

CONTROL, FLEXIBILITY AND SECURITY

The all-new Aertos 130IR controller is a serious, rugged tool. Designed by experienced UAV users, pilots and engineers for an unlimited future, the controller is essentially a handheld supercomputer with a Linux-powered Nvidia engine that contains more than 130 processing elements and delivers advanced image and data processing capabilities unparalleled in the industry. It's sleek and powerful, with a bright integrated video display. Users can add additional display devices as needed.

The controller's expandable architecture easily integrates OEM and partner applications, and its ergonomic design includes additional ports that allow developers and users to extend the hardware. Open-source Linux systems on both controller and aircraft support the development of custom user-specific applications, and coordinate and communicate with external databases and software. It's truly a robust, future-proof system.

And, the 130IR includes AES-128 encryption by default. It's engineered to be flexible and extendable and
to easily accommodate security upgrades.

MADE IN THE UNITED STATES

The Aertos 130IR system is designed and manufactured in America. No other UAV system matches the 130IR's rugged construction, advanced aerodynamics, suite of imagers and sensors, powerful mapping and tracking abilities, and enhanced stability and control - all in a powerful, extendable platform made with pride in Kansas, USA.

Omnidirectional Scene Sensors

The 130 IR's omnidirectional scene sensor array provides a data gathering capability unmatched by other UAVs.

This array of scene sensors and synthetic LIDAR equips the UAV with a view of its surroundings in all directions and delivers the capacity to precisely measure distances for enhanced tracking, digital odometry, 3D mapping, and much more.

Providing the UAV with environmental awareness and automating the vehicle's response to changing conditions greatly reduces the chances of pilot error, keeping the vehicle stable even on complicated flights inside pipes, corridors, or conduits.

INDOOR FLIGHT WITHOUT GPS

AIRCRAFT

Type	Aertos 130IR
Weight	5.95 lbs (2700g)
Max Angular Velocity	Pitch: 150º/s Yaw: 150º/s
Max Ascent Speed	17 ft/s (5 m/s)
Max Descent Speed	17 ft/s (5m/s)
Max Flight Time	Approx. 10 min (hovering at sea level with no wind)
Operating Temperature	-4º to 110º F (-20º to 43º C)
Diagonal Distance	21 inches (533.4 mm) edge to edge

IMAGERS AND SENSORS

Imagers	Sony® RX0II optical camera Sensor: 1" CMOS Video: Up to 4K @ 30p 100m Photo: 15.3 megapixels ISO: 125-12000 Format: RAW/JPEG
	FLIR® Boson 320 6.3mm IR camera upgradeable to Boson 640
Sensors	9-element omnidirectional scene sensor array high resolution depth sensing Synthetic LIDAR
FPV	Low latency FPV camera system Super Wide Dynamic Range

BATTERY

Type	LiOH 6S
Net Weight	1.43 lbs. (650g)
Maximum Capacity	4500 mAh
Configuration	6S1P/22.2V
Discharge Rate	25 C
Max Burst Discharge Rate	50 C
Dimensions	5.43 inches x 1.67 inches x 2.05 inches (138 mm length x 42.5 mm width x 52 mm height

CONTROLLER

Body	High impact composite Expandable ports Integrated video display
Processor	Nvidia Jetson Nano Linux OS

IN THE CASE

- Aertos 130IR UAS
  - Sony® RX0II imager
  - FLIR® Boson IR imager
  - Omnidirectional scene sensor array
- Aertos controller
- (3) LiOH batteries
- ISDT dual charger
- Pelican ATA flight case
- Replacement thruster
- Accessories

Digital Aerolus®

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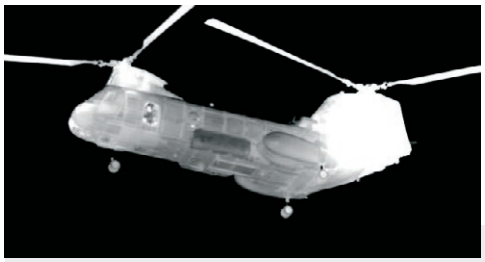
COMPACT LWIR THERMAL CAMERA

FLIR Boson®

The Boson® longwave infrared (LWIR) thermal camera module sets a new standard for size, weight, power, and performance (SWaP). It utilizes FLIR infrared video processing architecture to enable advanced image processing and several industry-standard communication interfaces while keeping power consumption low. The 12 µm pitch Vanadium Oxide (VOx) uncooled detector comes in two resolutions – 640 x 512 or 320 x 256. It is available with multiple lens configurations, adding flexibility to integration programs.

With a weight as low as 7.5 g and a camera body as small as 21 x 21 x 11 mm, the Boson represents an industry-leading reduction in SWaP with no reduction in performance. Advanced embedded processing and video analytics, as well as software-customizable functionality, give this small camera big capabilities, including integration with auxiliary sensors such as third-party cameras, GPS, and IMU.

www.flir.com/boson



DRAMATIC REDUCTION IN SIZE, WEIGHT AND POWER (SWaP) WITH NO REDUCTION IN PERFORMANCE

A full-featured VGA thermal camera module at less than 4.9 cm^3.

- 21 x 21 x 11 mm camera body and weight as low as 7.5 g
- Low power consumption, starting at 500 mW
- 12 µm pixel pitch VOx microbolometer with 320 and 640 resolutions
- Rugged construction and highest temperature rating -40°C to 80°C

POWERFUL INFRARED VIDEO PROCESSING ARCHITECTURE

FLIR infrared video processing with embedded industry-standard interfaces empowers advanced processing and analytics.

- Includes embedded algorithms for noise filters, gain control, blending, and more
- Software-customizable functionality for video processing and power dissipation requirements
- Built-in support for physical and protocol-level interface standards

WIDE CONFIGURABILITY FOR FASTER DEVELOPMENT AND LOWER COST-TO-MARKET

Unprecedented integration flexibility for fast, affordable developments.

- Customized applications through FLIR-trusted third party developers
- Mechanical/electrical compatibility across all versions
- Variety of hardware and image processing integration to fit OEM requirements

SPECIFICATIONS

Thermal Imager	FLIR Boson	
Sensor Technology	Uncooled VOx Microbolometer	
Array Format	320 × 256 or 640 × 512	
Pixel Pitch	12 µm	
Spectral Range	Longwave infrared: 7.5 µm – 14 µm	
Thermal Sensitivity	<40 mK (Industrial); <50 mK (Professional); <60 mK (Consumer)	
Full Frame Rate, Slow Frame Rate	60 Hz baseline; 30 Hz runtime selectable, ≤9 Hz available	
Non-uniformity Correction (NUC)	Factory calibrated; updated FFCs with FLIR Silent Shutterless NUC (SSN™)	
Solar Protection	Integral	
Continuous Electronic Zoom	2X zoom	
Symbol Overlay	Re-writable each frame; alpha blending for translucent overlay	
Optics		
Array Format	320 × 256	640 × 512
Horizontal Field of View (HFOV); Effective Focal Length	92°; 2.3 mm	95°; 4.9 mm
	50°; 4.3 mm	50°; 8.7 mm
	34°; 6.3 mm	32°; 14 mm
	24°; 9.1 mm	24°; 18 mm
	16°; 14 mm	18°; 24 mm
	12°; 18 mm	12°; 36 mm
	6°; 36 mm	8.0°; 55 mm
	4°; 55 mm	6°; 73 mm
Physical Attributes		
Size	21 × 21 × 11 mm (0.83 x 0.83 x 0.43 in) without lens or 640-model shutter	
Weight	7.5 g (0.26 oz) without lens or 640-model shutter	
Precision Mounting Holes	Four tapped M160.35 (rear cover) Lens support recommended when lens mass exceeds 7.5 g	
Interfacing		
Input Voltage	3.3 VDC	
Power Dissipation (Peak)	Varies by configuration; as low as 500 mW	
Video Channels	CMOS or USB-2	
Control Channels	UART or USB	
Configurable GPIO	Up to 11; user configurable	
Environmental		
Operating Temperature Range	-40°C to 80°C (-40°F to 176°F)	
Non-Operating Temperature Range	-50°C to 105°C (-58°F to 221°F)	
Shock	1,500 g @ 0.4 msec	
Operational Altitude	12,192 m (40,000 ft)	

Specifications are subject to change without notice.
For the most up-to-date specs, go to www.flir.com/boson

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NASDAQ: FLIR

19-0374-OEM-COR-Boson Datasheet

FLIR® | The World's Sixth Sense®

Specs

Aircraft

Dimensions	Unfolded, propellers excluded, 810×670×430 mm (L×W×H) Folded, propellers included, 430×420×430 mm (L×W×H)
Diagonal Wheelbase	895 mm
Weight (with single downward gimbal)	Approx. 3.6 kg (without batteries) Approx. 6.3 kg (with two TB60 batteries)
Max Payload	2.7 kg
Max Takeoff Weight	9 kg
Operating Frequency	2.4000-2.4835 GHz 5.725-5.850 GHz
EIRP	2.4000-2.4835 GHz: 29.5 dBm (FCC); 18.5dBm (CE) 18.5 dBm (SRRC); 18.5dBm (MIC) 5.725-5.850 GHz: 28.5 dBm (FCC); 12.5dBm (CE) 28.5 dBm (SRRC)
Hovering Accuracy (P-mode with GPS)	Vertical: ±0.1 m (Vision System enabled) ±0.5 m (GPS enabled) ±0.1 m (RTK enabled) Horizontal: ±0.3 m (Vision System enabled) ±1.5 m (GPS enabled) ±0.1 m (RTK enabled)
RTK Positioning Accuracy	When RTK enabled and fixed: 1 cm+1 ppm (Horizontal) 1.5 cm + 1 ppm (Vertical)
Max Angular Velocity	Pitch: 300°/s, Yaw: 100°/s
Max Pitch Angle	30° (P-mode, Forward Vision System enabled: 25°)
Max Ascent Speed	S mode: 6 m/s P mode：5 m/s
Max Descent Speed (vertical)	S mode: 5 m/s P mode：4 m/s

Max Descent Speed (tilt)	S Mode: 7 m/s
Max Speed	S mode: 23 m/s P mode： 17 m/s
Service Ceiling Above Sea Level	5000 m (with 2110 propellers, takeoff weight ≤ 7 kg) / 7000 m (with 2195 propellers, takeoff weight ≤ 7 kg)
Max Wind Resistance	15 m/s
Max Flight Time	55 min
Supported DJI Gimbals	Zenmuse XT2/XT S/Z30/H20/H20T
Supported Gimbal Configurations	Single Downward Gimbal, Dual Downward Gimbals, Single Upward Gimbal, Upward and Downward Gimbals, Gimbals
Ingress Protection Rating	IP45
GNSS	GPS+GLONASS+BeiDou+Galileo
Operating Temperature	-20°C to 50°C (-4°F to 122° F)

Remote Controller

Operating Frequency	2.4000-2.4835 GHz 5.725-5.850 GHz
Max Transmitting Distance (unobstructed, free of interference)	NCC/FCC: 15 km CE/MIC: 8 km SRRC: 8 km
EIRP	2.4000-2.4835 GHz: 29.5 dBm (FCC) 18.5dBm (CE) 18.5 dBm (SRRC); 18.5dBm (MIC) 5.725-5.850 GHz: 28.5 dBm (FCC); 12.5dBm (CE) 20.5 dBm (SRRC)
External battery	Name: WB37 Intelligent Battery Capacity: 4920 mAh Voltage: 7.6V Type: LiPo Energy: 37.39Wh Charging time (using BS60 Intelligent Battery Station): 70 minutes (15°C to 45°C); 130 minutes (0°C to 15°C)
Built-in battery	Type: 18650 lithium ion battery (5000 mAh @ 7.2 V) Charging: Use a USB charger with specification of 12V / 2A Rated power: 17 W Charging time: 2 hours and 15 minutes (Using a USB charger with specification of 12V / 2A)
Battery Life	Built-in battery: Approx. 2.5h Built-in battery+External battery: Approx. 4.5h
USB Power Supply	5 V / 1.5 A
Operating Temperature	-20°C to 40°C (-4 °F to 104 °F)

Vision System

Obstacle Sensing Range	Forward/Backward/Left/Right: 0.7-40m Upward/Downward: 0.6-30m
FOV	Forward/Backward/Downward: 65° (H), 50° (V) Left/Right/Upward: 75°(H), 60°(V)
Operating Environment	Surfaces with clear patterns and adequate lighting (> 15 lux)

Infrared ToF Sensing System

Obstacle Sensing Range	0.1-8m
FOV	30° (±15°)
Operating Environment	Large, diffuse and reflective obstacles (reflectivity >10%)

Top and bottom auxiliary light

Effective lighting distance	5 m

FPV Camera

Resolution	960p
FOV	145°
Frame rate	30 fps

Intelligent Flight Battery

Name	TB60
Capacity	5935 mAh
Voltage	52.8 V
Battery Type	LiPo 12S
Energy	274 Wh
Net Weight	Approx. 1.35 kg
Operating Temperature	-4°F to 122°F (-20°C to 50°C)
Ideal storage temperature	71.6°F to 86°F (22°C to 30°C)
Charging Temperature	-4°F to 104°F (-20°C to 40°C) (When the temperature is lower than 5°C, the self-heating function will be automatically enabled. Charging in temperature may shorten the lifetime of the battery)

Charging time	Using BS60 Intelligent Battery Station: 220V input: 60 minutes (fully charging two TB60 batteries), 30 minutes (charging two TB60 batteries from 20% 110V input: 70 minutes (fully charging two TB60 batteries), 40 minutes (charging two TB60 batteries from 20%

BS60 Intelligent Battery Station

Dimensions	501*403*252mm
Net Weight	8.37kg
Maximum Capacity	TB60 Intelligent Flight Battery × 8 WB37 Intelligent Battery × 4
Input	100-120 VAC, 50-60 Hz / 220-240 VAC, 50-60 Hz
Max. Input Power	1070W
Output Power	100-120 V: 750 W 220-240 V: 992 W
Operating Temperature	-4°F to 104°F (-20°C to 40°C)

Specs

General

Weight	Zenmuse H20: 678±5 g Zenmuse H20T: 828±5 g
Dimensions	Zenmuse H20: 150×114×151 mm Zenmuse H20T: 167×135×161 mm
Ingress Protection Rating	IP44
Operating Temperature	-20° to 50° C (Temperature Measurement is only available between -10° to 50° C)
Storage Temperature	-20° to 60° C
Laser Safety	Class 1M (IEC 60825-1:2014)
Supported Aircraft	Matrice 300 RTK

Gimbal

Angular Vibration Range	±0.01°
Mount	Detachable
Controllable Range	Pitch: -120° to +30° Yaw: ±320°
Mechanical Range	Pitch: -132.5° to +42.5° Yaw: ±330° Roll: -90° to +60°

Zoom Camera

Sensor	1/1.7" CMOS, 20 MP
Lens	DFOV: 66.6°-4° Focal length: 6.83-119.94 mm (equivalent: 31.7-556.2 mm) Aperture: f/2.8-f/11 (normal), f/1.6-f/11 (night scene) Focus: 1 m to ∞ (wide), 8 m to ∞ (telephoto)
Focus Mode	MF/AF-C/AF-S
Exposure Mode	Auto, Manual

Metering Mode	Spot metering, Center-weighted metering
AE LOCK	Supported
Electronic Shutter Speed	1 ~ 1/8000 s
ISO Range	Video: 100 - 25600 Photo: 100 - 25600
Video Resolution	3840x2160@30fps, 1920x1080@30fps
Video Format	MP4
Video subtitles	Supported
Photo Size	5184 × 3888
Photo Format	JPEG

Wide Camera

Sensor	1/2.3" CMOS, 12 MP
Lens	DFOV: 82.9° Focal length: 4.5 mm (equivalent: 24 mm) Aperture: f/2.8 Focus: 1 m to ∞
Exposure Mode	Auto
Exposure Compensation	±3.0 (1/3 increments)
Metering Mode	Spot metering, Center-weighted metering
AE LOCK	Supported
Shutter Speed	1 ~ 1/8000
ISO Range	Video: 100 - 25600 Photo: 100 - 25600
Video Resolution	1920×1080@30fps
Video Format	MP4
Video subtitles	Supported
Photo Size	4056 x 3040
Photo Format	JPEG

Thermal Camera (Zenmuse H20T)

Sensor	Uncooled VOx Microbolometer

	Aperture: F1.0 Focus: 5 m to ∞
Digital Zoom	1x, 2x, 4x, 8x
Video Resolution	640×512 @ 30 Hz
Video Format	MP4
Image Resolution	640×512
Image Format	R-JPEG (16 bit)
Pixel Pitch	12 μm
Spectral Band	8-14 μm
Sensitivity (NETD)	≤50 mK @ f/1.0
Temperature Measurement Method	Spot Meter, Area Measurement
Scene Range	-40 °C to 150 °C (High Gain) -40 °C to 550 °C (Low Gain)
Temperature alert	Supported
FFC	Auto/ manual
Palette	White hot/Fulgurite/Iron Red/Hot Iron/Medical/Arctic/Rainbow 1/Rainbow 2/Tint/Black Hot

Laser Rangefinder

Wave length	905 nm
Measurement range	3-1200 m (to a vertical surface with ≥12m diameter and 20% reflection rate)
Measurement accuracy	± (0.2 m + D×0.15%) D is the distance to a vertical surface

Features

Hybrid Optical Zoom	23×（DFOV：4°，EQV：556.2mm）
Max. Zoom	200×（DFOV：0.5°，EQV：4800mm）
One Click Capture	One click to save the video or picture of 3 cameras (zoom, wide and thermal camera) simultaneously
Point to Aim	Double click on the wide/thermal camera view, then the system will automatically move the gimbal to focus or point of interest
High-Res Grid Photo	Frame an area of interest in wide camera view, and the zoom camera will automatically capture a set of 20 MP of the area. These images are stored together with an overview image that can be viewed in greater detail.
Night Scene	Supported (zoom camera)

Storage

Supported SD Card	MicroSD card (Max capacity: 128 GB, UHS-1 Speed Grade 3 required)
Supported File Systems	FAT32 (≤ 32 GB), exFAT (> 32 GB)
Recommended Micro SD Cards	TOSHIBA EXCERIA PRO 32GB micro SD HC II SanDisk_Extreme PRO_32GB_3_A1_micro SD V30 HC I TOSHIBA EXCERIA PRO 64GB micro SD XC II SanDisk_Extreme PRO_64GB_3_A2_micro SD V30 XC I SAMSUNG_EVO_128GB_micro SD 3 XC I TOSHIBA EXCERIA M303E 32GB micro SD HC I TOSHIBA EXCERIA M303E 64GB micro SD XC I TOSHIBA EXCERIA M303E 64GB micro SD XC I TOSHIBA EXCERIA M303 128GB micro SD XC I SAMSUNG_EVO_64GB_micro SD 3 XC I

Built to Endure. Engineered to Adapt.

The ultimate platform for aerial productivity combines a rugged design and simple configurability to work as a solution for a variety of industrial applications. Improvements to the M200 Series V2 enhance intelligent control systems, flight performance, and add flight safety and data security features.

Watch Video

IP43 OcuSync 2.0 TimeSync Anti-Collision Beac

MATRICE 200 SERIES V2 Specs

M200 V2

Aircraft

Dimensions	Unfolded, propellers and landing gears included, 883×886×398 mm Folded, propellers and landing gears excluded, 722×247×242 mm
Diagonal Wheelbase	643 mm
Weight	Approx. 4.69 kg (with two TB55 batteries)

Max Takeoff Weight	6.14 kg
Max Payload	1.45 kg
Operating Frequency	2.4000-2.4835 GHz; 5.725-5.850 GHz
EIRP	2.4 GHz: ≤ 26 dBm (NCC/FCC); ≤ 20 dBm (CE/MIC); ≤ 20 dBm (SRRC) 5.8 GHz: ≤ 26 dBm (NCC/FCC); ≤ 14 dBm (CE); ≤ 26 dBm (SRRC)
Hovering Accuracy (P-mode with GPS)	Vertical:±1.64 feet (±0.5 m) or ±0.33 feet (±0.1 m, Downward Vision System enabled) Horizontal:±4.92 feet (±1.5 m) or ±0.98 feet (±0.3 m, Downward Vision System enabled)
Max Angular Velocity	Pitch: 300°/s, Yaw: 120°/s
Max Pitch Angle	S-mode: 35°; P-mode: 30° (Forward Vision System enabled: 25°); A-mode: 30°
Max Ascent Speed	16.4 ft/s (5 m/s)
Max Descent Speed (vertical)	9.8 ft/s (3 m/s)
Max Speed	S-mode/A-mode 81 kph (50.3 mph); P-mode: 61.2 kph (38 mph)
Max Service Ceiling Above Sea Level	9842 feet (3000 m, with 1760S propellers)
Max Wind Resistance	39.4 ft/s (12 m/s)
Max Flight Time (with two TB55 batteries)	38 min (no payload), 24 min (takeoff weight: 6.14 kg)
Supported DJI Gimbals	Zenmuse X4S/X5S/X7/XT/XT2/Z30
Supported Gimbal Mounting	Single Gimbal, Downward
Ingress Protection Rating	IP43
GNSS	GPS+GLONASS
Operating Temperature	-4° to 122° F (-20° to 50° C)

Downward Vision System

Velocity Range	<32.8 ft/s (10 m/s) at the height of 6.56 feet (2 m)
Altitude Range	<32.8 feet (10 m)
Operating Range	<32.8 feet (10 m)
Operating Environment	Surfaces with clear patterns and adequate lighting (> 15 lux)
Ultrasonic Sensor Operating Range	0.33-16.4 feet (0.1-5 m)
Ultrasonic Sensor Operating Environment	Non-absorbing material, rigid surface (thick indoor carpeting will reduce performance)

Upward Infrared Sensing System

Obstacle Sensing Range	0-16.4 feet (0-5 m)
FOV	±5°
Operating Environment	Large, diffuse and reflective obstacles (reflectivity >10%)

Charger (IN2C180)

Voltage	26.1 V
Rated Power	180 W

Remote Controller (GL900A)

Operating Frequency	2.4000-2.4835 GHz; 5.725-5.850 GHz
Max Transmitting Distance(unobstructed, free of interference)	NCC/FCC: 5 mi (8 km); CE/MIC: 3.1 mi (5 km); SRRC: 3.1 mi (5 km)
EIRP	2.4 GHz: ≤ 26 dBm (NCC/FCC); ≤ 20 dBm (CE/MIC); ≤ 20 dBm (SRRC) 5.8 GHz: ≤ 26 dBm (NCC/FCC); ≤ 14 dBm (CE); ≤ 26 dBm (SRRC)
Power Supply	Extended Intelligent Battery (Model: WB37-4920mAh-7.6V)
Output Power (max)	13 W (Without supplying power to monitor)
USB Power Supply	1 A⎓ 5.2 V (max)
Operating Temperature	-4° to 122° F (-20° to 50° C)

Forward Vision System

Obstacle Sensing Range	2.3-98.4 feet (0.7-30 m)
FOV	Horizontal 60°; Vertical: 54°
Operating Environment	Surfaces with clear patterns and adequate lighting (> 15 lux)

Intelligent Flight Battery (TB55-7660mAh-22.8V)

Capacity	7660 mAh
Voltage	22.8 V
Battery Type	LiPo 6S
Energy	174.6 Wh
Net Weight (Single One)	Approx. 885 g
Operating Temperature	-4° to 122° F (-20° to 50° C)
Charging Temperature	41° to 104° F (5° to 40° C)
Max Charging Power	180 W

Charging Hub (IN2CH)

Input Voltage	26.1 V
Input Current	6.9 A

M210 V2 / M210 RTK V2

Aircraft

Dimensions	M210 V2: Unfolded, propellers and landing gears included, 883×886×398 mm Folded, propellers and landing gears excluded, 722×282×242 mm M210 RTK V2: Unfolded, propellers and landing gears included, 883×886×427 mm Folded, propellers and landing gears excluded, 722×282×242 mm
Diagonal Wheelbase	643 mm
Weight	M210 V2: Approx. 4.8 kg (with two TB55 batteries); M210 RTK V2: Approx. 4.91 kg (with two TB55 batteries)
Max Takeoff Weight	6.14 kg
Max Payload	M210 V2: 1.34 kg; M210 RTK V2: 1.23 kg
Operating Frequency	2.4000-2.4835 GHz; 5.725-5.850 GHz
EIRP	2.4 GHz: ≤ 26 dBm (NCC/FCC); ≤ 20 dBm (CE/MIC); ≤ 20 dBm (SRRC) 5.8 GHz: ≤ 26 dBm (NCC/FCC); ≤ 14 dBm (CE); ≤ 26 dBm (SRRC)
Hovering Accuracy (P-mode with GPS)	Vertical: ±1.64 feet (±0.5 m) or ±0.33 feet (±0.1 m, Downward Vision System enabled) Horizontal: ±4.92 feet (±1.5 m) or ±0.98 feet (±0.3 m, Downward Vision System enabled)
Hovering Accuracy (D-RTK, M210 RTK V2)	Vertical: ±0.33 feet (±0.1 m); Horizontal: ±0.33 feet (±0.1 m)
Max Angular Velocity	Pitch: 300°/s, Yaw: 120°/s
Max Pitch Angle (Dual Downward Gimbal/Single Upward Gimbal)	S-mode: 30°; P-mode: 30° (Forward Vision System enabled: 25°); A-mode: 30°
Max Pitch Angle [Single Downward Gimbal (Gimbal Connector I)]	S-mode: 35°; P-mode: 30° (Forward Vision System enabled: 25°); A-mode: 30°
Max Ascent Speed	16.4 ft/s (5 m/s)
Max Descent Speed (vertical)	9.8 ft/s (3 m/s)
Max Speed (Dual Downward Gimbal/Single Upward Gimbal)	S-mode/A-mode: 73.8 kph (45.9 mph); P-mode: 61.2 kph (38 mph)
Max Speed [Single Downward Gimbal (Gimbal Connectorl)]	S-mode/A-mode: 81 kph (50.3 mph); P-mode: 61.2 kph (38 mph)
Max Service Ceiling Above Sea Level	9842 feet (3000 m, with 1760S propellers)
Max Wind Resistance	39.4 ft/s (12 m/s)
Max Flight Time (with two TB55 batteries)	M210 V2: 34 min (no payload), 24 min (takeoff weight: 6.14 kg) M210 RTK V2: 33 min (no payload), 24 min (takeoff weight: 6.14 kg)
Supported DJI Gimbals	Zenmuse X4S/X5S/X7/XT/XT2/Z30
Supported Gimbal Configurations	Single Downward Gimbal, Dual Downward Gimbals, Single Upward Gimbal
Ingress Protection Rating	IP43
GNSS	M210 V2: GPS+GLONASS;

