USERGUIDE

Software Version 3.4
Module: Casia X
Module Model: XACM-0100
Camera Type: 8.9 MP GigE
Camera Model: HEOC-0009

CASIA X

Ensuring no two aircraft collide mid-air.

REVISION 1.1 | 2024-10-08

CONTENTS

The world's smallest, lightest, lowest power, 360° coverage Detect, Alert, Avoid (DAA) solution for unpiloted aircraft.

Features

Detect & Avoid

Senses non-cooperative aircraft using a patented computer vision and AI system