	M210 RTK V2: GPS+GLONASS+BeiDou+Galileo
Operating Temperature	-4° to 122° F (-20° to 50° C)

Downward Vision System

Velocity Range	<32.8 ft/s (10 m/s) at the height of 6.56 feet (2 m)
Altitude Range	<32.8 feet (10 m)
Operating Range	<32.8 feet (10 m)
Operating Environment	Surfaces with clear patterns and adequate lighting (>15 lux)
Ultrasonic Sensor Operating Range	0.33-16.4 feet (0.1-5 m)
Ultrasonic Sensor Operating Environment	Non-absorbing material, rigid surfaces (thick indoor carpeting will adversely affect performance)

Upward Infrared Sensing System

Obstacle Sensing Range	0-16.4 feet (0-5 m)
FOV	±5°
Operating Environment	Large, diffuse, and reflective obstacles (reflectivity >10%)

Charger (IN2C180)

Voltage	26.1 V
Rated Power	180 W

Remote Controller (GL900A)

Operating Frequency	2.4000-2.4835 GHz; 5.725-5.850 GHz
Max Transmitting Distance(unobstructed, free of interference)	NCC/FCC: 5 mi (8 km); CE/MIC: 3.1 mi (5 km); SRRC: 3.1 mi (5 km)
EIRP	2.4 GHz: ≤ 26 dBm (NCC/FCC); ≤ 20 dBm (CE/MIC); ≤ 20 dBm (SRRC) 5.8 GHz: ≤ 26 dBm (NCC/FCC); ≤ 14 dBm (CE); ≤ 26 dBm (SRRC)
Power Supply	Extended Intelligent Battery (Model: WB37-4920mAh-7.6V)
Output Power (max)	13 W (Without supplying power to monitor)
USB Power Supply	1 A⎓5.2 V (max)
CrystalSky Monitor	DJI CrystalSky 7.85inch, Resolution: 2048×1536; Brightness: 2000 cd/m2; Operating System: Android 5.1; Storage: ROM 128GB
Operating Temperature	-4° to 122° F (-20° to 50° C)

Forward Vision System

Obstacle Sensing Range	2.3-98.4 feet (0.7-30 m)
FOV	Horizontal: 60°; Vertical: 54°
Operating Environment	Surfaces with clear patterns and adequate lighting (> 15 lux)

Intelligent Flight Battery (TB55-7660mAh-22.8V)

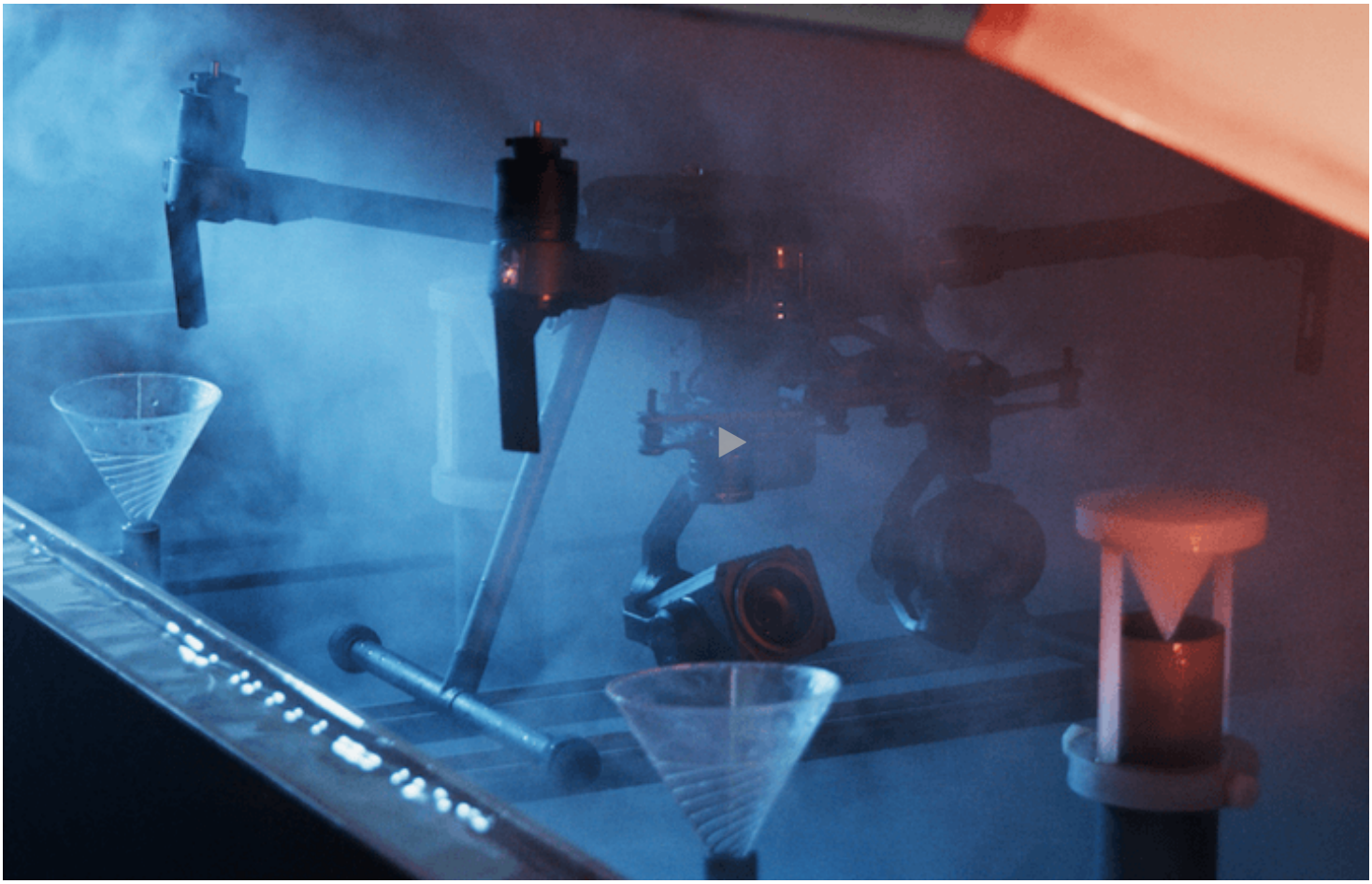
Capacity	7660 mAh
Voltage	22.8 V
Battery Type	LiPo 6S
Energy	174.6 Wh
Net Weight (Single One)	Approx. 885 g
Operating Temperature	-4° to 122° F (-20° to 50° C)
Charging Temperature	41° to 104° F (5° to 40° C)
Max Charging Power	180 W

Charging Hub (IN2CH)

Input Voltage	26.1 V
Input Current	6.9 A

MATRICE 200 SERIES V2 Videos

INTRO



Introducing the Matrice 200 Series V2

2019-03-04

Tutorials

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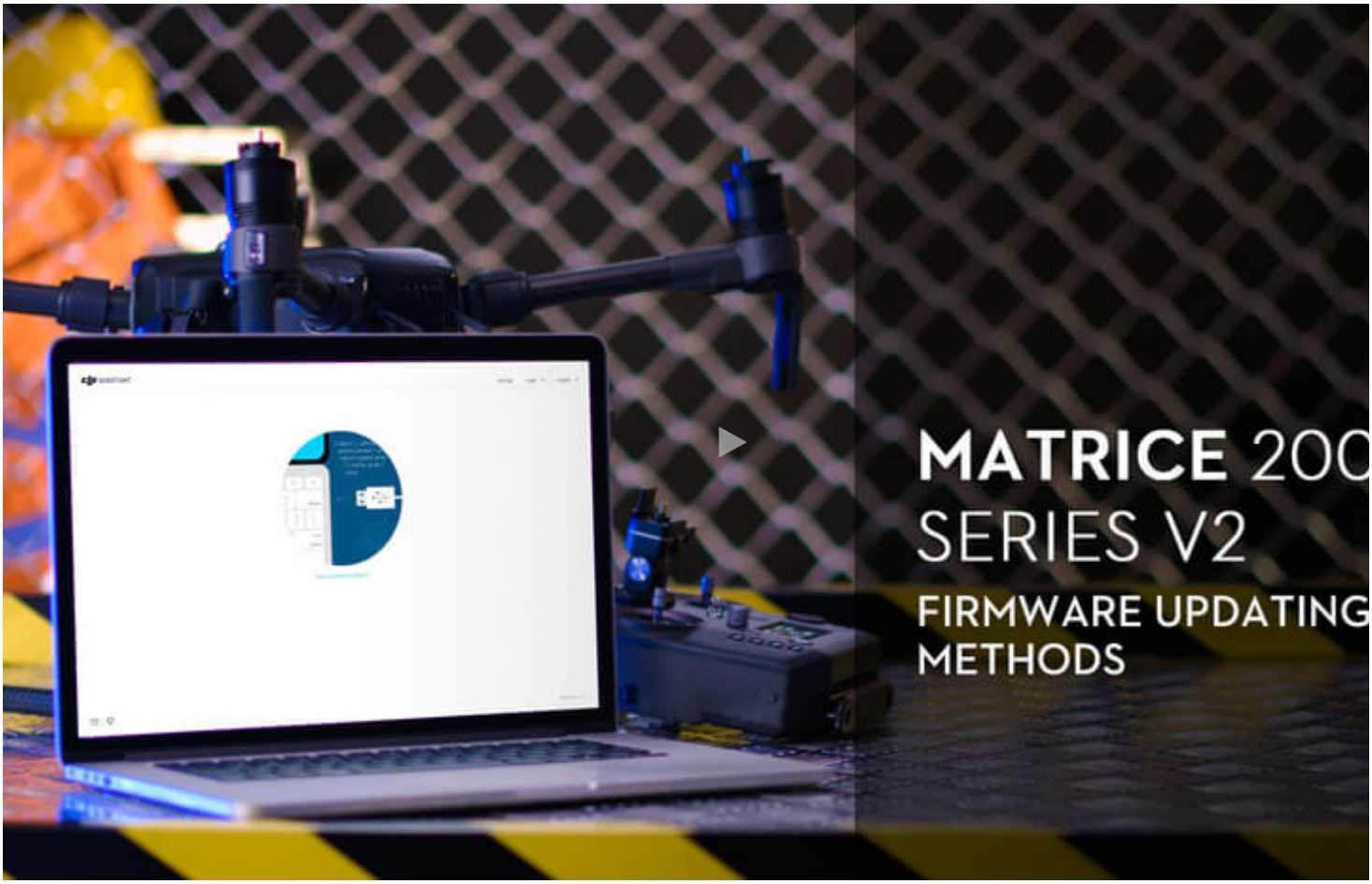
2019-02-21



Matrice 200 Series V2 - Firmware Updating Methods

2019-02-21

Matrice 200 Series V2 - Aircraft Linking Operation Instructions

2019-02-21

MATRICE 200 SERIES V2 Downloads

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MANUALS

M200 Series V2 Release Notes 2020-08-20	PDF
M200 V2 In the Box 2020-06-08	PDF
M200 V2 Quick Start Guide v1.4 2020-06-08	PDF
M210 V2 / M210 RTK V2 In the Box 2020-06-08	PDF
M210 V2 / M210 RTK V2 Quick Start Guide v1.4 2020-06-08	PDF
M200 V2 / M210 V2 / M210 RTK V2 User Manual v2.0 2020-05-15	PDF
M200 Series V2 Disclaimer and Safety Guidelines v1.4 2020-06-10	PDF
M200 Series V2 Intelligent Flight Battery Safety Guidelines v1.2 2020-06-10	PDF
D-RTK 2 High Precision GNSS Mobile Station User Guide v2.0 2020-06-11	PDF

Matrice 210 V2 Single Upward Gimbal Connector User Guide v1.2
2019-05-08 PDF

M210 V2 / M210 RTK V2 3D Module File of Components at the Rear of the Aircraft
2019-02-28 ZIP

CrystalSky User Manual v1.0
2018-08-30 PDF

Matrice 200 Series V2 GPS Kit Product Information
2019-05-08 PDF

Cendence S Remote Controller Product Information
2019-09-27 PDF

M200 Series V2 Maintenance Manual
2020-08-28 PDF

SOFTWARE

DJI Assistant 2 For Matrice URL

CAMERA FIRMWARE

Zenmuse Z30 Firmware V01.00.06.10
2020-05-08 ZIP

Zenmuse Z30 Release Notes
2020-05-08 PDF

Zenmuse XT2 Firmware V01.00.03.50
2020-05-08 ZIP

Zenmuse XT2 Release Notes
2020-05-08 PDF

Zenmuse XT Firmware V01.31.00.60
2019-03-08 ZIP

Zenmuse XT Release Notes
2019-03-08 PDF

APP / DJI Pilot

Android
Requires Android 5.0 or above.
Compatible with DJI Crystalsky, Mi Pad 3, Mi Pad 2, Samsung S2, Samsung S3, Huawei M2, Huawei M3, Nexus 9.
Huawei honor 9, Huawei P10, Google Pixel 2. One plus 6, LG G6, OPPO R15, VIVO X21, Nokia 7 plus, Mi Mix 2s, Samsung Galaxy S8.

*Support for additional devices available as testing and development continues.

MATRICE 200 SERIES V2 FAQ

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Battery

1.What is the flight time of the M200 Series V2 drones?

2.How long does it take to fully charge the TB55 Intelligent Flight Batteries of the M200 Series V2 drones?

3.How do I maintain the TB55 Intelligent Flight Batteries?

4.Can the TB55 Intelligent Flight Batteries be used in low-temperature environments?

5.Can the TB55 Intelligent Flight Batteries be taken onto a flight in the carry-on baggage?

6.Do the M200 Series V2 drones support TB50 batteries?

Propulsion

1.What is the maximum takeoff weight of the M200 Series V2 drones?

2.What are the maximum payload weights of the M200 Series V2 drones?

Remote Controller

1.How long does it take to fully charge the remote controller?

2.How long does a fully charged WB37 battery last?

3.Can the M200 Series remote controller be used for the M200 Series V2?

4.How are the remote controllers for V1 and V2 drones different visually?

5.What is the operating temperature of the remote controller?

6.What output interfaces does the remote controller have?

7.Does the M200 Series V2 support Dual Remote Controller Mode?

Transmission

1.What transmission system is used in the M200 Series V2 drones?

2.What is the actual transmission distance?

Gimbal Camera

1.What is the resolution of the FPV camera?

2.Which gimbal cameras are compatible with M200 Series V2 drones?

3.What dual gimbal combinations are supported by the M210 V2/M210 RTK V2?

4.Can the two downward gimbal cameras be controlled simultaneously on the M210 V2/M210 RTK V2?

5.Which gimbal cameras are supported in the upward gimbal mount of the M210 V2/M210 RTK V2 drones?

6.What upward+downward gimbal configurations are supported by the M210 V2/M210 RTK V2 drones?

7.Can the upward and downward gimbal cameras be controlled simultaneously on the M210 V2/M210 RTK V2?

8.Can I adjust the FPV camera's angle using the remote controller?

9.Which formats are supported by the Zenmuse X7 gimbal camera?

10.What should I keep in mind when using the upward gimbal?

Aircraft

1.How are the M200 Series and M200 Series V2 drones different visually?

2.Can I switch the dual downward gimbal connector on the M210 V2/M210 RTK V2 to a single downward gimbal connector?

3.What is the hovering precision of the M200 Series V2?

4.What is the ingress protection level of the Matrice 200 Series V2 drones?

5.Does my purchase of an M200 Series V2 drone come with a Micro SD card?

Application

1.What do I need to fully utilize the RTK functions of the M210 RTK V2?

2.What is the ingress protection rating of the DJI D-RTK2 High Precision GNSS Mobile Station For Matrice Series?

3.Which SDKs are supported by the M200 Series V2?

4.How do I get technical support for SDKs?

5.Can the External GPS Module for the M200 Series V2 be used for the M200 Series?

Surveying Solution

1.What payloads and software are required to use M210 RTK V2 for surveying and mapping?

2.How do I get started with the M210 RTK V2 with Zenmuse X7 for aerial mapping?

3.What positioning accuracy can M210 RTK V2 with Zenmuse X7 achieve?

4.Does the M210 RTK V2 + Zenmuse X7 support PPK?

5.How do I plan flight missions?

6.Can I resume a mission from a breakpoint?

7.Does DJI Pilot support storing photos in different file folders?

8.What microSD cards should I use?

9.Where are the photos written?

10.What formats of differential data does the M210 RTK V2 support?

11.What coordinate system does this solution use?

12.How do I know at what height I need to fly my drone based on my GSD requirements?

13.Will the images contain altitude information?

14.Can the images be used for reconstruction using a third-party software? How precise is the reconstruction?

15.Does the M210 RTK V2 support third-party base stations?

16.Is this solution compatible with DJI Terra?

17.Can I use the M210 RTK V2 with third-party payloads for mapping operations?

Software

1.What apps and software are supported by the M200 Series V2?

Specs

General

Name	Zenmuse XT2
Dimensions	With 25 mm lens: 123.7×112.6×127.1 mm With other lens: 118.02×111.6×125.5 mm

Gimbal

Angular Vibration Range	±0.01°
Mount	Detachable
Controllable Range	Tilt: +30° to -90° Pan: ±320°
Mechanical Range	Tilt: +45° to -130° Pan: ±330° Roll: -90° to +60°
Max Controllable Speed	Tilt: 90°/s Pan: 90°/s

Thermal Camera

Thermal Imager	Uncooled VOx Microbolometer
FPA/Digital Video Display Formats	640×512 336×256
Digital Zoom	640×512: 1x, 2x, 4x, 8x 336×256: 1x, 2x, 4x
Pixel Pitch	17 μm
Spectral Band	7.5-13.5 μm
Full Frame Rates	30 Hz
Exportable Frame Rates	<9 Hz
Sensitivity (NETD)	<50 mk @ f/1.0
Scene Range (High Gain)	640×512: -25° to 135℃

	336×256: -25° to 100℃
Scene Range (Low Gain)	-40° to 550℃
File Storage	MicroSD card*
Photo Format	JPEG, TIFF, R-JPEG
Video Format	8 bit: MOV, MP4 14 bit: TIFF Sequence, SEQ**

Visual Camera

Sensor	1/1.7" CMOS Effective Pixels: 12 M
Lens	Prime lens Focus at 8 mm FOV 57.12°× 42.44°
Digital Zoom	1x, 2x, 4x, 8x (Live View Only)
Photo Formats	JPEG
Video Formats	MOV, MP4
Video Resolutions	4K Ultra HD: 3840×2160 29.97p FHD: 1920×1080 29.97p
Working Modes	Capture, Record, Playback
Still Photography Modes	Single Shot Burst Shooting(3/5 frames) Interval (2/3/5/7/10/15/20/30 sec)
Video Caption	Supported
Anti-flicker	Auto, 50 Hz, 60 Hz
Storage	MicroSD card Max capacity: 128 GB. UHS-3 required Recommended model: Sandisk Extreme 16/32 GB UHS-3 microSDHC Sandisk Extreme 64/128 GB UHS-3 microSDXC
Supported File System	FAT 32 (≤32GB), exFAT (>32GB)

Image Processing & Display Control

Image Optimization	Yes
Digital Detail Enhancement	Yes
Polarity Control (Black Hot/ White Hot)	Yes

Models – Lens And Resolution Options

Note

The SD card, which is located near the lens, is used to store TIFF Sequence and SEQ infrared RAW video only. T format footage will be stored in the other SD card.

*It is recommended to use ImageJ to play the TIFF Sequence video and Flir Tools to play SEQ video

HIGH RESOLUTION GIMBALIZED DUAL THERMAL ZOOM PAYLOAD

FLIR VUE® TZ20

The dual-Boson® FLIR Vue TZ20 plug-and-play payload is designed to improve mission success and is fully integrated with the DJI V2 M200-series and M300 airframes. This system provides a wide 95-degree field of view for maximum situational awareness and a narrow 18-degree field of view to put more pixels on target when needed. With up to 20x zoom capabilities, the FLIR Vue TZ20 allows drone pilots from the public safety and industrial inspection sectors to gain field of view flexibility for improved image detail and magnification to assess situations and make critical decisions.

flir.com/vue-tz20

20X THERMAL ZOOM TO SUPPORT SITUATIONAL AWARENESS

Improve situational awareness with two FOVs and thermal zoom capabilities enables faster time to market

- Maintain wide field of view to cover large areas in a single flight
- Quickly hone in on target of interest with 2x, 5x, 10x, and 20x zoom
- Get more pixels on target instantaneously when needed

HIGH RESOLUTION DUAL FLIR BOSON CAMERAS

Advanced FLIR resolution and image processing

- See crisp detail with two 640 × 512 non-radiometric Boson cameras
- Record clear imagery with the full-featured VGA thermal camera module
- Rely on the quality of FLIR factory-calibrated subassembly

READY TO FLY OUT OF THE BOX

Plug-and-play with industry leading DJI airframes

- Quickly connect with Skyport V2.0 gimbal
- Compatible with DJI V2 M200-series and M300 airframes
- Record in-flight on two included Micro SD cards

SPECIFICATIONS

Overview	
Dimensions	Payload: 75 × 70 × 55 mm (2.95 × 2.75 × 2.17 in) With gimbal: 128 × 154× 141 mm (5.04 × 6.06 × 5.55 in)
Weight	640 g
Mechanical Interface	Skyport 2.0
Electrical Interface	Skyport 2.0, 13.6 V/4 A
Array format	2 Boson 640 × 512
Pixel Pitch	12 µm LWIR
IR Camera Optics	Wide FOV: 95° HFOV, 4.9 mm EFL Narrow FOV: 18° HFOV, 24 mm EFL
Thermal sensitivity	85 mK @ F/1.0
Zoom	5x optical (WFOV/NFOV), 4x digital Effective zoom: 1x (95°), 2x, 5x, 10x, 20x (4.5°)
Recording	Still: TIFF Video: MPEG (same as streaming)
Streaming	640 × 512 @ 30 Hz
Storage	2 micro SD cards
Ground control	DJI Pilot App
Gimbal	3-axis Pitch: 30° to -120° Yaw: ±320°
Airframe compatibility	DJI V2 Matrice 200-series and Matrice 300
Operating Temperature	-20°C to 45°C (-4°F to 113°F)
Storage Temperature	-20°C to 60°C (-4°F to 140°F)
Environmental sealing	IP44

Specifications are subject to change without notice. For the most up-to-date specs, go to www.flir.com

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FLIR® The World's Sixth Sense®

SHORT-RANGE TACTICAL QUADCOPTER

FLIR ION M440

Rugged, agile, and ready to deploy rapidly, the FLIR ION M440 tactical quadcopter is purpose-built for short-range reconnaissance. The ION is rucksack portable and hand-launched. Built-in daytime and nighttime obstacle avoidance reduce cognitive load for operators in tight, obstructive environments. The ION can fly for 35 minutes, reaching a top speed of 23 mph (10.3 m/s).

The ION's nimble flight capabilities pair with GPS-denied navigation. In GPS-denied or degraded environments, the ION can still maintain operation. The ION also utilizes accurate cursor-on-target, providing accurate coordinates for relay to the GCS. These battlefield capabilities combine improved situational awareness with intuitive operation to keep the warfighter safe and out of the line of fire in dangerous environments.

The ION M440 system is an NDAA-compliant drone designed and manufactured in the United States. The ION is pre-approved for government and military acquisition by the Defense Innovation Unit's Blue sUAS Program.

FEATURES

RAPIDLY DEPLOYABLE
Immediately soldier-deployable short-range reconnaissance VTOL system.

SAFER TO FLY
Embedded sensors and advanced flight algorithms offer a continuous collision avoidance failsafe.

OPERABLE IN GPS-DENIED ENVIRONMENTS
Maintains operational and flight capabilities in GPS-denied or degraded environments.

OPEN SYSTEM ARCHITECTURE
Features a high-powered discrete mission computer for advanced autonomous functions, is MAVLINK compliant, and interoperable with C-GCS, including TOGA.

APPLICATIONS

IMMEDIATE ISR

SITUATIONAL AWARENESS

FORCE PROTECTION

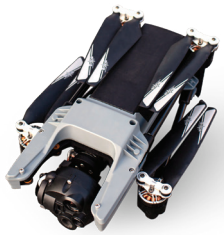
BEYOND LINE-OF-SIGHT RECONNAISSANCE

SPECIFICATIONS

ION M440 Kit Details

Standard Features
Air Vehicle
Lithium-Ion rechargeable smart battery
Battery Charger
Softshell portable case
Pelican hard shipping case
Field repair kit
ION 440 H-GCS

ION M440 H-GCS (ATAK integrated)	
Weight – with Payload	3.99lbs (1.8kg)
Dimensions – Folded	11.1" x 5.7" x 4.9" (28.2cm x 14.5cm x 12.4cm)
Dimensions – Unfolded	22.5" x 22" x 4.9" (56.4cm x 56cm x 12.4cm)
Payload	
Wide EO Sensor	12.0 MP EO Sensor with 3.37mm 82° FOV Lens
Narrow EO Sensor	12.0 MP EO Sensor with 3.37mm 28° FOV Lens
IR Sensor	320 x 256 px FLIR BOSON 320 with 6.3mm 34° FOV lens
EO Sensor Zoom	4x optical, 10x digital
Time of Flight Sensor	Forward Collision Avoidance
Performance	
Endurance	35 min (MSL: 100 ft, Ambient Temp: 4.5-37.7° C)
Speed	23 mph (10.3 m/s)
Environment	
Wind Tolerance	20kts (10.3 m/s)
Precipitation	0.25" per hour (0.64cm per hour)
Ambient Temperature Limit	-20°C, +50° C
Data Link	
Frequency	1800-1850 Mhz
Encryption	AES 256
Protocol	MAVLink
Range	3 km
Radio	1.8Ghz DDL, 2.4Ghz DDL



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21-0558-UIS_FLIR_ION_M440
US LTR

EXPORT

FLIR® | The World's Sixth Sense®

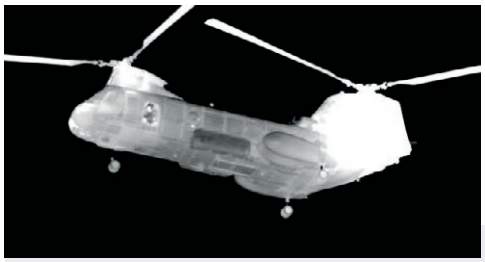
COMPACT LWIR THERMAL CAMERA

FLIR Boson®

The Boson® longwave infrared (LWIR) thermal camera module sets a new standard for size, weight, power, and performance (SWaP). It utilizes FLIR infrared video processing architecture to enable advanced image processing and several industry-standard communication interfaces while keeping power consumption low. The 12 µm pitch Vanadium Oxide (VOx) uncooled detector comes in two resolutions – 640 x 512 or 320 x 256. It is available with multiple lens configurations, adding flexibility to integration programs.

With a weight as low as 7.5 g and a camera body as small as 21 x 21 x 11 mm, the Boson represents an industry-leading reduction in SWaP with no reduction in performance. Advanced embedded processing and video analytics, as well as software-customizable functionality, give this small camera big capabilities, including integration with auxiliary sensors such as third-party cameras, GPS, and IMU.

www.flir.com/boson



DRAMATIC REDUCTION IN SIZE, WEIGHT AND POWER (SWaP) WITH NO REDUCTION IN PERFORMANCE

A full-featured VGA thermal camera module at less than 4.9 cm^3.

- 21 x 21 x 11 mm camera body and weight as low as 7.5 g
- Low power consumption, starting at 500 mW
- 12 µm pixel pitch VOx microbolometer with 320 and 640 resolutions
- Rugged construction and highest temperature rating -40°C to 80°C

POWERFUL INFRARED VIDEO PROCESSING ARCHITECTURE

FLIR infrared video processing with embedded industry-standard interfaces empowers advanced processing and analytics.

- Includes embedded algorithms for noise filters, gain control, blending, and more
- Software-customizable functionality for video processing and power dissipation requirements
- Built-in support for physical and protocol-level interface standards

WIDE CONFIGURABILITY FOR FASTER DEVELOPMENT AND LOWER COST-TO-MARKET

Unprecedented integration flexibility for fast, affordable developments.

- Customized applications through FLIR-trusted third party developers
- Mechanical/electrical compatibility across all versions
- Variety of hardware and image processing integration to fit OEM requirements

SPECIFICATIONS

Thermal Imager	FLIR Boson	
Sensor Technology	Uncooled VOx Microbolometer	
Array Format	320 × 256 or 640 × 512	
Pixel Pitch	12 µm	
Spectral Range	Longwave infrared: 7.5 µm – 14 µm	
Thermal Sensitivity	<40 mK (Industrial); <50 mK (Professional); <60 mK (Consumer)	
Full Frame Rate, Slow Frame Rate	60 Hz baseline; 30 Hz runtime selectable, ≤9 Hz available	
Non-uniformity Correction (NUC)	Factory calibrated; updated FFCs with FLIR Silent Shutterless NUC (SSN™)	
Solar Protection	Integral	
Continuous Electronic Zoom	2X zoom	
Symbol Overlay	Re-writable each frame; alpha blending for translucent overlay	
Optics		
Array Format	320 × 256	640 × 512
Horizontal Field of View (HFOV); Effective Focal Length	92°; 2.3 mm	95°; 4.9 mm
	50°; 4.3 mm	50°; 8.7 mm
	34°; 6.3 mm	32°; 14 mm
	24°; 9.1 mm	24°; 18 mm
	16°; 14 mm	18°; 24 mm
	12°; 18 mm	12°; 36 mm
	6°; 36 mm	8.0°; 55 mm
	4°; 55 mm	6°; 73 mm
Physical Attributes		
Size	21 × 21 × 11 mm (0.83 x 0.83 x 0.43 in) without lens or 640-model shutter	
Weight	7.5 g (0.26 oz) without lens or 640-model shutter	
Precision Mounting Holes	Four tapped M160.35 (rear cover) Lens support recommended when lens mass exceeds 7.5 g	
Interfacing		
Input Voltage	3.3 VDC	
Power Dissipation (Peak)	Varies by configuration; as low as 500 mW	
Video Channels	CMOS or USB-2	
Control Channels	UART or USB	
Configurable GPIO	Up to 11; user configurable	
Environmental		
Operating Temperature Range	-40°C to 80°C (-40°F to 176°F)	
Non-Operating Temperature Range	-50°C to 105°C (-58°F to 221°F)	
Shock	1,500 g @ 0.4 msec	
Operational Altitude	12,192 m (40,000 ft)	

Specifications are subject to change without notice.
For the most up-to-date specs, go to www.flir.com/boson

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19-0374-OEM-COR-Boson Datasheet

FLIR® | The World's Sixth Sense®

ELIOS 2

INTUITIVE INDOOR INSPECTION

Elios 2 is the most intuitive, reliable, and precise indoor inspection drone. Keep your workforce out of harm's way while performing flawless inspections right from the first flight using cutting edge drone data capture capabilities.

FLYABILITY

FEATURES

DESIGNED FOR INDOOR

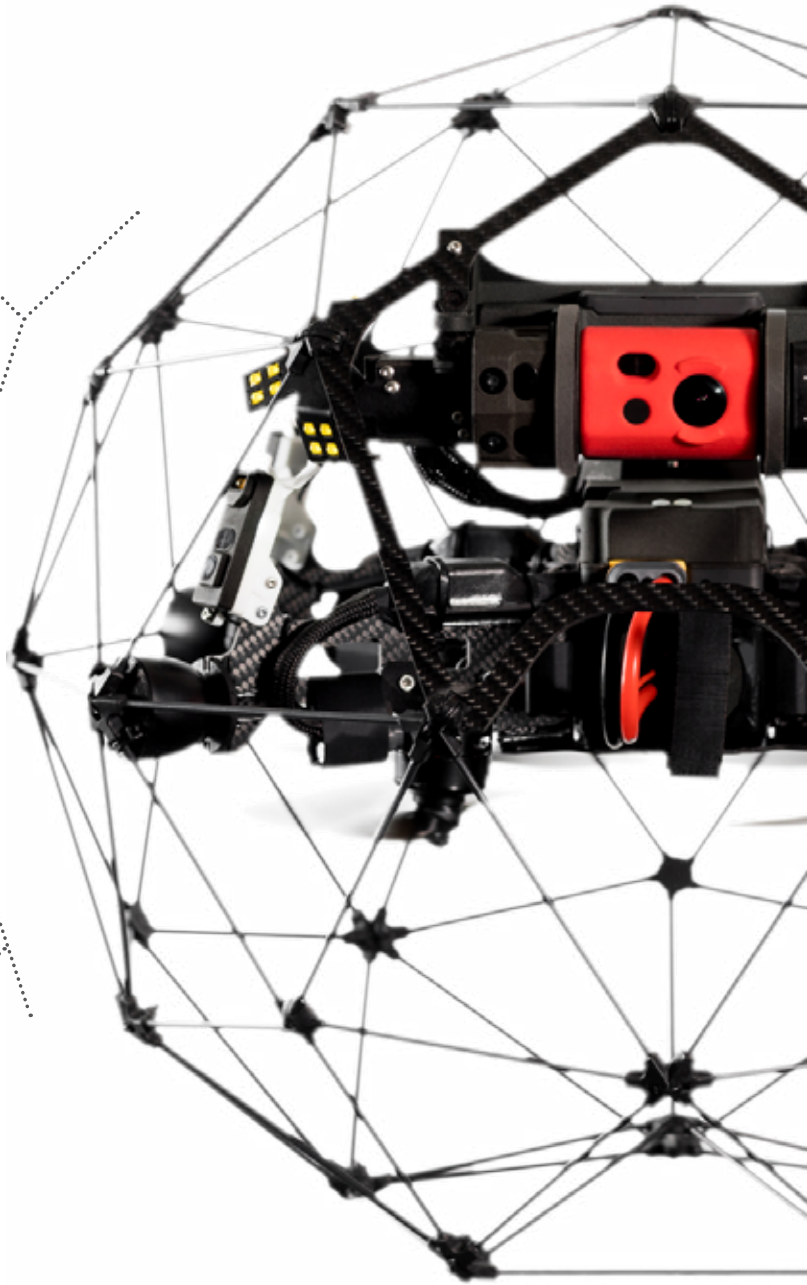
Collision-resilient
Shockproof payload
Confined space accessibility
Robust wireless transmission

INTUITIVE TO FLY

GPS-free stabilization
Distance lock
Full HD live streaming

BUILT FOR YOUR SUCCESS

Easy maintenance
Training included
Dedicated support team



DATA QUALITY

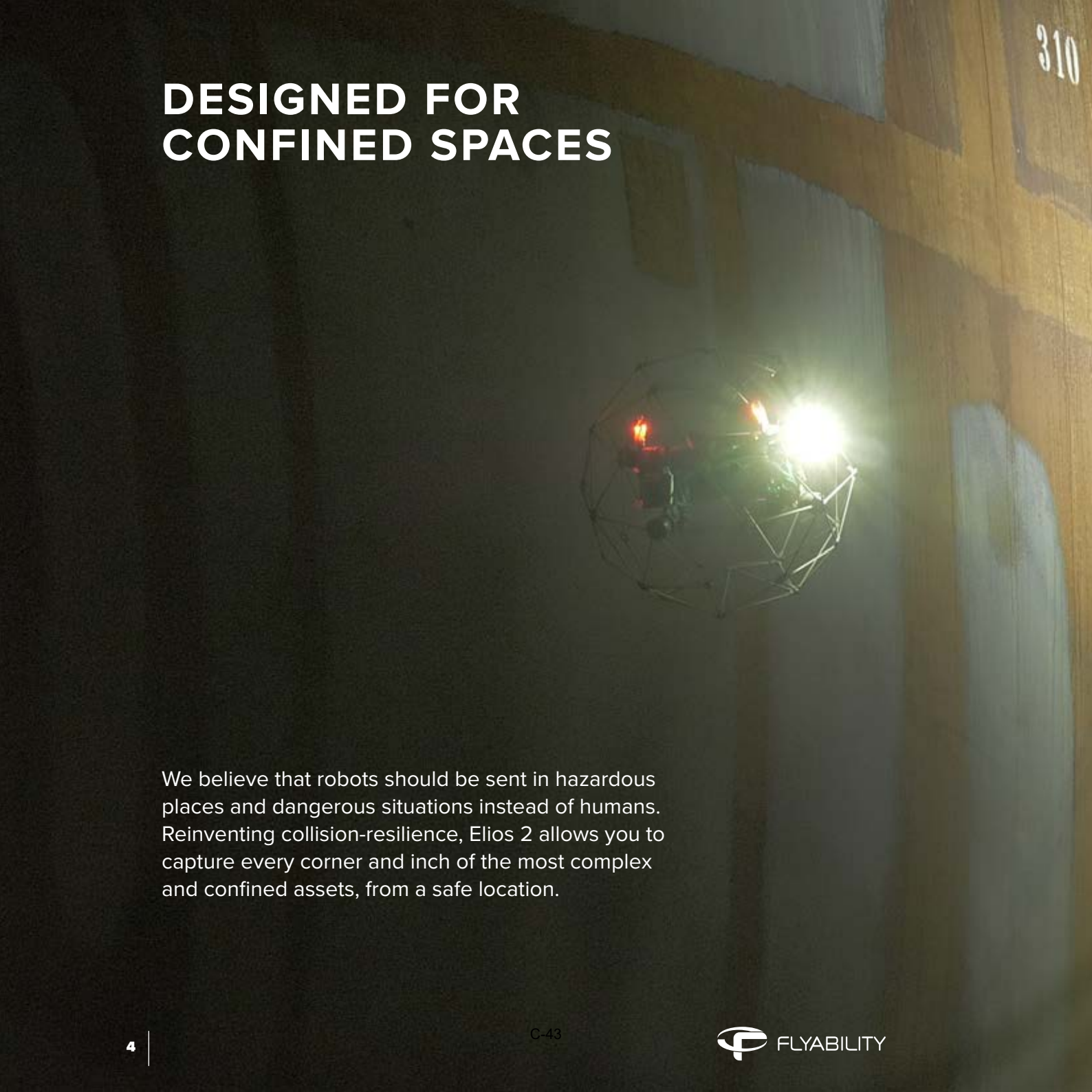
Close up inspection
4k Camera
Thermal camera
180° tiltable camera pod
10K lumen
Adjustable lighting
Dustproof lighting
Oblique lighting
Obstruction-free

DATA PROCESSING

Streamlined data management
3D modeling
2D measurement

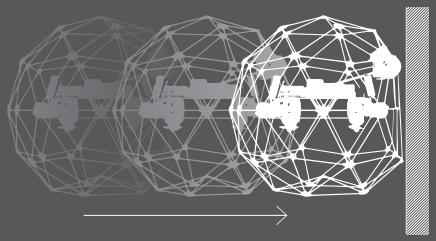
Patented Technology

DESIGNED FOR CONFINED SPACES



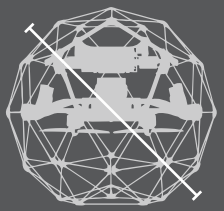
We believe that robots should be sent in hazardous places and dangerous situations instead of humans. Reinventing collision-resilience, Elios 2 allows you to capture every corner and inch of the most complex and confined assets, from a safe location.

INDOOR CAPABILITIES



COLLISION RESILIENCE

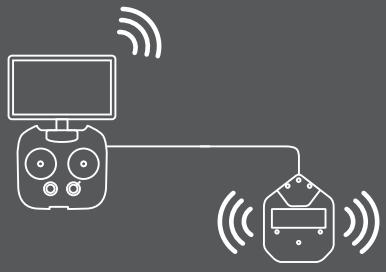
With a spherical cage protecting propellers from impacts, Elios 2 remains always stable through lightning-fast corrections on the propellers' speed and direction of rotation. The entire payload is mounted on a retractable structure that protects it from damages in case of frontal shocks.



< 40 cm
< 15.7 in

ACCESSIBILITY

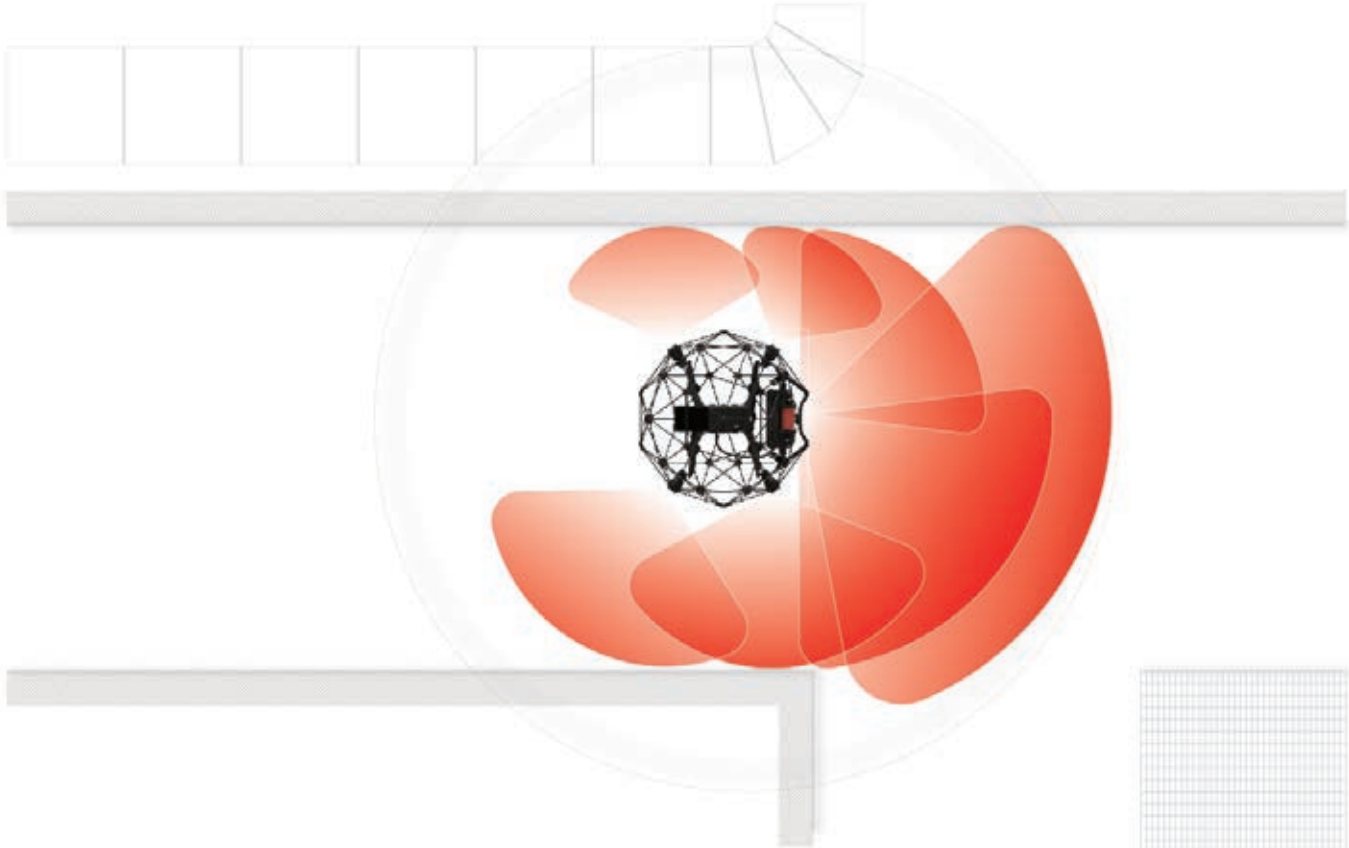
With an overall dimension just below 40 cm (15.7 in) Elios 2 fits into standard manholes and can enter any space where an inspection is needed. It can safely and easily be flown into assets without any human access needed; at no point do workers need to enter the space during the inspection.



ROBUST TRANSMISSION

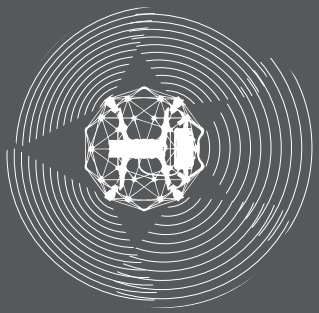
Perform remote inspections beyond line of sight, through walls and past obstacles with Elios 2. Its wireless transmission system overcomes the needs of indoor configurations and is compatible with the Range Extender for the most complex setups.

INTUITIVE TO FLY



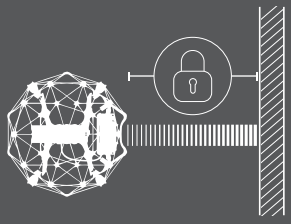
Get the job done! Elios 2 intuitive flight experience makes anyone feel like a seasoned pilot from the first flight. Perform flawless inspections with an effective and user-friendly tool, deployed within minutes.

FLIGHT EXPERIENCE



GPS-FREE STABILIZATION

Take razor-sharp close-up images in GPS-denied environments, in dark and troubled air flows, beyond line of sight. Elios 2 features 7 stability sensors specifically designed for indoor allowing it to hover in place and easily navigate through unstructured spaces.

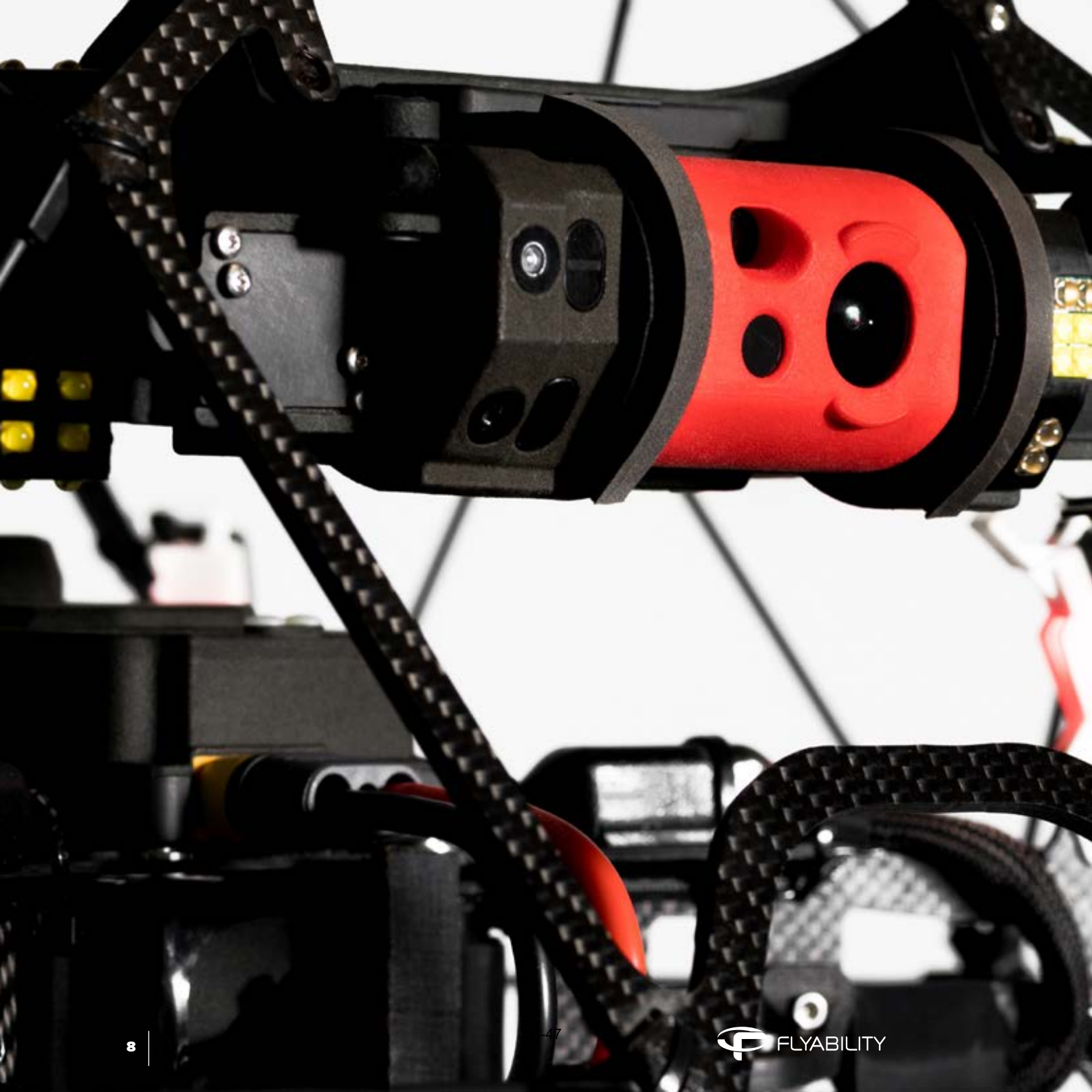


DISTANCE LOCK

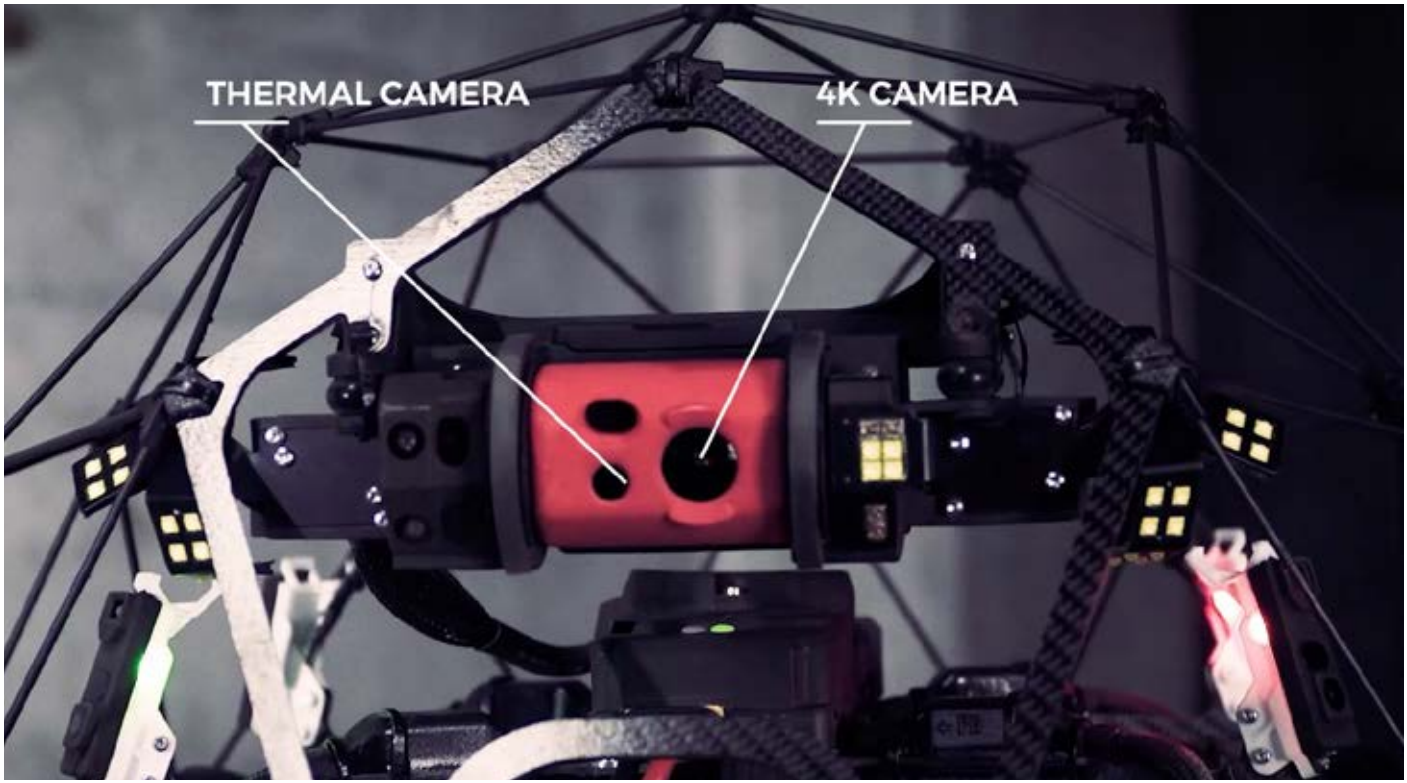
Perform smooth inspections of long and repetitive features like welding, or beams. With the distance lock, Elios 2 remains at a set distance, ranging from 30 cm to 200 cm (1 - 6 ft) autonomously.

FULL HD LIVE STREAMING

Experience a greater situational awareness and perform live inspections in First-Person View (FPV) thanks to the increased details of the Full HD live streaming built into Elios 2.



ACCURATE DATA CAPTURE



THERMAL & 4K CLOSE-UP INSPECTION

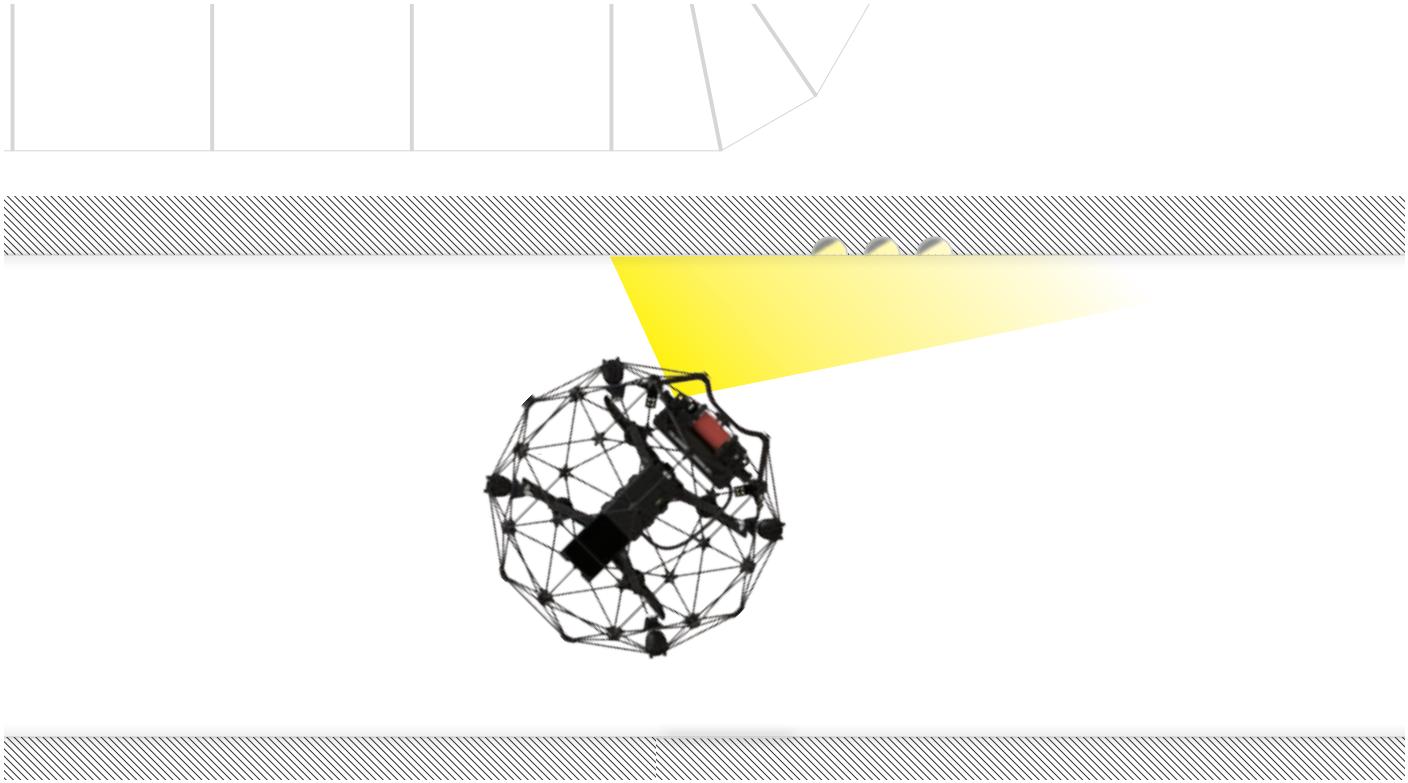
When it comes to visual inspections, data is what matters.
So, we've placed Elios 2 payload in the front cage-opening, fitted with a thermal and a 4K camera side by side. 12MP still and video recording gives you stunning detailed images with 0.18 mm/px resolution to spot the tiniest cracks from floor to ceiling.

10K LUMENS

The Elios 2 features the most powerful and intelligent lighting system ever built on a commercial drone. Carrying 10’000 lumens of light, adjustable to your needs, Elios 2 provides the right amount of lighting whether you need to see the big picture or the tiniest crack.

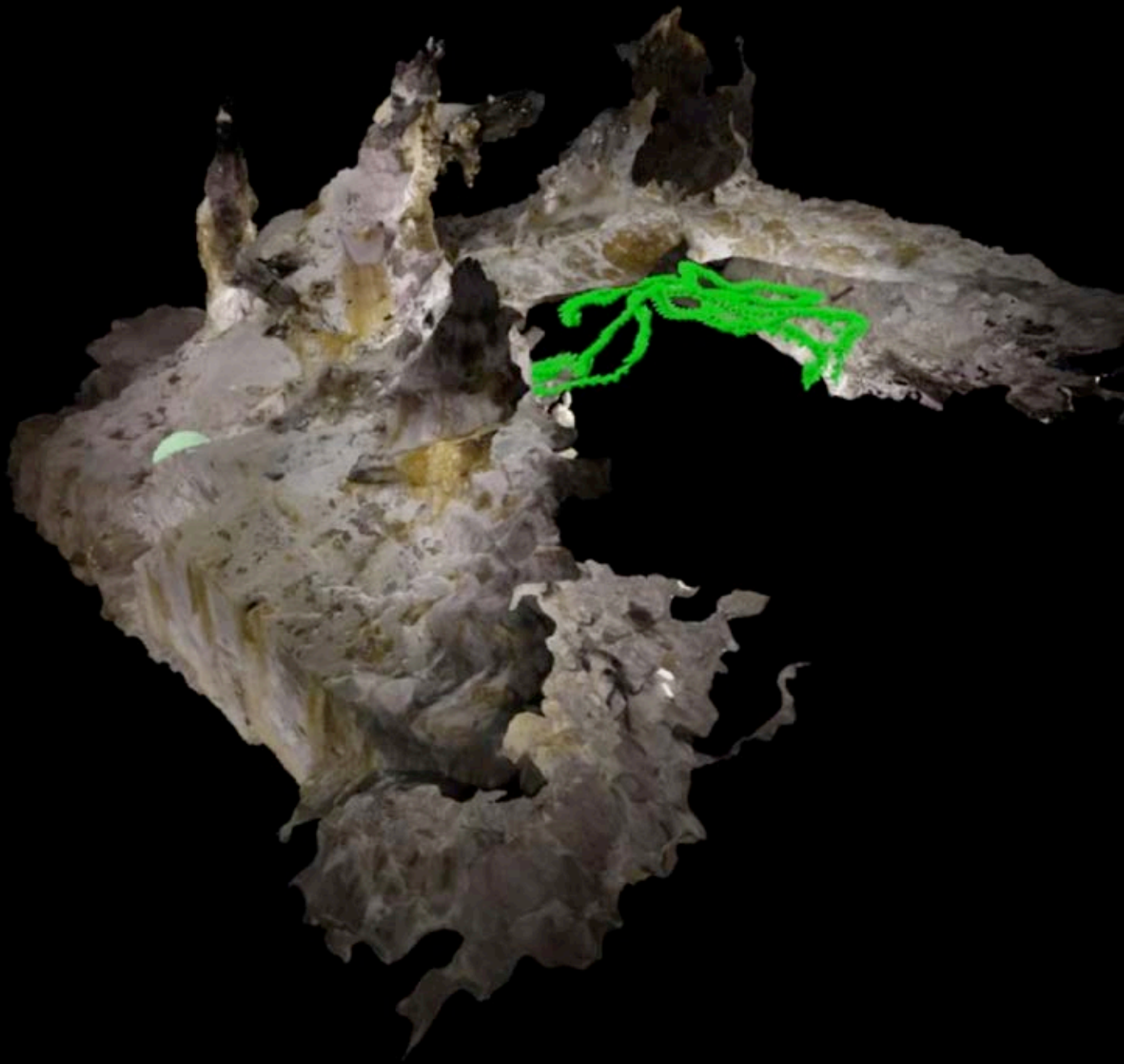
DUSTPROOF LIGHTING

Industrial indoor spaces are often full of dust, which makes First-Person View aircraft navigation difficult. Dustproof lighting allows you to traverse dirty places without losing sight of your objective.

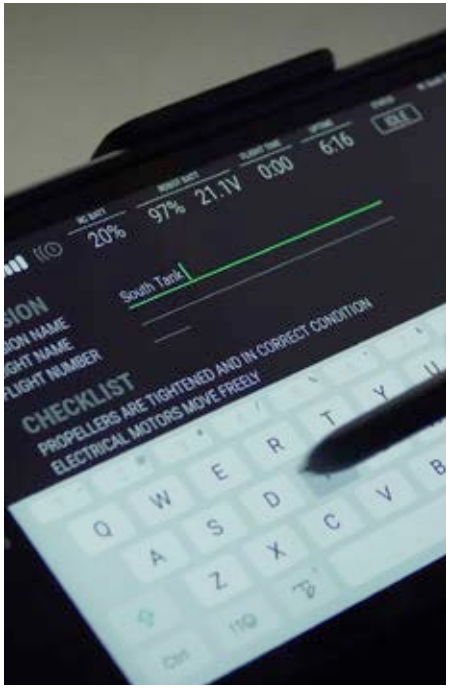


OBLIQUE LIGHTING

To reveal textures and identify defects, inspectors use a lighting technique that creates shadows in asperities. Reproducing this technique with our new oblique lighting systems, looking for pitting, cracks, or build-ups becomes as natural as doing it with a flashlight.

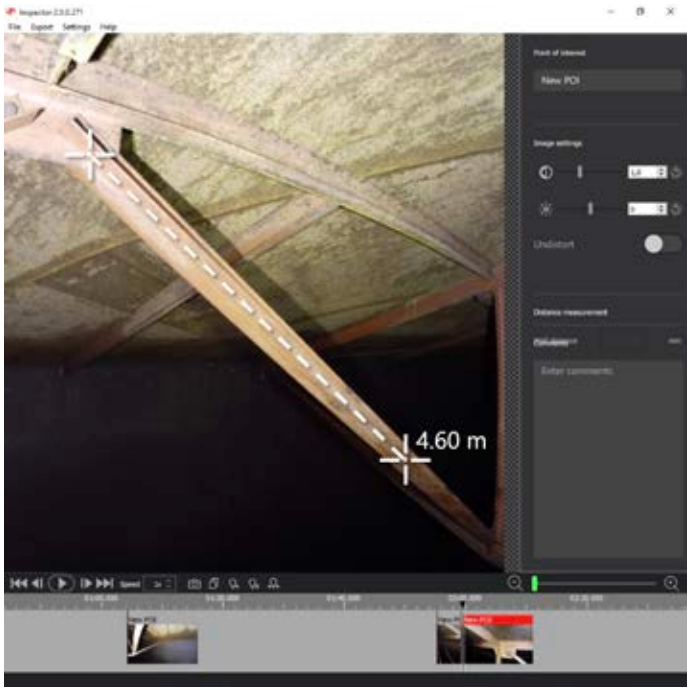


BUILD UPON ACTIONABLE DATA



FROM PLANNING TO REPORTING, WE'VE GOT YOU COVERED

Cockpit 2.0 has been designed to let you prepare your inspection reports on the fly. Once your mission is completed, simply connect Elios 2 to your computer using the USB port fitted on the drone to import all of your work into Inspector 2.0. From there, you will be able to further investigate captured data, document findings, and create reports.



3D MODELING

Change the way you deliver, visualize, and interpret data by building 3D models. Using third-party photogrammetry software such as Pix4D Mapper or Agisoft Photoscan, Elios 2 enables the creation of digital twins which reveals details of your assets.

SIZABLE INSIGHTS

Turn visual information into insights by adding figures to features. During data processing in Inspector, simply draw a line on the image and you will get a 2D measurement.

BUILT FOR YOUR SUCCESS

TRAINING INCLUDED

Because we want you to make the most out of your drone, one full day of training is offered with each purchase of a unit

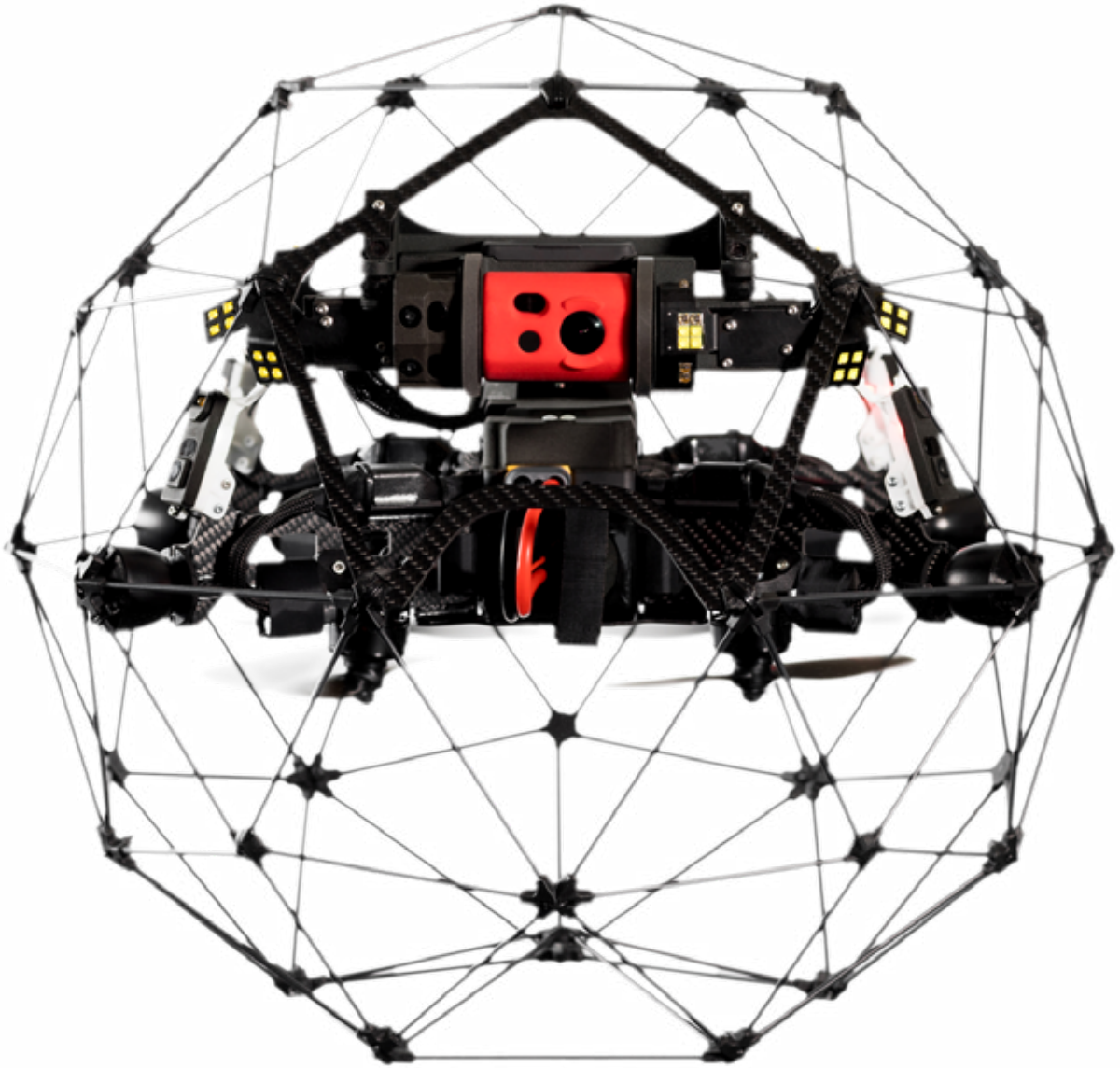
EASY MAINTENANCE

Elios 2 is engineered to be easily serviceable, minimizing the reasons to ever send your drone back to Flyability.

DEDICATED SUPPORT TEAM

For any assistance, in the field or at your office, our dedicated support team will travel the world for you.

TECHNICAL SPECIFICATION
AIRCRAFT



AIRCRAFT

CONFIGURATION	Quadcopter
DIMENSIONS	Fits in a < 400 mm sphere; 15.75 in
MOTORS	4 fast reversing electric brushless motors
PROPELLERS	4 propellers, 5 inches
TAKE-OFF WEIGHT	< 1450 g ; < 3,2 lbs Includes battery, payload & protection
MAX FLIGHT TIME	Up to 10 min
MAX ASCENT SPEED	1.5 m/s ; 5 ft/s
MAX DESCENT SPEED	1 m/s; 3,3 ft/s
MAX SPEED	1.3 m/s (Assist Mode) ; 4,25 ft/s 4 m/s (Attitude mode) ; 13.12 ft/s 6.5 m/s (Sport mode) ; 19.69 ft/s
MAX PITCH ANGLE	0.15 rad (Attitude mode) 0.2 rad (Assist Mode) 0.3 rad (Sport mode)
MAX WIND RESISTANCE	3 m/s (Assist Mode) ; 9,85 ft/s 5 m/s (Sport mode) ; 16,4 ft/s
FLIGHT CONTROL SENSORS	IMU, magnetometer, barometer, 7 vision and distance sensors
MATERIALS	Carbon fiber composites, magnesium alloy, aeronautical grade aluminum, high-quality thermoplastics
OPERATING TEMP.	0 °C to 50 °C* ; 32 °F to 122 °F
FLIGHT MODES	OPTI - Assist Mode ATTI - Attitude mode SPORT - Sport mode
FAIL SAFE	Auto-landing on signal lost
OPERATING FREQUENCY	2404 – 2483 MHz (UAV to RC)
EIRP	2.4 GHz: ≤ 32 dBm (FCC); ≤20 dBm (CE); ≤10 dBm/MHz (MIC)
INGRESS PROTECTION	Splash and dust resistant
NOISE LEVEL	99 dB(A) hover 120 dB(A) max @ 1m

*additional precaution have to be taken between 0-10°C and 40-50°C. Stability, flight performance and flight time might be reduced

SMART BATTERY

RATED CAPACITY	5200 mAh
NOMINAL VOLTAGE	19 V
BATTERY TYPE	LiPo 5S HV Smart Battery: - Improved safety (protection for: overcharge, overcurrent, over/ under-temperature) - Plug-and-play charging - Self-balancing - Storage self-discharge - State-of-Charge estimation - Cycle counter - Battery ID
ENERGY	98.8 Wh
CHARGING TIME	1.5 h
BATTERY CHANGE TIME	< 1 min
COMPLIANCE	Approved for carry-on luggage. Complies with IATA Dangerous Good Regulation.
NET WEIGHT	550 g ; 1,2 lbs
OPERATING TEMPERATURE	0-50°C *
CHARGING TEMPERATURE	10 - 45°C ; 50°F - 113°F
MAX CHARGING POWER	150 VA AC power
CHARGER	Elios 2's Smart Battery Charger

*additional precaution have to be taken between 0-10°C and 40-50°C. Stability, flight performance and flight time might be reduced.

PAYLOAD CHASSIS

PAYLOAD HEAD	Damped for vibrations
CAMERA POD UPWARD TILT	+90 degrees
CAMERA POD DOWNWARD TILT	-90 degrees
PAYLOAD PROTECTION	Load limiting mechanism to protect the payload in the case of a frontal shock.

MAIN CAMERA

SENSOR	1/2.3" CMOS Effective Pixels: 12.3 M Sensitivity: Optimized for low light performance
PHOTO FORMATS	JPG
VIDEO FORMATS	MOV
VIDEO RECORDING RESOLUTIONS	4k Ultra HD: 3840 x 2160 at 30 fps FHD: 1920 x 1080 at 30 fps
VIDEO STREAMING RESOLUTION	FHD: 1920 x 1080 at 30 fps
MOVIE FOV	114° horizontal, 130.8° diagonal
PHOTO FOV	118.8° horizontal, 148.6° diagonal
TOTAL VERTICAL FOV	approximately 260° including camera tilt

LENS	2.71 mm focal length Fixed focal
CONTROL MODES	Auto mode with manual EV compensation
FILE STORAGE	MicroSD card (onboard the aircraft) Max capacity: 128 GB Recommended model: Sandisk Extreme micro SDXC UHS-I V30
SUPPORTED FILE SYSTEM	FAT32 for cards up to 32 GB, exFAT for cards bigger than 32 GB

THERMAL CAMERA

SENSOR	Lepton 3.5 FLIR
VIDEO RECORDING RESOLUTION	160 x 120 at 9 fps
LENS	FOV 56° x 42°, Depth of field 15cm to infinity
SENSITIVITY (NEDT)	<50 mK
WAVELENGTH (LWIR)	8-14 µm

LIGHTING SYSTEM

TYPE	High-efficiency LEDs for even lighting in front, top and bottom, optimized for low impact of dust on picture quality. IR light used for stabilization system.
CONTROL	From remote controller, adaptive light beam controlled by camera pitch
MODES	Indirect/dustproof lighting Close up lighting Selective/oblique lighting
LIGHT OUTPUT	10k lumens

OPERATIONAL SAFETY & CRASHWORTHINESS

NAVIGATION LIGHTS	Green (starboard) and red (port) lights.
PROTECTION CAGE	Carbon fiber cage with soft coating, modular subcomponents for maintenance ease, thermoplastic elastomer suspensions, front opening dimensioned for easy battery access.
COLLISION TOLERANCE	Uniform all around the drone, up to 3 m/s on flat objects, up to 1.5 m/s on sharp objects

TECHNICAL SPECIFICATION
GROUND CONTROL STATION

REMOTE CONTROLLER

OPERATING FREQUENCIES	2404 - 2483 MHz (RC to UAV) 5738 - 5808 MHz (RC to RC) 920.6 - 928 MHz (RC to RC, Japan only)
MAX TRANSMISSION DISTANCE	Up to 500 m in direct line of sight
EIRP	2.4 Ghz ≤20 dBm, 5.8 GHz ≤13 dBm, 920 MHz ≤10 dBm
WEIGHT	810 g (924 g with tablet holder)
OPERATING TEMP.	0 °C to 40 °C
OUTPUT PORT	HDMI, SDI, USB
BATTERY	6000 mAh 2S
CONTROLS	Aircraft control and payload settings
OPTIONS	Optional remote controller (camera operator) with video stream reception on a secondary screen, and dual control of camera settings.
BATTERY CHARGER	17.4 V / 57 W

TABLET

MODEL	Samsung Galaxy Tab Active 2
BATTERY CHARGER	USB Charger 5V
OPERATING TEMP.	-15 °C to 40 °C
CHARGING TEMP.	-15 °C to 40 °C
CHARGING TIME	5 hours
WORKING TIME	5 hours (when receiving video stream) to 76 hours (idle)
WEIGHT	415 g

TECHNICAL SPECIFICATION
ACCESSORIES & SOFTWARE

TRANSPORT CASE

DIMENSIONS	61 x 44 x 53 cm
WEIGHT	11.5 kg
COMPLIANCE	IATA compliant for checked-in luggage.

COCKPIT SOFTWARE

FEATURES	Real time video and UAV telemetry, status visualization (remaining battery, payload settings, warnings, etc.), control payload settings and various configurations.
OPERATING SYSTEM	Android. Optimized for tablet provided with UAV system

INSPECTOR SOFTWARE

FEATURES	Video and thermal video viewer (frame by frame), flight log analysis including point of interests recorded during flight, screenshots and flight data export.
OPERATING SYSTEM	Windows 7, 8 and 10 (32 and 64 bits)

FLYABILITY

Flyability is a Swiss company building solutions for the inspection and exploration of indoor, inaccessible, and confined spaces. By allowing drones to be used safely inside buildings, it enables industrial companies and inspection professionals to reduce downtime, inspection costs, and risks to workers. With hundreds of customers in over 50 countries in Power Generation, Oil & Gas, Chemicals, Maritime, Infrastructures & Utilities, and Public Safety, Flyability has pioneered and continues to lead the innovation in the commercial indoor drone space.

Flyability SA

EPFL Innovation Park — Building C

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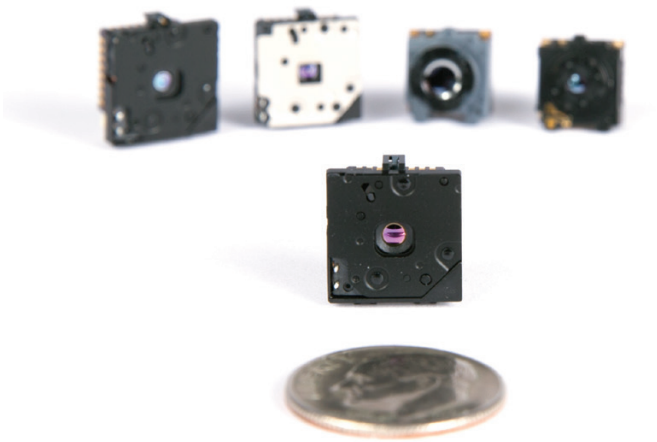
+41 21 311 55 00

sales@flyability.com

WWW.FLYABILITY.COM/**ELIOS-2**

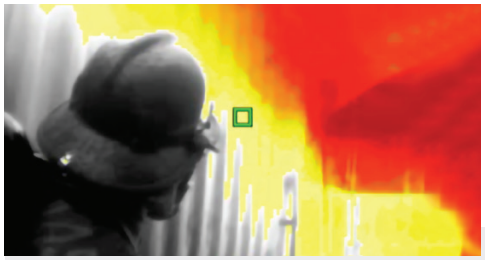


HIGH RESOLUTION MICRO THERMAL CAMERA

FLIR LEPTON® 3 & 3.5

FLIR's highest resolution LWIR micro thermal imaging module now includes LEPTON 3.5. LEPTON 3.5 offers the same 160x120, 12 micron, uncooled FPA found in the Lepton 3.0 but now provides calibrated radiometric output across the entire 19,200 pixel array. Lepton 3.5 also increases the scene dynamic range to +400 degrees C providing even greater flexibility for demanding applications. Incorporating the same form and fit as the other most popular Lepton products, the Lepton 3.5 allows for a fast and easy upgrade path with little effort. The revolutionary Lepton was the first complete longwave infrared sensor small enough to be used in smartphones and other mobile platforms. The new radiometric Lepton 3.5 offers users more advanced capability where temperature values and high temperature scenes are required. Smaller than a dime, low power consumption, unmatched image quality, and simple integration coupled with the lowest cost of any FPA based thermal sensor on the market today provides users the tool for innovative product development efforts.

www.flir.com/lepton



ENHANCED IR SENSOR

Greater resolution & sensitivity than common thermopile arrays

- 160 x 120 active pixels
- Thermal sensitivity <50 mK
- Low operating power – 140 mW typical, 650 mW during shutter event
- Low power standby mode

MICRO THERMAL IMAGER

Uncooled thermal imaging for small electronics

- 56° lens
- Integrated digital thermal image processing
- Integrated shutter
- Fast time to image (<0.5 seconds)

For Lepton 3.5

- Optional radiometry for temperature values of every pixel
- Increased scene dynamic range: +400° C (450° C typical)

EASE OF INTEGRATION

Simplifies development & manufacturing of thermal-enabled devices

- Small 11.8 x 12.7 x 7.2 mm package
- SPI video interfaces
- Uses standard cell phone-compatible power supplies
- Two-wire serial control interface
- 32-pin socket interface to connector

SPECIFICATIONS

Overview	Lepton 3	Lepton 3.5
Sensor technology	Uncooled VOx microbolometer	Uncooled VOx microbolometer
Spectral range	Longwave infrared, 8 µm to 14 µm	Longwave infrared, 8 µm to 14 µm
Array format	160 x 120, progressive scan	160 x 120, progressive scan
Pixel size	12 µm	12 µm
Effective frame rate	8.7 Hz (commercial application exportable)	8.7 Hz (commercial application exportable)
Thermal sensitivity	<50 mK (0.050° C)	<50 mK (0.050° C)
Temperature compensation	Automatic. Output image independent of camera temperature.	Automatic. Output image independent of camera temperature.
Radiometric Accuracy		High gain Mode: Greater of +/- 5° C or 5% (typical) Low Gain Mode: Greater of +/- 10° C or 10% (typical)
Non-uniformity corrections	Integral Shutter	Integral Shutter
Scene dynamic range	0° to 120° C	High Gain Mode: -10° to +140° C Low Gain Mode: -10° to +400° C (at room temperature) -10° to +450° C (typical)
Image optimization	Factory configured and fully automated	Factory configured and fully automated
FOV - horizontal	57°	57°
FOV - diagonal	71°	71°
Lens Type	f/1.1	f/1.1
Output format	User-selectable 14-bit, 8-bit (AGC applied), or 24-bit RGB (AGC and colorization applied)	User-selectable 14-bit, 8-bit (AGC applied), or 24-bit RGB (AGC and colorization applied)
Solar protection	Integral	Integral
Electrical		
Input clock	25-MHz nominal, CMOS IO Voltage Levels	25-MHz nominal, CMOS IO Voltage Levels
Video data interface	Video over SPI	Video over SPI
Control port	CCI (I2C-like), CMOS IO Voltage Levels	CCI (I2C-like), CMOS IO Voltage Levels
Input supply voltage (nominal)	2.8 V, 1.2 V, 2.5 V to 3.1 V IO	2.8 V, 1.2 V, 2.5 V to 3.1 V IO
Power dissipation (Typical, room temp)	Nominally 150 mW (operating), 650 mW (during shutter event), 5 mW (standby)	Nominally 150 mW (operating), 650 mW (during shutter event), 5 mW (standby)
Mechanical		
Package dimensions – socket version (w x l x h)	10.50 x 12.70 x 7.14	10.50 x 12.70 x 7.14
Weight	0.9 grams	0.9 grams
Environmental		
Optimum operating temperature range	-10°C to +65°C	-10°C to +80°C
Non-operating temperature range	-40 °C to +80 °C	-40 °C to +80 °C
Shock	1500 G @ 0.4 ms	1500 G @ 0.4 ms
Ordering		
Part Numbers	500-0726-01	500-0771-01

Specifications are subject to change without notice. For the most up-to-date specs, go to www.flir.com

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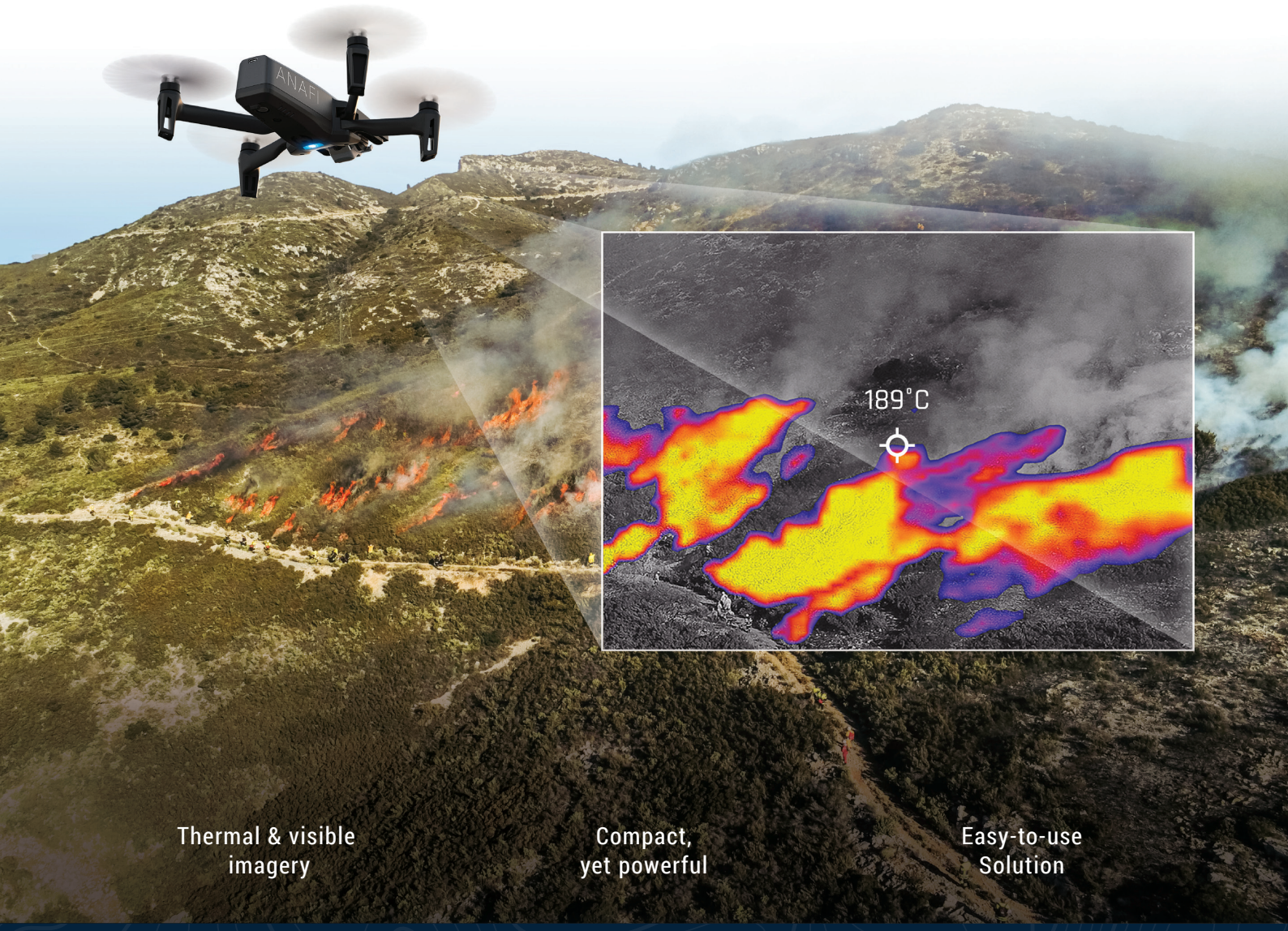
FLIR® | The World's Sixth Sense®

ANAFI™
THERMAL

The ultra-compact, fully-integrated thermal drone

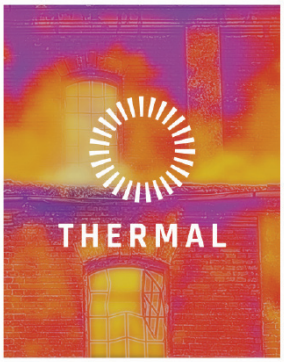


Thermal & visible imagery

Compact, yet powerful

Easy-to-use Solution

Parrot®



THERMAL & VISIBLE IMAGERY

TWO INTEGRATED SENSORS WORKING IN FULL SYNCHRONIZATION

• FLIR radiometric thermal sensor[1]: 160x120 resolution, 57° HFOV, -10°C to +400°C temperature range

• Sony Sensor[2] for visible images (RGB): 1/2.4" 21MP CMOS, 4K HDR video recording capabilities

• Blended thermal & RGB images in thermal view (temporal synchronisation of thermal & RGB images)

• Record videos and capture pictures in thermal or visible formats
(video quality: 1440x1080p in thermal view / 4K HDR in visible view)

• 3-axis hybrid stabilisation (2-axis mechanical combined with 3-axis digital stabilisation)

• +/-90° = 180° camera tilt (Zenith to Nadir views)

• Zoom function (3x digital zoom in thermal view)

COMPACT & POWERFUL

OPTIMIZED PERFORMANCES IN AN ULTRA-PORTABLE SOLUTION

• All-in-one: everything you need in one solution

• Easy-to-carry solution in its compact shoulder bag which fits smartphones or tablets

• Fast and easy to unfold drone for ultra quick set-up
(less than 3 seconds)

• Ultra-compact, lightweight yet robust carbon-reinforced drone design

• Up to 26 minutes flight time per Smart Battery (3 smart batteries included)

• USB-C on-the-go charging system (compatible with Powerbanks)

• Multi-port USB charger to charge all 3 batteries together in 3h30

• Perfect stability against winds of up to 50 km/h

• Super quiet flights

Made for iPhone

FreeFlight 6

GET IT ON Google Play

Download on the App Store

EASY-TO-USE

USER-FRIENDLY INTERFACE TO CAPTURE AND ANALYZE THERMAL AND RGB DATA

- Intuitive manual flight with FreeFlight 6 mobile app
- Easy dual-use of thermal & visible views in one app, on one screen
- Automatic scouting with FlightPlan[3]: autonomous flight made easier (to capture either thermal or RGB images)
- Compatible with Pix4Dcapture for optimal automatic RGB data acquisition
- Smart RTH and Geofence for safer flights
- Direct in-app analysis of thermal images (videos & pictures) using FreeFlight 6:
  - In-app customized color palettes
  - Temperature of each point
  - Min and max temperature of each scene

1. FLIR is a registered trademark of FLIR® Systems, Inc

2. Sony is a registered trademark of Sony Corporation

3. FlightPlan is available at no additional cost within the FreeFlight 6.5 version when using an ANAFI Thermal

TECHNICAL SPECIFICATIONS

Drone
- Size folded: 218x69x64mm
- Size unfolded (propellers unfolded): 242x315x64mm
- Weight: 315g
- Max transmission range: 4km with Parrot SkyController 3
- Max flight time: 26min
- Max speed: 55km/h
- Max vertical speed: 4m/s
- Max wind resistance: 50km/h
- Service ceiling: 4.500m above sea level
- Operating temperature: -10°C to 40°C

Sensors:
- GNSS: GPS + GLONASS
- Barometer and magnetometer
- Vertical camera and ultra-sound sensor
- 2x6-axis IMU
- 2x3-axis accelerometers
- 2x3-axis gyroscopes

Controller
- Size folded: 94x152x72mm
- Size unfolded: 153x152x116mm
- Weight: 386g
- Transmission system: Wi-Fi 802.11a/b/g/n
- Operating frequencies: 2.4GHz – 5.8GHz
- Max transmission range: 4km
- Live streaming resolution: 720p (HD) 1280x720
- Battery capacity: 2,500mAh 3.6V
- Supported mobile devices:
  - Without tablet holder: screen size up to 6.2"
  - With tablet holder: screen size up to 10"
- USB ports: USB-C (charge), USB-A (connection)

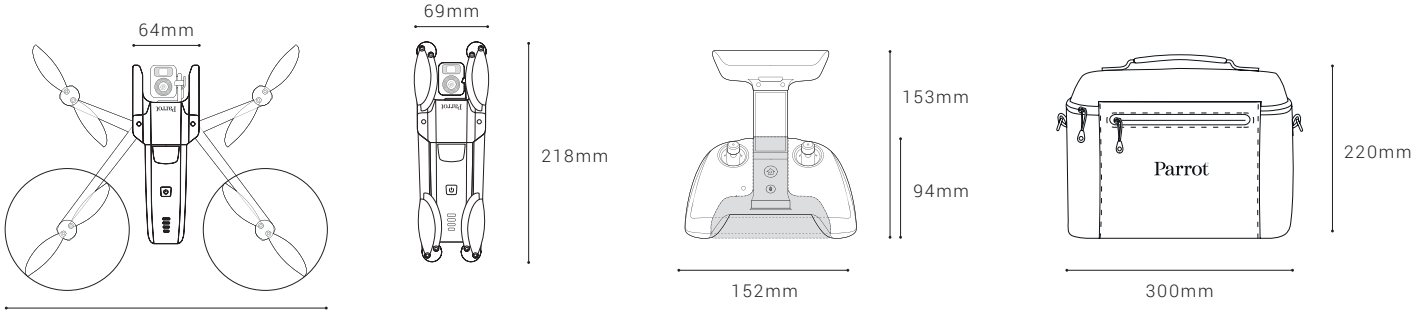
RGB camera
- Sensor: CMOS 1/2.4", 21MP
- LD-ASPH lens:
  - Aperture: f/2.4
  - Focal length: 26mm (equivalent 35mm)
- Depth of field: 1.5m to infinity
- Video format: MP4 (H264)
- Video resolution:
  - 4K Cinema (4096x2160 24fps)
  - 4K UHD (3840x2160 24/25/30fps)
  - FHD (1920x1080 24/25/30/48/50/60fps)
  - HD (1280x720 96/100/120fps)
- Video HFOV: 69°
- HDR: 4K UHD, 2.7K and 1080p videos, JPEG photos
- Digital zoom:
  - Lossless: up to x2.8 (FHD), up to x1.9 (2.7K), up to x1.4 (4K UHD)
  - Standard: up to 3x (all resolutions)
- Photo formats: JPEG, DNG (RAW)
- Photo modes: single, burst, bracketing, timer and panorama
- Photo resolution:
  - Wide: 21MP (5344x4016) / 4:3 / 84° HFOV
  - Rectilinear: 12MP (4000x3000) / 4:3 / 75.5° HFOV
- Shutter speed: 1 to 1/10000s
- ISO: 100 to 3200
- EV compensation: [-3, +3]
- Max video bitrate: 100Mbps

Image stabilization
- 3-axis hybrid stabilization:
  - Mechanical: 2-axis (roll & pitch)
  - Electronic (EIS): 3-axis (roll, pitch & yaw)
  - Controllable tilt range: -90° to +90° (nadir to zenith)

Thermal camera
- Sensor: microbolometer FLIR LEPTON 3.5 (radiometric)
- Resolution: 160x120
- HFOV: 57°
- Pixel pitch: 12µm
- Spectral band: 8-14µm
- Photo format: JPEG
- Photo resolution: 3264x2448 (4/3)
- Photo modes: Single / Timelapse / GPS Lapse
- Video format: MP4 (H264)
- Video recording resolution: 1440x1080, 9fps
- Precision: ±5% max.(High-gain) or ±10% max.(Low-gain)
- Scene Dynamic Range: -10° à +140°C (High-gain) or -10° à +400°C (Low-gain)
- Video: MP4

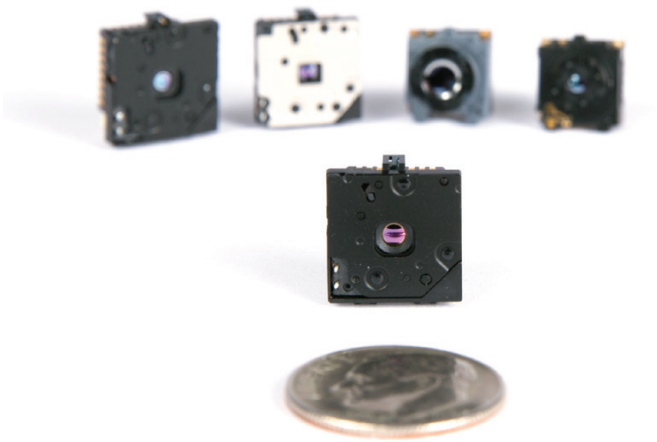
Smart battery
- Type: LiPo 2S
- Capacity: 2700mAh
- Voltage: 7.6V
- Weight: 124 g
- Temperature range: -20°C / 60°C
- Charging time: 1h15
- Max charging power: 26.1W (3A * 8.7V)

Charger
- Power: 52 W
- Input AC: 100–240 V, 50–60 Hz, 1,5A (Max)
- Output:
  - 4x USB: DC 5V/6.8A (each 2.4A Max)
  - USB quick charge 3.0: DC 3.6V-6.5V/3A, 6.5V-9V/2A, 9V-12V/1.5A
- Energy efficiency: Level VI
- Dimensions: 95x28.8x61mm
- Weight: 200g
- AC Power Cords: US, EU, UK



PACK CONTENT

1 ANAFI Thermal drone, 1 Parrot SkyController 3, 1 shoulder bag, 3 smart batteries, 1 multi-port USB charger, 1 tablet holder, 8 additional propeller blades & mounting tool, 16GB microSD card, 4 USB-A/USB-C cables



HIGH RESOLUTION MICRO THERMAL CAMERA

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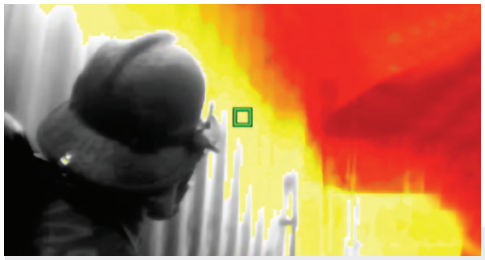

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Greater resolution & sensitivity than common thermopile arrays

- 160 x 120 active pixels
- Thermal sensitivity <50 mK
- Low operating power – 140 mW typical, 650 mW during shutter event
- Low power standby mode

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For Lepton 3.5

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- Uses standard cell phone-compatible power supplies
- Two-wire serial control interface
- 32-pin socket interface to connector

SPECIFICATIONS

Overview	Lepton 3	Lepton 3.5
Sensor technology	Uncooled VOx microbolometer	Uncooled VOx microbolometer
Spectral range	Longwave infrared, 8 µm to 14 µm	Longwave infrared, 8 µm to 14 µm
Array format	160 x 120, progressive scan	160 x 120, progressive scan
Pixel size	12 µm	12 µm
Effective frame rate	8.7 Hz (commercial application exportable)	8.7 Hz (commercial application exportable)
Thermal sensitivity	<50 mK (0.050° C)	<50 mK (0.050° C)
Temperature compensation	Automatic. Output image independent of camera temperature.	Automatic. Output image independent of camera temperature.
Radiometric Accuracy		High gain Mode: Greater of +/- 5° C or 5% (typical) Low Gain Mode: Greater of +/- 10° C or 10% (typical)
Non-uniformity corrections	Integral Shutter	Integral Shutter
Scene dynamic range	0° to 120° C	High Gain Mode: -10° to +140° C Low Gain Mode: -10° to +400° C (at room temperature) -10° to +450° C (typical)
Image optimization	Factory configured and fully automated	Factory configured and fully automated
FOV - horizontal	57°	57°
FOV - diagonal	71°	71°
Lens Type	f/1.1	f/1.1
Output format	User-selectable 14-bit, 8-bit (AGC applied), or 24-bit RGB (AGC and colorization applied)	User-selectable 14-bit, 8-bit (AGC applied), or 24-bit RGB (AGC and colorization applied)
Solar protection	Integral	Integral
Electrical		
Input clock	25-MHz nominal, CMOS IO Voltage Levels	25-MHz nominal, CMOS IO Voltage Levels
Video data interface	Video over SPI	Video over SPI
Control port	CCI (I2C-like), CMOS IO Voltage Levels	CCI (I2C-like), CMOS IO Voltage Levels
Input supply voltage (nominal)	2.8 V, 1.2 V, 2.5 V to 3.1 V IO	2.8 V, 1.2 V, 2.5 V to 3.1 V IO
Power dissipation (Typical, room temp)	Nominally 150 mW (operating), 650 mW (during shutter event), 5 mW (standby)	Nominally 150 mW (operating), 650 mW (during shutter event), 5 mW (standby)
Mechanical		
Package dimensions – socket version (w x l x h)	10.50 x 12.70 x 7.14	10.50 x 12.70 x 7.14
Weight	0.9 grams	0.9 grams
Environmental		
Optimum operating temperature range	-10°C to +65°C	-10°C to +80°C
Non-operating temperature range	-40 °C to +80 °C	-40 °C to +80 °C
Shock	1500 G @ 0.4 ms	1500 G @ 0.4 ms
Ordering		
Part Numbers	500-0726-01	500-0771-01

Specifications are subject to change without notice. For the most up-to-date specs, go to www.flir.com

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FLIR® The World's Sixth Sense®

ANAFI USA

A DRONE DESIGNED FOR FIRST RESPONDERS AND ENTERPRISE PROFESSIONALS

PARROT'S NEXT-GENERATION DRONE OFFERS 32X ZOOM, THERMAL IMAGING, A RUGGEDIZED AIRFRAME, AND ADVANCED DATA SECURITY

Parrot

32X ZOOM AND ADVANCED IMAGING SYSTEM

POWERFUL TRIPLE CAMERA WITH UP TO 32x CONTINUOUS ZOOM

- Records visible and thermal photos and videos (video quality: 1280x720p in thermal spectrum / up to 4K HDR in visible spectrum)
- Hybrid 3-axis stabilization (2-axis mechanical stabilization and 3-axis digital stabilization)
- A CMOS 1/2.4'' sensor and EO (electro-optical) tele-camera for a 32x stabilized zoom and stealth observation capabilities
- A CMOS 1/2.4'' sensor and EO wide camera for visible spectrum short-range reconnaissance
- A FLIR Boson® 320 longwave infrared (LWIR) thermal camera: 320x256 resolution, 50° HFOV, temperature range -10 °C to +150 °C
- Gimbal tilt range from -140° (beyond nadir) to +110° (over zenith)
- Replay, edit and analyze thermal media from the drone on the device, without downloading

EASY TO OPERATE

FLIGHT-READY IN LESS THAN 55 SECONDS, NO BUILT-IN LIMITATIONS FOR NFZ, WEIGHS ONLY 1.1 LB (500 G)

- The drone unfolds, powers on and connects securely to its controller in less than 55 seconds
- No GPS synchronization required to take off: flies perfectly indoor and in obstructed areas
- Hand launch and hand landing features for difficult terrains
- No built-in limitation for NFZ (no-fly zone)
- Quietest drone in its class: sound level of just 79 dB when it is at 50 cm off the ground
- Standard USB-C charging
- Weighs 1.1 lb (500 g)
- Flight time of 32 minutes – best in class for a drone of its size

RUGGEDIZED

IP53 QUALIFIED FOR WATER AND DUST RESISTANCE

- IP53 (5 against solids: dust protected / 3 against liquids: sprayed water and rain protected)
- Stabilized imaging ensures high-quality footage even at 15 m/s wind conditions

TRUSTED AND SECURE

MADE IN USA, ENCRYPTION READY

- Same high-end security, durability and imaging capabilities as Parrot's Short-Range Reconnaissance (SRR) drone designed for the U.S. Army
- Manufactured in Massachusetts, USA
- SD card encryption with AES-XTS algorithm and 512-bit key length. Complete protection of photos and videos if the drone is lost
- Secure WPA2 Wi-Fi connection to authenticate and encrypt the link between the remote controller and ANAFI USA
- Signed firmware prevents any malicious modification of the drone's software
- Use of trusted standards and open protocols such as Wi-Fi, WPA2, RTP/RTSP, H.264, and GUTMA
- GDPR compliant - no data is shared by default without the consent of the user
- With the user's consent, flight data is stored in secure European servers - local copies on the drone

NEW FLIGHT FEATURES

ADVANCED FLIGHT FEATURES DESIGNED TO MEET THE UNIQUE NEEDS OF PROFESSIONALS

- Powered by a new version of FreeFlight 6, ANAFI's acclaimed piloting software
- Fly by coordinates in assisted framing or full autonomous flights: define points of interest (POI), waypoints (WP) and landing points with their satellite navigation coordinates (GPS, GLONASS, GALILEO)
- Create a flight plan with pre-set automatic flights and target-tracking
- Editable "Return to Home" (RTH) feature

SOFTWARE ECOSYSTEM

COMPATIBLE WITH INDUSTRY-LEADING SOLUTION PROVIDERS, AVAILABLE SDK FOR AN EVER-GROWING ECOSYSTEM

- Open source SDK (Software Development Kit) for application developers
- Compatible with the industry-leading mapping software Pix4Dreact (2D mapping)
- Natively compatible with Survae (intelligent video, image, and data platform), DroneLogbook (operation and fleet management), Kittyhawk (security and compliance for enterprise UAS operations), Dronesense (the all-in-one platform for public safety operations), Planck AeroSystems (landing on moving vehicle) and Skyward, A Verizon company (aviation management platform)

TECHNICAL SPECIFICATIONS

ANAFI USA

- Weight: 500 g / 1 lb
- Maximum transmission range: 2.5 miles (4km) with the Parrot Skycontroller 3
- Maximum flight time: 32 minutes
- Maximum horizontal speed: 14,7 m/s (52.92 km/h or 32.88 mph)
- Maximum vertical speed: 4 m/s (14.40 km/h or 8.95 mph)
- Maximum wind resistance: 14,7 m/s (52.92 km/h or 32.88 mph)
- Service ceiling: 6.000 m above MSL (Mean Sea Level)
- Optional altitude fencing & geofencing
- Operating temperature: -32F (-35°C) to 110F (43°C)
- No take-off temperature limitation
- Manage your data privately between drone and device OR share anonymous data on secured European servers

DIMENSIONS:

- Size folded: 252 x 104 x 82 mm (9.92 x 4.09 x 3.23")
- Size unfolded: 282 x 373 x 84 mm (11.10 x 14.69 x 3.30")

SENSORS:

- Satellite navigation: GPS, GLONASS & GALILEO
- Barometer and magnetometer
- Vertical camera and ultra-sonar
- 2 x 6-axis IMU
- 2 x 3-axis accelerometers
- 2 x 3-axis gyroscopes

EO IMAGE CHAIN

- 2 Sensors: 1/2.4
- Digital Zoom: x32
- Electronic shutter speed: 1s to 1/10000s
- ISO Range: 100-3200
- Video resolution: 4K/FHD/HD
- Video Format: MP4 (H264)
- Photo Resolution: Wide: 21MP (84° FOV); Rectilinear: up to 16MP (up to 75.5° FOV)
- Photo Formats: JPEG, DNG (Digital NeGative RAW)

IR IMAGE CHAIN

Sensor: FLIR BOSON

- 320x256 resolution
- -40°C to +150°C temperature range
- Thermal Sensitivity: <60mK
- Photo Format: JPEG
- Video Format: MP4 (H264)
- Video Recording Resolution: 1280x720, 9fps

IMAGE STABILIZATION

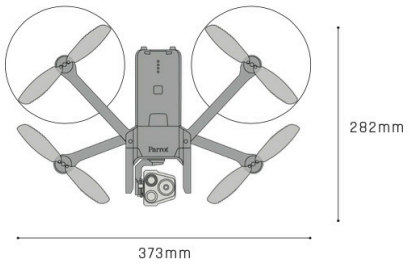
- 3-camera IR/EO stabilized gimbal:
  - Hybrid: 3-axis
  - Mechanical: 2-axis roll / pitch
  - Electronics (EIS): 3-axis yaw / roll / pitch
- Controllable gimbal tilt range: -140° to +110°

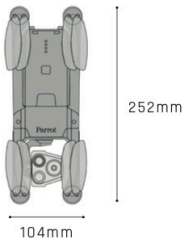
FAST-CHARGING SMART BATTERY

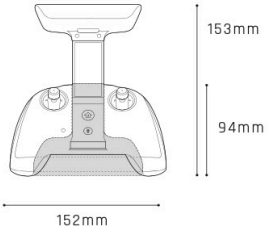
- Type: High density LiPo (3 x 4.4V cells)
- Capacity: 3400 mAh
- Battery life: 32 minutes
- Charing port: USB-C
- Charges in 2h with an USB-PD (Power Delivery) charger – not included in the pack
- Charges in 3h20 with the fast-charging port of the provided charger
- Weight: 195 g / 0.43 lb
- Voltage: 11,55 V
- Max charging power: 30 W

PARROT SKYCONTROLLER 3

- Folded size: 94 x 152 x 72 mm
- Unfolded size: 153 x 152 x 116 mm
- Weight: 283 g / 0.62 lb
- Transmission system: Wi-Fi 802.11a/b/g/n
- Operating frequency: 2.4 - 5.8 GHz
- Max. transmission distance: 4 km / 2.48 mi
- Resolution of live video feed: HD 720p
- Battery capacity: 2500mAh 3.6V
- Battery life: 2h30 (Android) / 5h30 (iOS)
- Compatible mobile devices: Screen size up to 6.5"
- USB ports: USB-C (Charge), USB-A (Connection)







PACK CONTENT

1 ANAFI USA drone, 3 (1+2) smart batteries,
1 Skycontroller 3, 1 tablet holder, 1 multi-port fast USB charger,
1 additional set of propeller blades, 4 USB-A/USB-C cables, 1 hard case

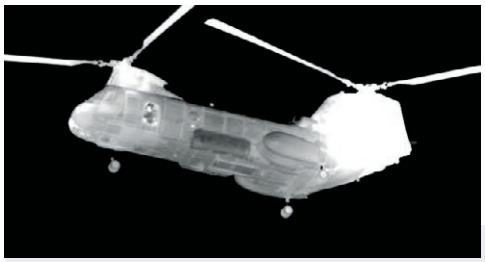
COMPACT LWIR THERMAL CAMERA

FLIR Boson®

The Boson® longwave infrared (LWIR) thermal camera module sets a new standard for size, weight, power, and performance (SWaP). It utilizes FLIR infrared video processing architecture to enable advanced image processing and several industry-standard communication interfaces while keeping power consumption low. The 12 µm pitch Vanadium Oxide (VOx) uncooled detector comes in two resolutions – 640 x 512 or 320 x 256. It is available with multiple lens configurations, adding flexibility to integration programs.

With a weight as low as 7.5 g and a camera body as small as 21 x 21 x 11 mm, the Boson represents an industry-leading reduction in SWaP with no reduction in performance. Advanced embedded processing and video analytics, as well as software-customizable functionality, give this small camera big capabilities, including integration with auxiliary sensors such as third-party cameras, GPS, and IMU.

www.flir.com/boson



DRAMATIC REDUCTION IN SIZE, WEIGHT AND POWER (SWaP) WITH NO REDUCTION IN PERFORMANCE

A full-featured VGA thermal camera module at less than 4.9 cm^3.

- 21 x 21 x 11 mm camera body and weight as low as 7.5 g
- Low power consumption, starting at 500 mW
- 12 µm pixel pitch VOx microbolometer with 320 and 640 resolutions
- Rugged construction and highest temperature rating -40°C to 80°C

POWERFUL INFRARED VIDEO PROCESSING ARCHITECTURE

FLIR infrared video processing with embedded industry-standard interfaces empowers advanced processing and analytics.

- Includes embedded algorithms for noise filters, gain control, blending, and more
- Software-customizable functionality for video processing and power dissipation requirements
- Built-in support for physical and protocol-level interface standards

WIDE CONFIGURABILITY FOR FASTER DEVELOPMENT AND LOWER COST-TO-MARKET

Unprecedented integration flexibility for fast, affordable developments.

- Customized applications through FLIR-trusted third party developers
- Mechanical/electrical compatibility across all versions
- Variety of hardware and image processing integration to fit OEM requirements

SPECIFICATIONS

Thermal Imager	FLIR Boson	
Sensor Technology	Uncooled VOx Microbolometer	
Array Format	320 × 256 or 640 × 512	
Pixel Pitch	12 µm	
Spectral Range	Longwave infrared: 7.5 µm – 14 µm	
Thermal Sensitivity	<40 mK (Industrial); <50 mK (Professional); <60 mK (Consumer)	
Full Frame Rate, Slow Frame Rate	60 Hz baseline; 30 Hz runtime selectable, ≤9 Hz available	
Non-uniformity Correction (NUC)	Factory calibrated; updated FFCs with FLIR Silent Shutterless NUC (SSN™)	
Solar Protection	Integral	
Continuous Electronic Zoom	2X zoom	
Symbol Overlay	Re-writable each frame; alpha blending for translucent overlay	
Optics		
Array Format	320 × 256	640 × 512
Horizontal Field of View (HFOV); Effective Focal Length	92°; 2.3 mm	95°; 4.9 mm
	50°; 4.3 mm	50°; 8.7 mm
	34°; 6.3 mm	32°; 14 mm
	24°; 9.1 mm	24°; 18 mm
	16°; 14 mm	18°; 24 mm
	12°; 18 mm	12°; 36 mm
	6°; 36 mm	8.0°; 55 mm
	4°; 55 mm	6°; 73 mm
Physical Attributes		
Size	21 × 21 × 11 mm (0.83 x 0.83 x 0.43 in) without lens or 640-model shutter	
Weight	7.5 g (0.26 oz) without lens or 640-model shutter	
Precision Mounting Holes	Four tapped M160.35 (rear cover) Lens support recommended when lens mass exceeds 7.5 g	
Interfacing		
Input Voltage	3.3 VDC	
Power Dissipation (Peak)	Varies by configuration; as low as 500 mW	
Video Channels	CMOS or USB-2	
Control Channels	UART or USB	
Configurable GPIO	Up to 11; user configurable	
Environmental		
Operating Temperature Range	-40°C to 80°C (-40°F to 176°F)	
Non-Operating Temperature Range	-50°C to 105°C (-58°F to 221°F)	
Shock	1,500 g @ 0.4 msec	
Operational Altitude	12,192 m (40,000 ft)	

Specifications are subject to change without notice.
For the most up-to-date specs, go to www.flir.com/boson

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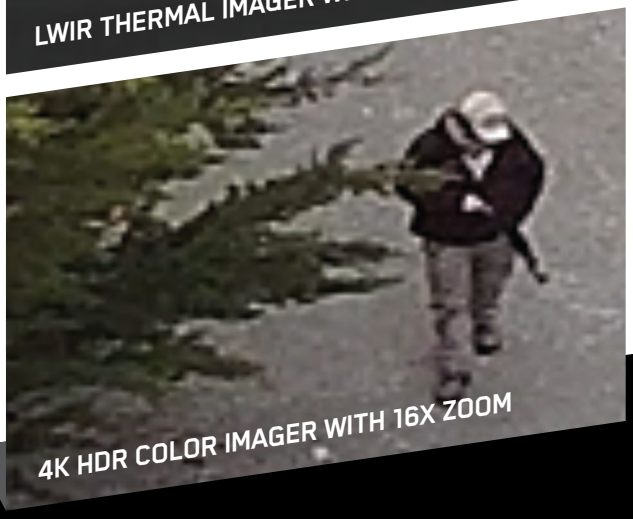
Skydio

Skydio X2D

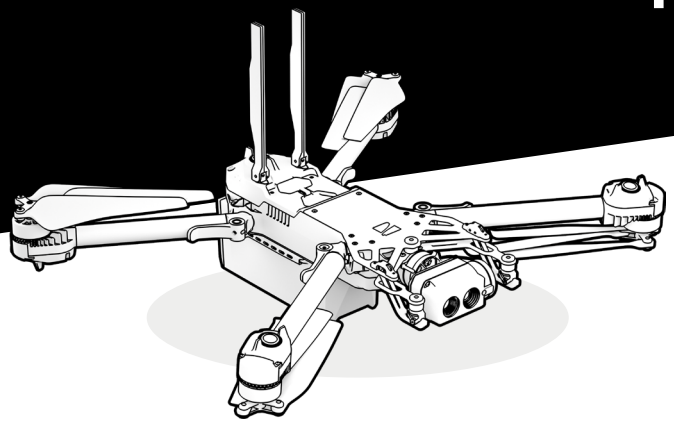


Skydio X2D uses unmatched AI to turn every operator into an expert pilot

Skydio X2D is the ultimate reconnaissance tool. X2D pairs breakthrough autonomy software with a ruggedized airframe with folding arms for easy "pack and go" transportation, a thermal camera, and expected up to 35 minutes of flight time. X2D is equipped with six 4k navigation cameras for 360 degree obstacle avoidance and a dual sensor payload that includes 12MP color and 320x256 LWIR sensors. Built to exceed the Short-Range Reconnaissance (SRR) requirements for the U.S. Army, X2D helps military operators and federal agencies perform reconnaissance, search and rescue, and security patrol missions. Designed, assembled, and supported in the USA, X2D turns anyone into an expert pilot.

RANGE	OBSTACLE AVOIDANCE	FLIGHT TIME
expected up to 10 km	360° 45 megapixel	expected up to 35 min

X2D & Controller Specs



AIRCRAFT

DIMENSIONS (UNFOLDED, FLYING)	26.1" X 22.4" X 8.3"
DIMENSIONS (FOLDED, NO BATTERY)	11.9" X 5.5" X 3.6"
WEIGHT	1325 g
COLOR CAMERA	4K60P HDR Camera with 16x zoom
THERMAL CAMERA	320p LWIR Thermal Imager with 8x zoom

SKYDIO AUTONOMY

MAIN PROCESSOR	NVIDIA Tegra X2 SOC
GPU	256-core NVIDIA Pascal™ GPU
CPU	Dual-Core NVIDIA Denver 2 64-bit CPU Quad-Core ARM®-A57 MPCore
RAM	4 GB 128-bit LPDDR4
OBSTACLE AVOIDANCE COVERAGE	Omnidirectional and above/below Super fisheye lenses for 360° view
3D WORLD MODEL UPDATE RATE	> 1 million points per second
WORLD MODEL-TO-ACTION UPDATE RATE	500 iterations per second
ONBOARD AI	9 custom deep networks used in flight
USER-SELECTABLE SUBJECTS FOR TRACKING	People and motor vehicles
OBJECT TRACKING AND IDENTIFICATION	Up to 10 simultaneous objects of interest
CALIBRATION	Automated online calibration of lens parameters, camera rotations, wind speed, and air density

HANDSET

DIMENSIONS	10.75" x 5.25 x 3.0"
WEIGHT	1130 g
INPUT	Dual 2-axis joysticks, dual rockers & 10 buttons
SENSORS	GPS, Barometer, Compass, Gyro, ACC
MEMORY	256 GB disk, 12 GB RAM
PROCESSOR	Qualcomm Snapdragon 855

CONTROLLER SOFTWARE

OPERATING SYSTEM	Android 9
APPLICATIONS	Skydio, QGroundControl
WIRELESS LINKS	4G LTE, Wifi, Bluetooth
WIRED LINKS	USB 3.1, (via dongle) HDMI, SD, Ethernet
OPERATING FREQUENCIES	1.8 / 5 GHz
MAX RANGE	Expected up to 10 km / expected up to 6 km
CHANNEL BANDWIDTH	1/2/4/5/8/10/20 MHz
VIDEO	Up to 1080p60, 20 Mbps
ENCRYPTION	AES-256 for 1.8GHz, AES-128 for 5GHz

SYSTEM SECURITY

SD CARD ENCRYPTION	AES-CBC algorithm using unique file encryption keys (FEKs) encrypted using Open SSL (2048-bit key RSA). Decryption keys never stored on vehicle.
WIRELESS CONNECTION	AES-256 for 1.8GHz, AES-128 for 5GHz
FIRMWARE	Signed and Encrypted
MEDIA ENCRYPTION	Encrypted SD Cards with physical Yubikey
CONTROLS	Ability to provision and deprovision devices
INFRASTRUCTURE	Key provisioning burned-in at time of manufacture

Contact enterprise@skydio.com today to learn more about integrating Skydio X2.

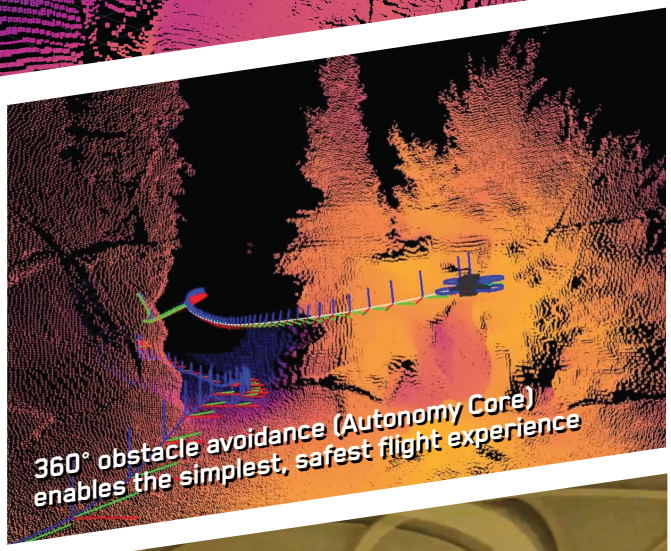
Designed and assembled in the USA

Skydio

Skydio Autonomy

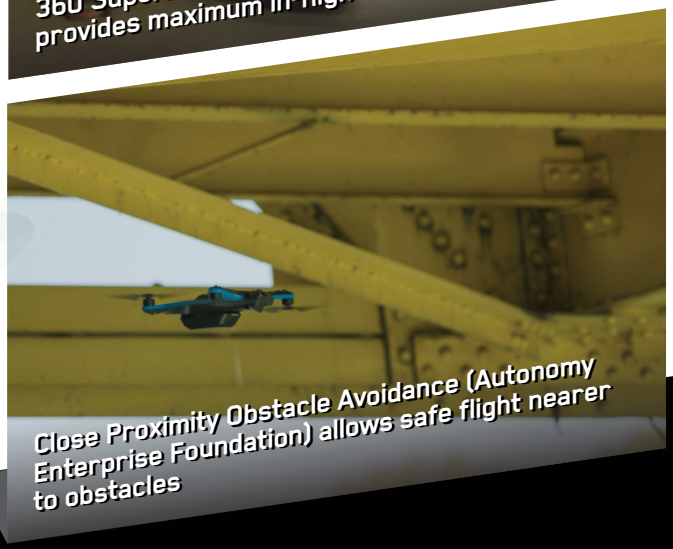
A new generation of drone intelligence

Anyone who has flown a Skydio will tell you the flight experience is unlike any other drone, and the reason is Skydio Autonomy™. The result of a decade of R&D at the cutting edge of artificial intelligence, computer vision, and robotics, Skydio Autonomy flies with the skills of an expert pilot. Using breakthrough AI, it creates a 3D model of its surroundings that updates at a rate of over one million data points per second, and runs up to nine deep neural networks onboard the drone to predict into the future to make intelligent decisions. Skydio drones fly autonomously through the most demanding environments, and keep you safe from obstacles when you take control.



360° obstacle avoidance (Autonomy Core) enables the simplest, safest flight experience

360 Superzoom (Autonomy Enterprise Foundation) provides maximum in-flight awareness



Close Proximity Obstacle Avoidance (Autonomy Enterprise Foundation) allows safe flight nearer to obstacles

Skydio Autonomy is true AI for drones

Skydio hardware is designed from the ground up to support the autonomy stack. Our aircraft carry the Nvidia TX2, one of the fastest embedded AI computing device available, and six fisheye 4K navigation cameras that see everything around the drone. But the real difference is in the software. While GPS and magnetometers enabled the previous generation of manual drones, the next era belongs to software-driven technology powered by breakthrough artificial intelligence that can make drones work for their pilots, instead of the other way around.

Contact enterprise@skydio.com today to learn more about integrating Skydio Autonomy.

Designed and assembled in the USA

The Evolution of Drones

Manual drones have peaked. The future belongs to software-driven aircraft.

AGE OF TOYS

- Pilot operated
- RC-based

AGE OF MANUAL HARDWARE

- Pilot operated
- GPS-based
- Sensor payloads

AGE OF AI-DRIVEN AUTONOMY

- Software, AI-driven navigation
- Native obstacle avoidance
- Fully automated workflows
- Integrated solutions

Autonomy Features

SKYDIO AUTONOMY CORE

Out-of-the-box, every Skydio drone is equipped with Autonomy Core, enabling a revolutionary flight experience, even in GPS-denied environments. Autonomy Core turns anyone into an expert pilot.

REAL-TIME 3D MAPPING	Drone uses six paired navigational cameras to achieve depth perception and to maintain a 3D map of its surroundings in real-time.
OBJECT AND SCENE RECOGNITION	Deep learning algorithms enable the drone to recognize objects and predict how they will persist in the environment.
MOTION PLANNING	Drone plots a safe path through its environment to fulfill the pilot's commands or reach pre-planned locations.
360° OBSTACLE AVOIDANCE	Drone uses paired cameras and real-time 3D mapping to detect static obstacles and plot intelligent paths around them.
SUBJECT DETECTION	Deep learning algorithms are used to detect subjects, allowing the drone to recognize vehicles and people.
SKYDIO VISUAL NAVIGATOR™	Vision-based navigation system that does not depend on GPS or magnetometer calibration, enabling flight in GPS-denied, indoor, and metallic environments.
WAYPOINT MISSIONS	Map view which presents the drone's position superimposed on satellite imagery and directs the drone to fly to a point on the map.

SKYDIO AUTONOMY ENTERPRISE FOUNDATION

For pilots flying the most complex missions, Autonomy Enterprise Foundation provides enhanced functionality to help get the job done, with features designed to extend the pilot's situational awareness and facilitate flight in more obstacle-dense environments. This is an optional software package for any Skydio drone.

360 SUPERZOOM	Blends the six 4K navigation cameras to create an omnidirectional view. Allows the user to zoom digitally with algorithmic image stabilization.
PRECISION MODE	Tunes the system for ultra-precise positioning of the drone based on joystick inputs. (AEF feature for S2. Included with Autonomy Core for X2).
CLOSE PROXIMITY OBSTACLE AVOIDANCE	The drone can fly even closer to objects with full obstacle avoidance capabilities.
180 VERTICAL VIEW	Gimbal can look straight up overhead of the drone.
VISUAL RETURN-TO-HOME	Ability to RTH purely using visual wayfinding when flying in GPS denied environments.
POINT-OF-INTEREST ORBIT	Drone will navigate itself while revolving around a user-defined point on a map.
TRACK-IN-PLACE	Ability to visually track a car or person from a fixed position from farther away.
OFFLINE MAPS	Download maps ahead of time to use map-based features without a cellular LTE connection. AEF feature for S2. Included with Autonomy Core for X2.

COMPACT LWIR THERMAL CAMERA

FLIR Boson®

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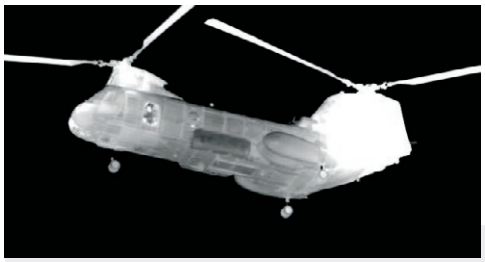

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Weight	7.5 g (0.26 oz) without lens or 640-model shutter	
Precision Mounting Holes	Four tapped M160.35 (rear cover) Lens support recommended when lens mass exceeds 7.5 g	
Interfacing		
Input Voltage	3.3 VDC	
Power Dissipation (Peak)	Varies by configuration; as low as 500 mW	
Video Channels	CMOS or USB-2	
Control Channels	UART or USB	
Configurable GPIO	Up to 11; user configurable	
Environmental		
Operating Temperature Range	-40°C to 80°C (-40°F to 176°F)	
Non-Operating Temperature Range	-50°C to 105°C (-58°F to 221°F)	
Shock	1,500 g @ 0.4 msec	
Operational Altitude	12,192 m (40,000 ft)	

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FLIR® | The World's Sixth Sense®

TEAL™

GOLDEN EAGLE sUAS PLATFORM

THE NEXT ERA OF FLIGHT

Golden Eagle is an American-made sUAS designed specifically for use by the US DoD, government agencies and commercial businesses. While Golden Eagle specializes in providing short-range ISR capabilities to warfighters, other uses include managing wildlife and land, public safety rapid response, inspection, and monitoring.

A CHANGING GLOBAL SPATIAL DATA ACQUISITION LANDSCAPE

Before Golden Eagle, Group 1 sUAS and the new class of American-made drone hardware, drones were only made and offered by entities domiciled in unallied foreign countries. This introduced dual-use, dependency, and data-flow concerns to National Security and the entire sUAS industry.

Teal worked with top teams in government, public safety and the commercial sector to design Golden Eagle to be a superior sUAS for real-world use cases that operators deal with every day. The result - a platform that is American-made, secure, and feature both onboard computing & advanced autonomy

THE LEADING AMERICAN sUAS PLATFORM

Teal's flagship sUAS, Golden Eagle, is a superior American-made sUAS platform focusing on effortless use, reliability, and extreme effectiveness. It features secure and encrypted communication, high endurance and range, modular architecture, EO/IR capability, near-silent propulsion, optimized SWaP, and scalable design.

Teal's platform is a combination of powerful hardware and software, is developed and produced in America, and is Section 848 compliant of the FY20 NDAA.

FEATURES

INTEGRATED COMPUTE PLATFORM

Powerful CPU and GPU for real-time edge processing of computer vision and AI applications.

VERTICALLY INTEGRATED

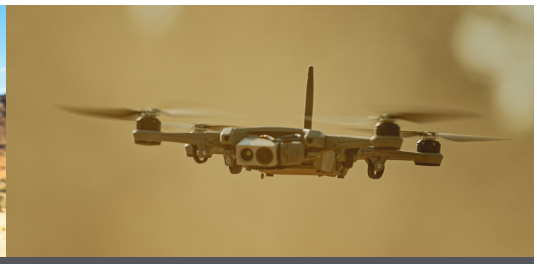
Vertically integrated and fully modular. Payload, propulsion, and battery systems can be quickly repaired, replaced, and upgraded.

AUTONOMY

Visual obstacle avoidance and visual inertial odometry provide GPS denied navigation and high level of autonomy.

EO and IR

Next generation FLIR imaging comes standard, with surveillance grade visible imaging and high sensitivity thermal imaging.



SPECIFICATIONS

GENERAL

SIZE

- Motor Diagonal: 13.9”
- Tactical Case: 160 in^3
- Hard Case: 16” x 13” x 7”

Flight Time: 20-30 Minutes
Max Horizontal Flight Speed: 50 MPH
Wind Resistance: 25 MPH
Weight: 2.3 Pounds
Max Flight Altitude from Controller: 2,000 Feet
Flight Controller: PX4
Operation Temp Range: -32° - 110° F

CAMERA

System: FLIR Hadron Dual Camera EO/IR Payload with Dual-axis Gimbal Stabilization
EO Sensor: Sony IMX412 4056x3040 Pixels 1/2.3” 12.3MP CMOS
EO Video Recording: Up to 4K@60FPS
Video Format: MPEG-4
Gimbal Pitch Controllable Range: -135° - +45°
IR Sensor: Boson, 320x256 Pixels
IR Video Recording: Native@30Hz
Storage: UFS 64GB Encrypted Onboard
Optional Removable Micro SD Card

PROCESSOR

Main Processor: Qualcomm Snapdragon 845
GPU: Qualcomm Adreno 630
CPU: Octa-core Qualcomm Kryo 385 64-bit CPU
Image Signal Processor: Qualcomm Spectra 280 with Dual 14-bit CPU
Memory: 8 GB LPDDR4X

COMMUNICATION

Compatible Ground Control Systems: Teal Air Control (TAC), TOGA, MAVLink GCS
Range: 3KM+
Operating Frequencies: 900, 1800, & 2400 MHz
Encryption: AES 256
Protocol: MAVLink

TEAL DRONES

Teal was founded in 2014 by George Matus (17 at the time) in Salt Lake City, Utah. Teal’s purpose is to enable unmanned systems to be more than just flying cameras. With a strong team and a backbone of venture support, Teal is helping to rebuild America’s sUAS industrial base to ultimately compete on a global scale.

BUNDLE SOLUTIONS

GOLDEN EAGLE
AIRCRAFT

PRICING:

With 1.8GHz Radio:	**$9,500**
With 2.4GHz Radio:	**$9,450**

BUNDLED SOLUTION INCLUDES:

Golden Eagle with radio
FLIR Hadron EO/IR Payload
2 Performance Battery Packs
Golden Eagle Hard Case
Golden Eagle Tactical Case
Performance Spares Kit
Online Training and Certification

TEAL AIR CONTROL (TAC)
CONTROLLER

PRICING:

With 1.8GHz Radio:	**$5,400**
With 2.4GHz Radio:	**$5,350**

BUNDLED SOLUTION INCLUDES:

TAC Ground Control Station with Radio
Performance Battery Pack
Teal High Speed Battery Charger
TAC Hard Case
TAC Antenna

Teal - Training Portal FAQs - 2021.01

1) Can you provide a copy of the Operator Training course syllabus?

1. Understanding Laws and Regulations
    a. FAA Regulations
    b. Federal Law
    c. State Law
    d. Industry Regulations
    e. COA Waiver Guide
    f. 333 Exemption History
2. FAA Drone Pilot Licensing (Part 107)
    a. Part 107 Curriculum
    b. Applicable Regulations
    c. Airspace Classifications / Operating Requirements & Flight Restrictions
    d. Aviation Weather Sources
    e. Effect of Weather on sUAS Performance
    f. sUAS Loading
    g. Emergency Procedures
    h. Crew Resource Management
    i. Radio Communication Procedures
    j. sUAS Performance Determination
    k. Pilot Performance and Physiological Factors
    l. Aeronautical Decision Making
    m. Airport Operations
    n. Maintenance and PreFlight Inspection Procedures
3. Testing
    a. Part 107 Practice Exam
    b. Safety Certification
    c. Pilot Certification
    d. Public Safety Certification
    e. Operations Certification
    f. Train the Trainer Certification
4. Teal Equipment Familiarity
    a. Software Overview
    b. Hardware Overview
    c. Operators Manual
    d. Reveal Farsight Overview
    e. Reveal Farsight Manual
    f. Reveal Executive Whitepaper
    g. QGroundControl Manual
5. Bundled Components
    a. Pix4D React
    b. Reveal Technologies Farsight
    c. DroneSense

6. Flight Training
    a. Basic Flight Maneuvers
    b. Intermediate Flight Maneuvers
    c. Advanced Flight Maneuvers
7. Case Studies
    a. Crime Scene Modeling
    b. Data Management & Security
    c. Crowd Monitoring
    d. Fire & Rescue Response
    e. Suspect Pursuit
    f. First Response
    g. BVLOS Operations
    h. Topo Maps
    i. DTMs and DSMs
    j. 3D Modeling
    k. Building Information Modeling (BIM)
    l. Custom Object Recognition Development
    m. Utility & Infrastructure Inspection
    n. Drones and Perimeter Security
8. Internal Drone Program Setup
    a. Objective
    b. Checklist
    c. Proposed Schedule
    d. Directory of Resources
    e. Supplemental Resources
9. Equipment Tracking
    a. Internal Equipment Inventory Systems
    b. Drone Logbook Template & Instructions
    c. Drone Logbook Selection Guide
    d. Equipment Checkout Log
    e. FAA Equipment Registration Process
10. Equipment Maintenance
    a. Teal Maintenance Manual
    b. Diagnostic Tools
11. Equipment Insurance
    a. Best Practices
    b. Directory of Insurers
12. Public Relations
    a. New Program Announcement
    b. Drone Technology Day Presentation
    c. Incident Report Response
    d. News Report Response
13. Train the Trainer
    a. Teal Training Outline

2) Do you provide Basic Operator Qualification training, if so, how long is the training course?

Yes! See the Teal Training Portal Syllabus for a list of all related courses and the estimated duration for each course. Completing all modules in the training portal is currently estimated at 96 hours.

3) Do you provide Train-The-Trainer training, if so, how long is the training course?

Yes! This is estimated at 5 hours.

4) Is there a difference in course time for novice and advanced operators?

Yes! Please see the Syllabus and corresponding hours. The total training time depends on which a la carte courses you select.

5) Can Operator Training course be conducted in person?

The Teal Training Portal is designed to provide all the content necessary for an organization to set up their own internal training program including a train the trainer program in order to teach internally, when and where desired. The cost of Portal access is including the purchase of most drone bundles.

Outside trainers can be provided through Teal resellers although there may be added costs.

6) Is there flexibility in providing Operator Training course in order to achieve back-to-back training?

Yes. In person trainers can be sourced through one or more Teal resellers which provides scheduling flexibility.

oem cameras.com
For FLIR Sales and Service contact us at:
Phone: 1-888-919-2263 | Outside the U.S.: +1-845-343-4077 | Fax: +1-845-343-4299
Address: P.O. Box 4242 Middletown, New York 10941 USA

PRE-INTEGRATED RGB / THERMAL MODULE

FLIR® Hadron™

The FLIR® Hadron™ is SWaP+C optimized RGB/Thermal module designed for simplicity and performance. This light weight, low power, compact form factor includes a 12MP RGB camera, Boson thermal camera (with shutter), complete integration of IMU and can operate at up to 60 Hz. Hadron's design ensuring maximum battery life and flight time, especially for small airframes. You can now offer your customers the power of thermal with the addition of this small module.

HADRON POWERS EO/IR VISION ON THE GOLDEN EAGLE

Hadron serves as the camera payload on the Teal Drones Golden Eagle, an advanced sUAS platform designed to spec for the United States Army that is now available for public use. Initially developed to locate individuals in low-visibility conditions, the Golden Eagle is also equipped to perform in a wide range of industrial applications.

RGB/THERMAL MODULE

View thermal and HD color images in flight. Ideal for inspection, locate and identify subjects in low light and dark conditions.

COMPACT FORM FACTOR

High resolution output designed for smaller class airframes. Low profile design enables flexible positioning on the airframe and SWaP to maintain longer air time.

FAST TIME TO MARKET

Reduce engineering and exploratory costs with this ready-out-of-the-box solution from a single source supplier.

SPECIFICATIONS

OVERVIEW	
Size	24 x 45 x 36 mm
Weight	42.8g
ELECTRICAL & MECHANICAL	
Mechanical Interface	Screw mount to back plate
ENVIRONMENTAL & APPROVALS	
Operational & Storage Temperature	-20°C to +60°C
Tested EMI Performance	FCC part 15 Class B
Environmental Sealing	IP53 (with the rear interfaces sealed)
IMAGING & OPTICAL	
IR Camera Sensor	Boson 320x256 pixels, 12mm pitch, USB video and CCI
IR Camera Optics	EFL 6.3mm, 34° HFOV, F/# 1.0
IR Camera Video	Full resolution @ 60Hz or 30Hz
EO Camera Sensor	Sony IMX412, 4056x3040 pixels, 1.55mm pitch, 4-lane MIPI
EO Camera Video	Full resolution @ 60Hz See IMX412 datasheet for more options
IMU	ICM20602, I2C or SPI (selectable)
EO Camera Optics	Sunny SYD1201A, EFL 3.7mm, 80° HFOV, F/# 2.8
POWER	
Power	5V supply voltage. Typical power dissipation < 1300mW, Max < 2820mW
Electrical Interface	Hadron connector: Hirose DF40C-50DP-0.4V(51)
	Example of mating connector: DF40HC(2.5)-50DS-0.4V(51)

Specifications are subject to change without notice.

For FLIR Sales and Service contact us at:
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Address: P.O. Box 4242 Middletown, New York 10941 USA

Appendix D

Selected Handheld IR Sensor Data Sheets

COMPACT THERMAL CAMERA

FLIR C5™

The FLIR C5 compact thermal camera is your go-to tool for building inspections, facilities maintenance, HVAC/R, electrical repair, and other troubleshooting applications. Featuring a thermal camera, visual inspection camera, and LED flashlight, the powerful FLIR C5 makes it easy to identify hidden problems. Built-in FLIR Ignite™ cloud connectivity allows direct data transfer, storage, and backup, so images are always available on all your devices. The 3.5 inch integrated touchscreen is simple to use, so you can quickly inspect, document repairs, and share evidence with customers. With the FLIR C5 in your pocket, you'll be ready anytime to find hot fuses, air leaks, plumbing issues, and more.

www.flir.com/C5

FIND AND TROUBLESHOOT

Quickly find hidden faults and reduce diagnostic time with this powerful, professional tool

- Identify and troubleshoot problems faster with the 160 × 120 true thermal imager and 5-megapixel visual camera
- Save time on manual thermal adjustments using 1-Touch Level/Span, which auto-adjusts the level and span in an area of interest with one touch
- Instantly recognize the location of a temperature issue with FLIR MSX® (Multi-Spectral Dynamic Imaging), which uses scene details from the built-in visual camera and embosses them onto the full thermal image

DOCUMENT AND SHARE

Pinpoint and communicate potential issues faster

- Upload directly to FLIR Ignite to conveniently store, organize, and back-up images
- Identify and describe potential issues by adding annotations to images
- Share findings easily and securely by sending a password-protected link via email
- Provide customers professional reports with images that document problems and repairs using preferred software, such as FLIR Thermal Studio

RUGGED, RELIABLE, AND COMPACT

Take the portable, affordable C5 with you to every job – it's the perfect tool for every person on your team

- IP54 enclosure provides a high level of protection against dust and water
- Designed to withstand a 2 m (6.6 ft) drop
- Carry the compact C5 in your pocket or stow easily in a crowded tool bag
- See into dark, difficult-to-reach areas with the help of the bright LED flashlight

SPECIFICATIONS

Overview	
IR sensor	160 × 120 (19,200 pixels)
Thermal sensitivity/NETD	<70 mK
Field of view (FOV)	54° × 42°
Minimum focus distance	• Thermal: 0.1 m (3.94 in) • MSX®: 0.3 m (11.8 in)
Image frequency	8.7 Hz
Focus	Focus free
Spectral range	8–14 µm
Screen size	3.5 in
Visual camera	5 MP
Digital camera focus	Fixed
Image Presentation	
Image adjustment	• Automatic level and span • Manual level and span • 1-Touch level and span
Image modes	• Infrared image • Visual image • MSX (Embossed visual details on thermal image) • Picture-in-picture (IR area on visual image)
Gallery	Thumbnails and custom folder structure
Color palettes	• Iron • Gray • Rainbow • Arctic • Lava • Rainbow HC
Screen rotation	Yes
Touchscreen	Capacitive touch
Measurement & Analysis	
Object temperature range	-20 to 400°C (-4 to 752°F)
Accuracy	At ambient temp. 15 to 35°C (59 to 95°F) and object temp. above 0°C (32°F) 0 to 100°C (32 to 212°F): ±3°C (±5.5°F) 100 to 400°C (212 to 752°F): ±3%
Measurement functions	• Spot • Box with max./min.
Measurement correction	• Emissivity; matt/semi-matt/semi-gloss + custom value • Reflected apparent temperature • Atmospheric compensation

Image Storage & Streaming	
Storage media	Internal memory and onboard FLIR Ignite cloud connectivity (with Wi-Fi)
Image storage capacity	>5000 images
Image file format	Standard JPEG, 14-bit measurement data included
Communication & Connectivity	
Wi-Fi®	802.11 a/ac/b/g/n (2.4 and 5 GHz)
USB	USB 2.0, Type-C connector
Bluetooth®	PAN
Image upload	Directly upload images to FLIR Ignite cloud library and services
Additional Information	
Battery type	Rechargeable built-in Lithium ion battery
Battery operating time	4 hours
Charging system	USB-C (1 A)
Charging time	2 hours
External power operation	5 V, USB-C
Operating temperature range	-10 to 50°C (14 to 122°F)
Storage temperature range	-40 to 70°C (-40 to 158°F)
Encapsulation	Camera housing and lens: IP54 (IEC 60529)
Drop test	Designed for 2 m (6.6 ft)
Weight (including battery)	0.19 kg (0.42 lb)
Size (L × W × H)	138 × 84 × 24 mm (5.4 × 3.3 × 0.94 in)
Tripod mounting (built-in)	UNC ¼"-20

Specifications are subject to change without notice. For the most up-to-date specs, go to www.flir.com

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NASDAQ: FLIR

19-2717-INS-C5

FLIR® | The World's Sixth Sense®

Seek SHOTPRO™

AFFORDABLE, HIGH-RESOLUTION THERMAL IMAGING WITH SEEKFUSION™ TECHNOLOGY

KEY CAMERA SPECS

- 320 x 240 Thermal Sensor
- 57° Field of View
- -40 to 626F Temperature Measurement
- SeekFusion™ Thermal + Visible
- Large Color Touch Screen
- Works Day & Night

Seek thermal

thermal.com

Seek ShotPRO is the most advanced thermal imaging camera for building professionals. Snap photo and video and analyze immediately with new on-board thermography tools. Add spot measurements and temperature boxes to create time-saving reports on the spot. Precisely diagnose problems with 16x higher resolution than comparably priced cameras. Take full control of photos and video by adjusting the blend between visible and thermal images. Share and stream to any smartphone or tablet over WiFi. Mount to a tripod and live stream to colleagues to tackle tougher jobs in the challenging environments. Seek ShotPRO puts durable and sleek thermal imaging expertise in your pocket.

Designed and Manufactured in Santa Barbara, California with Global Components.

Product Name:	Seek ShotPRO
Product Type:	Thermal Imaging Camera
Seek ShotPRO UPC & PN	UPC: 00859356006217 Part Number: SQ-AAA

Single Unit	
Included in the box:	• Seek ShotPRO • Wrist Lanyard • Welcome Guide • USB Cable
Device Dimensions (H x W x D)	8 x 14 x 2.8 cm 3.125 x 5.5 x 1.1 inches
Device Weight:	7.2 ounces 205 grams
Box Dimensions (H x W x D)	18 x 12 x 4.5 cm 7 x 4.75 x 1.75 inches
Box Weight:	14.5 ounces 410 grams

On-Device Analysis
Capture, edit and analyze photos in the field – all from your device.

SeekFusion™
Find problems faster with adjustable blend of visible and thermal images.

More Pixels, More Precision
Sixteen times more resolution than the competition. Best in class thermal resolution.

WiFi Streaming
Stream live video to any mobile device for collaboration and fixed monitoring.

KEY FEATURES

320 x 240 Best in Class Thermal Resolution
Identify, diagnose and report problems faster with high resolution thermal images and video

SeekFusion™ Technology
See exactly what you're looking at with combined visible and thermal images

Large Color Touch Screen
3.5" color touchscreen with 640x480 resolution so you can see more detail

WIFI Live View
Stream a live thermal view onto your smartphone or tablet over WiFi

Long-Lasting Battery Life
Best-in-class battery life of up to 4 hours continuous thermal imaging

Durable, Pocket-Sized Housing
Built with a rugged, IP54 rating

BENEFITS & USES

Easy-to-Use Interface
Diagnose problems on-the-spot and analyzes images on your device

Inspect Electrical Panels, Connections, and Fuses
Find electrical faults faster and with more confidence

Check Ventilation Systems for Proper Installation
Ensure grilles, registers, and diffusers are sealed for maximum efficiency

Spot Duct Leaks Invisible to the Human Eye
Easily scan a large ducting network to reveal the air leaks

Identify Inefficient Air Handlers
Diagnose faulty equipment and improve energy efficiency

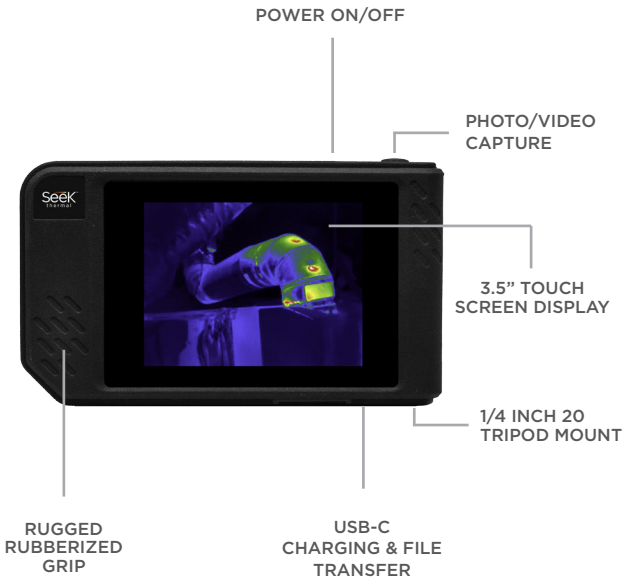
Find Missing Insulation
Easily find missing or poor-performing insulation in seconds

TECHNICAL SUMMARY

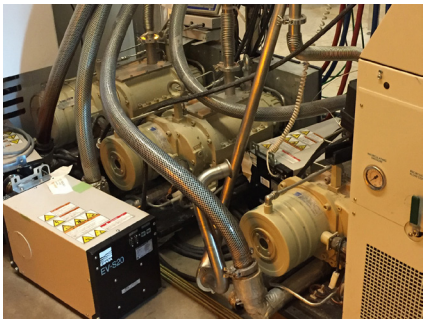
SPECIFICATIONS	DESCRIPTION
Thermal Sensor	320 x 240 (76,800 pixels)
SeekFusion™	Yes
Field of View	57 Degree FOV
Temperature Range	-40°F to 626°F (-40°C to 330°C)
Frame Rate	< 9 Hz
Focus	Fixed Focus
Light/Flash	Yes
Display	3.5" Color Display (648 x 480 Resolution)
Microbolometer	Vanadium Oxide
Thermal Sensitivity	< 70 mK
Spectral Range	7.5 – 14 Microns
User Interface	Intuitive Touch Screen
Temp. Display Scale	Fahrenheit, Celsius or Kelvin
Color Palettes	White, Black, Tyrian, Spectra, Iron, Prism, Amber & Hi
Storage Media	4GB Internal Storage
Battery	Up to 4 Hours Thermal Imaging
WiFi	WiFi enabled. Connect & stream via SeekView app

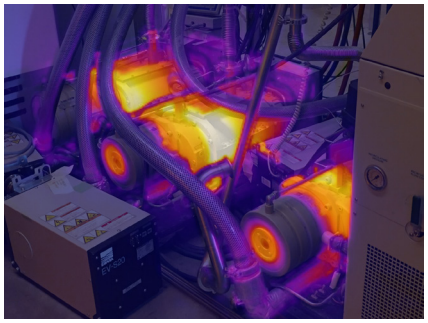
For support and user guides
visit **support.thermal.com**

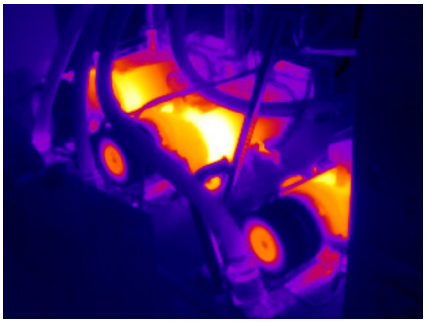
OVERVIEW

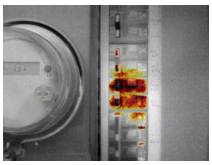


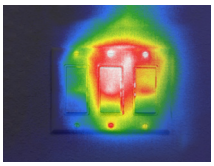
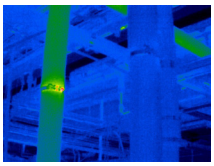
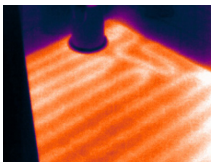
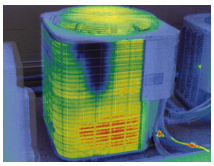
SEEKFUSION™


VISIBLE IMAGE


SEEKFUSION™ IMAGE


THERMAL IMAGE



Seek more at thermal.com

6300 Hollister Ave, Santa Barbara, CA 93117 USA

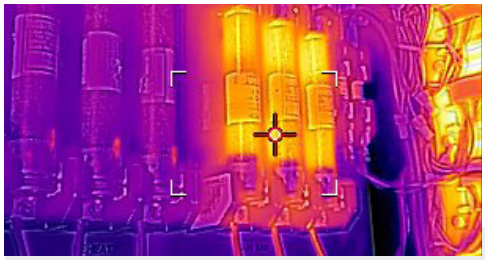
Seek Thermal engineers, designs and manufacturers high quality thermal imaging products and core platforms for consumer, commercial, and heat sensing IoT data applications. With headquarters in Santa Barbara, California, the global hub of thermal imaging innovation, the company has developed breakthrough thermal imaging camera cores that will enable a range of affordable products for use at home, work and play. For more information visit thermal.com and follow #seekthermal on Instagram and @seekthermal on Twitter.

INFRARED CAMERA WITH MSX® & WI-FI

FLIR Ex-Series™

FLIR E4, E5-XT, E6-XT, and E8-XT are powerful, cost-effective, easy-to-use troubleshooting tools for building, electrical, and mechanical applications. With four resolution options—up to 320 × 240 infrared pixels—and the ability to accurately measure temperatures from -20°C to 550°C/-4°F to 1022°F (E6-XT and E8-XT), the Ex-Series has models to fit your target size, working distance, visual detail needs, and budget. All models include MSX® technology for extraordinary thermal imaging detail. Wi-Fi connectivity to smartphones and tablets via the FLIR Tools® Mobile app makes sharing images and sending reports from any location easier, enabling you to make critical decisions faster. With Ex-Series cameras, you can gain the competitive advantage by providing clients with thermal images that clearly reveal the source of electrical, mechanical, and building-related problems.

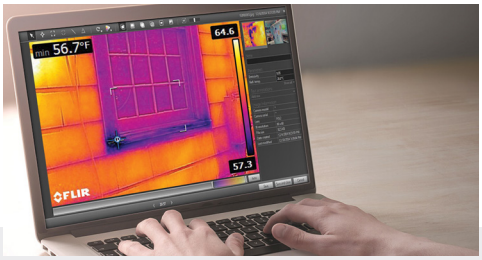
www.flir.com/Ex-Series



EASY TO USE

Intuitive graphic interface simplifies measurements in both thermal and MSX mode

- Fully automatic and focus-free
- Accurately measure your target using center spot or max/min area box
- Navigate easily to on-screen settings, image modes, and measurement tools using simple button controls
- Activate MSX to enhance IR images with visual detail for better perspective and interpretation



CONVENIENT TO SHARE IMAGES AND FINDINGS

Download images, create reports, and share what you've found instantly

- Records standard JPEGs with embedded temperature data for easy sharing with clients
- Wi-Fi connectivity to mobile devices via the FLIR Tools Mobile app
- Rapid Wi-Fi or USB image transfer for documentation
- Image analysis and editing, plus report creation, through FLIR Tools

COMPACT AND RUGGED

Built for portability and safe, efficient use in harsh environments

- Lightweight and well-balanced at just 1.2 lbs (0.575 kg)
- Withstands a 2-meter drop test
- IP54 Enclosure provides a high level of protection against dust and water
- Comes with 2-year warranty coverage on the camera and 10-year coverage for the detector

SPECIFICATIONS

Image and optical data	E4	E5-XT	E6-XT	E8-XT
IR resolution	80 × 60 (4,800 pixels)	160 × 120 (19,200 pixels)	240 × 180 (43,200 pixels)	320 × 240 (76,800 pixels)
Thermal sensitivity/NETD	<0.15°C (0.27°F) / <150 mK	<0.10°C (0.27°F) / <100 mK	<0.06°C (0.11°F) / <60 mK	<0.05°C (0.09°F) / <50 mK
Spatial resolution (IFOV)	10.3 mrad	5.2 mrad	3.4 mrad	2.6 mrad
Field of view (FOV)	45° × 34°			
F-number	1.5			
Image frequency	9 Hz			
Focus	Focus-free			
Detector data				
Detector type	Focal Plane Array (FPA), uncooled microbolometer			
Spectral range	7.5–13 µm			
Image presentation and modes				
Display	3" 320 × 240 color LCD			
Image adjustment	Automatic adjust/lock image			
Image modes	Thermal MSX, thermal, picture-in-picture, thermal blending, digital camera			
Color palettes	Iron, Rainbow, Black & White			
Measurement and analysis				
Object temperature range	–20°C to 250°C (–4°F to 482°F)	-20°C to 400°C (-4°F to 752°F) in two ranges	-20°C to 550°C (-4°F to 1022°F) in two ranges	-20°C to 550°C (-4°F to 1022°F) in two ranges
Accuracy	±2°C (±3.6°F) or ±2% of reading for ambient temperature 10°C to 35°C (50°F to 95°F) and object temperature above 0°C (32°F)			
Spotmeter	Center spot			
Area	Box with max/min			
Isotherm	Above alarm, below alarm			
Data communication and interfaces				
Interfaces	USB Micro: data transfer to and from PC and Mac device			
Wi-Fi	Peer-to-peer or infrastructure			
File format	Standard JPEG, 14-bit measurement data included			
General				
Operating temperature range	-15°C to 50°C (5°F to 122°F)			
Battery	Rechargeable 3.6 V Li ion battery			
Battery operating time	Approx. 4 hours at 25°C (77°F) ambient temperature and typical use			
Battery charging time	2.5 hours to 90% capacity in camera. 2 hours in charger			
Drop	2 m (6.6 ft.)			
Camera weight, incl. battery	0.575 kg (1.27 lb.)			
Camera size (L × W × H)	244 × 95 × 140 mm (9.6 × 3.7 × 5.5 in)			
Box contents	Infrared camera, hard transport case, battery, USB cable, power supply/charger with EU, UK, US and Australian plugs, printed documentation			

Specifications are subject to change without notice. For the most up-to-date specs, go to www.flir.com

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FLIR® | The World's Sixth Sense®

FLIR

FLIR Exx-Series

ADVANCED THERMAL IMAGING CAMERAS

SPECIFICATIONS

Model	E54	E76	E86	E96
IR resolution	320 × 240 pixels	320 × 240 pixels	464 × 348 pixels	640 × 480 pixels
Resolution with UltraMax® enhancement	—	307,200 pixels	645,888 pixels	1.2 megapixels
MSX® image enhancement	Yes: details from visual camera add depth and perspective			
Built-in visual camera	5 MP, fixed focus, with built in LED light			
Thermal sensitivity	<40 mK @ 30°C (86°F)	<30 mK @ 30°C (86°F), 42°lens	<30 mK @ 30°C (86°F), 42°lens	<30 mK @ 30°C (86°F), 42°lens
Temperature range	-20°C to 120°C (-4°F to 248°F); 0°C to 650°C (32°F to 1202°F)	-20°C to 120°C (-4°F to 248°F); 0°C to 650°C (32°F to 1202°F)	-20°C to 120°C (-4°F to 248°F); 0°C to 650°C (32°F to 1202°F); 300°C to 1500°C (572°F to 2732°F)	-20°C to 120°C (-4°F to 248°F); 0°C to 650°C (32°F to 1202°F); 300°C to 1500°C (572°F to 2732°F)
Optional temperature range	—	300°C to 1000°C (572°F to 1832°F)		
Accuracy	±2°C (±3.6°F) or ±2% of the reading			
Focus modes	Manual	Continuous laser distance meter (LDM), one-shot LDM, one-shot contrast, manual	Continuous LDM, one-shot LDM, one-shot contrast, manual	Continuous LDM, one-shot LDM, one-shot contrast, manual
Digital zoom	1–4x continuous			1–8x continuous
Measurement tools	3 spotmeters in live mode, 1 area meter in live mode	3 spotmeters in live mode, 3 area meters in live mode		
Measurement presets	None, center spot, hot spot, cold spot, 3 spots, hot spot-spot*	None, center spot, hot spot, cold spot, User Presets 1&2		
Available lenses	None (fixed lens)	14°, 24°, 42°, macro (2x)		
Lens identification	—	Automatic (FLIR AutoCal™)		
1-Touch Level/Span	Yes: automatic contrast enhancement			
Laser pointer	Yes			
Laser distance meter	—	Yes		
Area measurement information	—	—	Yes	
On-camera routing software	FLIR Inspection Route™ — enabled			
On-camera report building	Voice annotation and GPS tagging to images and video; on-screen text; sketch on infrared images from touchscreen			
FLIR software integration	FLIR Thermal Studio Starter, FLIR Thermal Studio, FLIR Thermal Studio Pro, FLIR Research Studio			
Radiometric JPEG	Yes			
IR, radiometric, visual video recording	Yes			
IR, radiometric, visual video streaming	Yes, over UVC (radiometric, non-radiometric, visual) and Wi-Fi (non-radiometric, visual)			
Communication modes	USB 2.0, Bluetooth, Wi-Fi, DisplayPort			
METERLiNK®	Yes			
Display	640 × 480 pixels (VGA) Dragontrail® touchscreen			
Drop-testing	2 m (6.6 ft)			
Battery operation time	>2.5 hours, typical use			

*Hot spot to center spot Delta measurement

Specifications are subject to change. For the most up-to-date specifications, please visit flir.com.

FLIR AutoCal™ Lenses

FLIR E76, E86, and E96 camera are compatible with all our interchangeable AutoCal lenses. The camera automatically recognizes when a new lens is attached and launches a wizard to begin auto-calibrating the camera with the lens—no need to send the camera in for service. This helps ensure the camera always produces high-quality images and precise thermal measurements.

WHAT LENS DO YOU NEED?

14°, 29 mm lens: this telephoto lens has a narrow field of view for precise focus and crisp imaging of distant targets.

24°, 17 mm lens: often considered the "standard" lens, the 24° x 18° field of view allows users to remain a safe distance from energized equipment (e.g. 3 m/6.6 ft) while still obtaining a crisp focus on smaller targets.

42°, 10 mm lens: this wide-angle lens captures the largest field of view for imaging buildings, roofs, or other areas where it's important to gather the most information in a single image.

THE Exx-SERIES and FLIR THERMAL STUDIO PRO

EMPOWERED WITH REPORTING SOLUTIONS TO STREAMLINE INSPECTIONS

Exx-Series cameras are the first FLIR models to come with our exclusive Inspection Route Camera Option automatically enabled in the camera.

Designed for thermographers who regularly inspect large numbers of objects over the course of a day, FLIR Inspection Route guides the user along a pre-defined route of inspection points so they can collect images and data in a structured manner.

The route begins in FLIR Thermal Studio Pro software, where users build their plan using the Route Creator plugin. They can include as many inspection targets as needed and organize them for maximum efficiency. Once they export the completed route to the Exx camera, they're ready to begin the day.

The predefined route guides the user's on-site movement to each inspection asset, automatically collecting and organizing saved images for a seamless import into FLIR Thermal Studio Pro. By ensuring that nothing is missed and that all inspection results are organized from start, the suite of FLIR inspection software speeds up inspections, improves organization, and simplifies reporting.

Learn more about FLIR Thermal Studio Pro, the FLIR Route Creator Plug-in, and the FLIR Inspection Route Camera Option at FLIR.com.

www.flir.com/exx-series

Ti401 PRO, Ti480 PRO, TiX501 and TiX580 Infrared Cameras

SUPERIOR IMAGE QUALITY

RESOLUTION
640 x 480 (307,200 pixels)

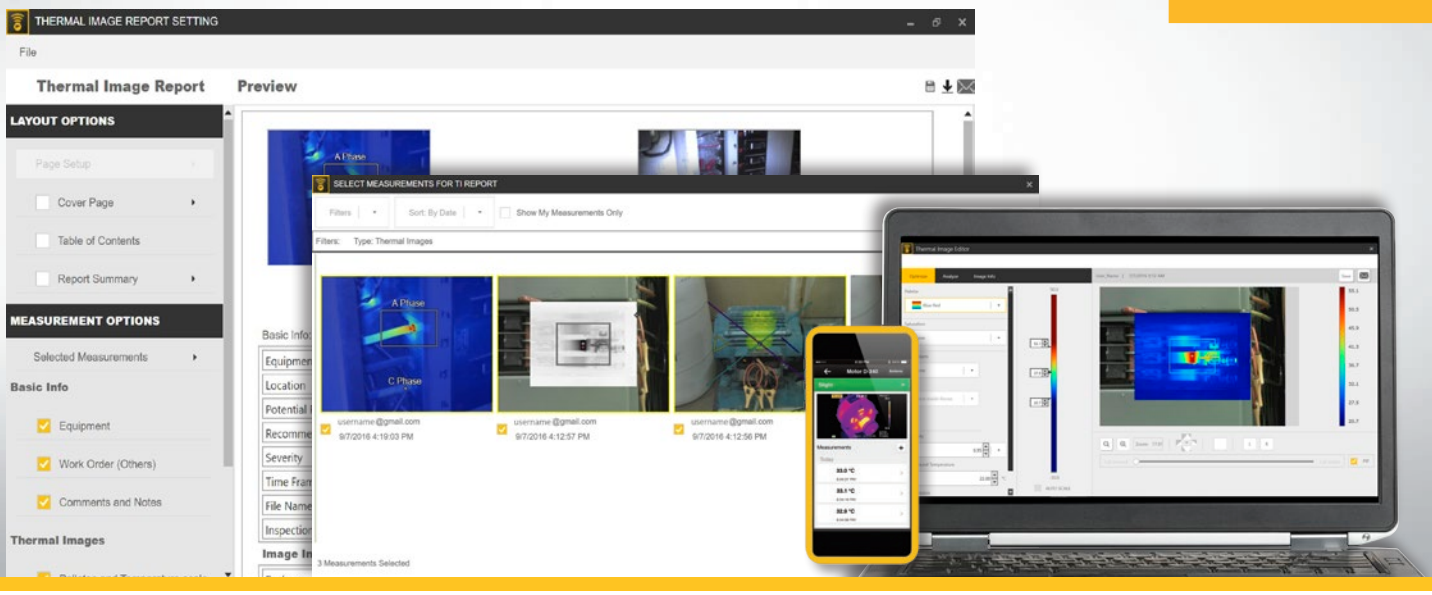
SPATIAL RESOLUTION
0.93 mRad

FIELD OF VIEW
34 °H x 24 °V

Fluke Connect™ compatible

We recognize that it's not one approach for all—each industry, business and success measure is unique. Optimally engineered, Fluke cameras are aligned to drive efficiency through the latest in thermography technology advancements. They offer everything needed for industrial professionals to safely, quickly and easily find, assess and solve mission-critical problems before they result in downtime, become costly or even disastrous.

- In-focus images in a matter of seconds. **LaserSharp™ Auto Focus** uses a built-in laser distance meter that calculates and displays the distance from your designated target and immediately adjusts the focus.
- Shoot images near…and far. Interchangeable **Smart Lenses** require no calibration and give you the versatility and image quality needed to conduct inspections in almost any environment.
- Simply the best optics to transmit energy and produce high quality infrared images. Fluke uses only 100 % diamond-turned germanium lenses with specialty coatings.
- See more details when you adjust the level of infrared and visible light with patented IR-Fusion™ technology.
- Edit and analyze images on camera—edit emissivity, enable color alarms and markers, and adjust IR-Fusion™ visual and infrared image blending.
- Manage data, capture multiple measurements (mechanical, electrical and thermal) and organize them by piece of equipment with Fluke Connect™ software.
- Inspect multiple complex targets or targets from varying distances. Capture a clear, accurate image focused throughout the field of view with **MultiSharp™ Focus**. The camera automatically processes a stack of images focused near and far with the Ti480 PRO and TiX580.



FLUKE CONNECT

Powerful, easy-to-use Fluke Connect™

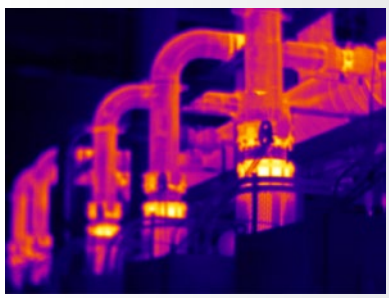
A comprehensive and connected software platform that represents the future of integrated equipment maintenance, monitoring, analysis and reporting. It's easier than ever to optimize thermal images, perform analytics, generate quick, customizable, robust reports, and export images to the format of your choice in the cloud. And you will be able to integrate with Fluke Connect—the largest integrated system of maintenance software and tools in the world.

- Modern visual design
- Intuitive navigation—easier to learn, easier and faster to work in
- Simplified work flows
- Simplified reporting workflow and better report templates
- Fluke Connect Cloud storage

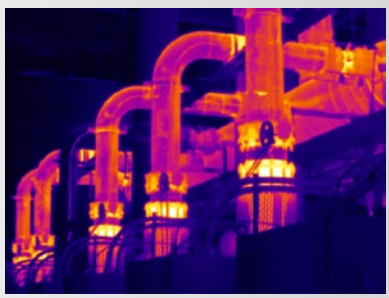
Download at **flukeconnect.com**

Fluke Connect and Fluke Connect cloud storage not available in all countries.

100% Focused–Every object. Near and far. MultiSharp™ Focus.



Manual focus



MultiSharp Focus

D-11

FLUKE®

Detailed specifications

	Ti401 PRO	Ti480 PRO	TiX501	TiX580
Key Features				
Infrared resolution	640 x 480 (307,200 pixels)			
SuperResolution	No	Yes, in software. Captures and combines 4x the data to create a 1280 x 960 image	No	Yes, in software. Captures and combines 4x the data to create a 1280 x 960 image
IFOV with standard lens (spatial resolution)	0.93 mRad, D:S 1065:1			
Field of view	34 °H x 24 °V			
Minimum focus distance	15 cm (approx. 6 in)			
MultiSharp Focus	No	Yes, focused near and far, throughout the field of view	No	Yes, focused near and far, throughout the field of view
LaserSharp Auto Focus	Yes, for consistently in-focus images. Every. Single. Time			
Laser distance meter	Yes, calculates distance to the target for precisely focused images and displays distance on screen			
Advanced manual focus	Yes			
Wireless connectivity	Yes, to PC, iPhone® and iPad® (iOS 4s and later), Android™ 4.3 and up, and WiFi to LAN (where available)			
Fluke Connect app compatible	Yes*, connect your camera to your smartphone, and images taken automatically upload to the Fluke Connect app for saving and sharing			
Fluke Connect Assets	Through the desktop, assign images to assets, easily compare measurement types in one location and create reports.		Future**, Automatically assign images to assets, easily compare measurement types in one location and create reports through a cloud-based system.	
Fluke Connect instant cloud upload	Yes*, connect your camera to your building's WiFi network, and images taken automatically upload to the Fluke Connect system for viewing on your smartphone or PC			
Fluke Connect instant server upload	Yes**	Yes**	Yes**	Yes**
IR-Fusion technology	Yes, adds the context of the visible details to your infrared image			
Ruggedized touchscreen display	3.5 inch (landscape), 640 x 480 LCD		5.7 inch (14.4 cm) landscape 640 x 480 LCD	
Ergonomic design	Pistol-grip design for one-handed use		240 ° rotatable (articulating) lens	
Thermal sensitivity (NETD)**	≤ 0.075 °C at 30 °C target temp (75 mK)	≤ 0.05 °C at 30 °C target temp (50 mK)	≤ 0.075 °C at 30 °C target temp (75 mK)	≤ 0.05 °C at 30 °C target temp (50 mK)
Level and span	Smooth auto and manual scaling			
Touchscreen adjustable level/span	Yes. Span and level can be easily and quickly set by simply touching the screen			
Fast auto toggle between manual and auto modes	Yes			
Fast auto-rescale in manual mode	Yes			
Minimum span (in manual mode)	2.0 °C (3.6 °F)			
Minimum span (in auto mode)	3.0 °C (5.4 °F)			
Built-in digital camera (visible light)	5MP			
Frame rate	60 Hz or 9 Hz versions			
Laser pointer	Yes			
LED light (torch)	Yes			
Digital Zoom	No	2x and 4x	2x	2x, 4x, 8x
Data storage and image capture				
Extensive memory options	Removable 4 GB micro SD memory card, 4 GB internal flash memory, save to USB flash drive capability, upload for permanent storage			
Image capture, review, save mechanism	One-handed image capture, review, and save capability		Yes, edit and analyze captured images on camera	
Image file formats	bmp, jpeg, is2	bmp, jpeg, is2, is3, AVI	bmp, jpeg, is2, is3, AVI	bmp, jpeg, is2, is3, AVI
Memory review	Thumbnail and full screen review			
Software	Full analysis and reporting software with access to the Fluke Connect system			
Analyze and store radiometric data on a PC	Yes			
Export file formats with Fluke Connect software	Bitmap (.bmp), GIF, JPEG, PNG, TIFF			
Voice annotation	60 seconds maximum recording time per image; reviewable playback on camera, optional Bluetooth headset available but not required			
IR-PhotoNotes	Yes - 2 images	Yes - 5 images	Yes - 2 images	Yes - 5 images
Text annotations	Yes. Including standard shortcuts as well as user programmable options			
Video recording and formats	No	Standard and radiometric	Standard	Standard and radiometric
Remote control operations	Remote display through Fluke Connect	Remote display and control operation through Fluke Connect	Remote display through Fluke Connect	Remote display and control operation through Fluke Connect
Auto capture (temperature and interval)	No	Yes	No	Yes
MATLAB® and LabVIEW® tool boxes	–	Integrate camera data, infrared video and images into software to support R&D analysis		

FLUKE®

Detailed specifications

	Ti401 PRO	Ti480 PRO	TiX501	TiX580
Battery				
Batteries (field-replaceable, rechargeable)	Two lithium ion smart battery packs with five-segment LED display to show charge level			
Battery life	2–3 hours per battery (actual life varies depending on settings and usage)			
Battery charging time	2.5 hours to full charge			
Battery charging system	Two-bay battery charger or in-imager charging. Optional 12 V automotive charging adapter			
AC operation	AC operation with included power supply (100 V AC to 240 V AC, 50/60 Hz)			
Power saving	User selectable sleep and power off modes			
Temperature measurement				
Temperature measurement range (not calibrated below -10 °C)	-20 °C to +650 °C (-4 °F to +1,202 °F)	-20 °C to +1,000 °C (-4 °F to 1,832 °F)	-20 °C to +650 °C (-4 °F to +1,202 °F)	-20 °C to +1,000 °C (-4 °F to 1,832 °F)
Accuracy	± 2 °C or 2 % (at 25 °C nominal, whichever is greater)			
On-screen emissivity correction	Yes (both value and table)			
On-screen reflected background temperature compensation	Yes			
On-screen transmission correction	Yes			
Line temperature graph	No	Yes	No	Yes
Color palettes				
Standard palettes	9: Rainbow, Ironbow, Blue-Red, High Contrast, Amber, Amber Inverted, Hot Metal, Grayscale, Grayscale Inverted		8: Ironbow, Blue-Red, High Contrast, Amber, Amber Inverted, Hot Metal, Grayscale, Grayscale Inverted	
Ultra Contrast palettes	9: Rainbow, Ironbow, Blue-Red, High Contrast, Amber, Amber Inverted, Hot Metal, Grayscale, Grayscale Inverted		8: Ironbow Ultra, Blue-Red Ultra, High Contrast Ultra, Amber Ultra, Amber Inverted Ultra, Hot Metal Ultra, Grayscale Ultra, Grayscale Inverted Ultra	
Smart lenses				
Macro–25 micron lens: 25 MAC2	Yes			
2 x telephoto lens: TELE 2	Yes			
4 x telephoto lens: TELE4	Yes			
Wide angle lens: WIDE 2	Yes			
General specifications				
Color alarms (temperature alarms)	High temperature, low temperature, and isotherms (within range)			
Infrared spectral band	7.5 µm to 14 µm (long wave)			
Operating Temperature	-10 °C to +50 °C (14 °F to 122 °F)			
Storage Temperature	-20 °C to +50 °C (-4 °F to 122 °F) without batteries			
Relative humidity	10 % to 95 % non-condensing			
Center-point temperature measurement	Yes			
Spot temperature	Hot and cold spot markers		Hot and cold spot markers, individually enabled	
User-definable spot markers	No	3 user-definable spot markers	2 user-definable spot markers	3 user-definable spot markers
User defined measurement boxes	1 expandable-contractible measurement box with MIN-MAX-AVG temp display	Up to 3 expandable-contractible measurement box with MIN-MAX-AVG temp display	1 expandable-contractible measurement box with MIN-MAX-AVG temp display	3-Expandable-contractible measurement box with MIN-MAX-AVG temp display
Hard Case	Rugged, hard carrying case; soft transport bag	Rugged, IP67 rated, airtight hardcase with custom foam insert		
Safety	IEC 61010-1: Overvoltage category II, Pollution Degree 2			
Electromagnetic compatibility	IEC 61326-1: Basic EM environment. CISPR 11: Group 1, Class A			
Australian RCM	IEC 61326-1			
US FCC	CFR 47, Part 15 Subpart B			
Vibration	0.03 g2/Hz (3.8 g), 2.5 g IEC 60068-2-6			
Shock	25 g, IEC 68-2-29			
Drop	Engineered to withstand 2 meter (6.5 feet) drop with standard lens		Engineered to withstand 1 meter (3.3 feet) drop with standard lens	
Size (H x W x L)	27.7 cm x 12.2 cm x 16.7 cm (10.9 in x 4.8 in x 6.5 in)		27.3 cm x 15.9 cm x 9.7 cm (10.8 in x 6.3 in x 3.8 in)	
Weight (battery included)	1.04 kg (2.3 lb)		1.54 kg (3.4 lb)	
Enclosure rating	IEC 60529: IP54 (protected against dust, limited ingress; protection against water spray from all directions)			
Warranty	Two-years (standard), extended warranties are available			
Recommended calibration cycle	Two-years (assumes normal operation and normal aging)			
Supported languages	Czech, Dutch, English, Finnish, French, German, Hungarian, Italian, Japanese, Korean, Polish, Portuguese, Russian, Simplified Chinese, Spanish, Swedish, Traditional Chinese, and Turkish			
RoHS compliant	Yes			

Please Note: Fluke Connect analysis and reporting software is available in all countries but Fluke Connect is not. Please check availability with your authorized Fluke distributor
**Indicates Fluke Connect™ features that will be available soon. Watch the Fluke website for software and firmware updates.

Ordering information

FLK-Ti401 PRO 60 Hz Infrared Camera
FLK-Ti401 PRO 9 Hz Infrared Camera
FLK-Ti480 PRO 60 Hz Infrared Camera
FLK-Ti480 PRO 9 Hz Infrared Camera
FLK-TiX501 60 Hz Infrared Camera
FLK-TiX501 9 Hz Infrared Camera
FLK-TiX580 60 Hz Infrared Camera
FLK-TiX580 9 Hz Infrared Camera

Included
Included Infrared camera with standard infrared lens; AC power supply and battery pack charger (including universal AC adapters); two rugged lithium ion smart battery packs; USB cable; HDMI video cable; 4GB micro SD card; and adjustable hand strap. **Available by free download:** Fluke Connect™ desktop software and user manual

Ti401 PRO only
Rugged, hard carrying case, soft transport bag

Ti480 PRO, TiX501, TiX580 only
Rugged, IP67 rated, airtight hard carrying case

TiX501, TiX580 only
Adjustable neck strap

Optional accessories
FLK-LENS/TELE2 Infrared Telephoto Lens (2X magnification)
FLK-LENS/4XTELE2 Infrared Telephoto Lens (4X magnification)
FLK-LENS/WIDE2 Infrared Wide Angle Lens
FLK-LENS/25MAC2 25 Micron Macro Infrared Lens
TI-CAR-CHARGER Car Charger
FLK-TI-VISOR3 Sun Visor
BOOK-ITP Introduction to Thermography Principles Book
TI-TRIPOD3 Tripod Mounting Accessory
FLK-TI-BLUETOOTH Bluetooth headset
FLK-TI-SBP3 Additional Smart Battery
FLK-TI-SBC3B Additional Smart Battery Charger
FLK-TIX5XX-SBP4 Additional Smart Battery
FLK-TI-SBC3B Additional Smart Battery Charger

TiX501 and TiX580 additional accessories
FLK-TIX5X-LENS CAP Infrared Lens Cover
FLK-TIX5XX-NECK Neck strap
FLUKE-TIX5XX HAND Hand strap
FLK-TI-BLUETOOTH Bluetooth Headset
FLK-TIX5XX-HDMI HDMI Cable

Visit www.fluke.com to get complete details on these products or ask your local Fluke sales representative.

Preventive maintenance simplified. Rework eliminated.

Save time and improve the reliability of your maintenance data by wirelessly syncing measurements using the Fluke Connect™ system.

- Eliminate data-entry errors by saving measurements directly from the tool and associating them with the work order, report or asset record.
- Maximize uptime and make confident maintenance decisions with data you can trust and trace.
- Move away from clipboards, notebooks and multiple spreadsheets with a wireless one-step measurement transfer.
- Access baseline, historical and current measurements by asset.
- Share your measurement data using ShareLive™ video calls and emails.
- The PRO series infrared cameras are part of a growing system of connected test tools and equipment maintenance software. Visit the website to learn more about the Fluke Connect™ system.

Find out more at **flukeconnect.com**

Download on the App Store

ANDROID APP ON Google play

All trademarks are the property of their respective owners. WiFi or cellular service required to share data. Smartphone, wireless service and data plan not included with purchase. First 5GB of storage is free. Phone support details can be viewed at **fluke.com/phones**.

Smart phone wireless service and data plan not included with purchase. Fluke Connect is not available in all countries.

Fluke. *Keeping your world up and running.®*

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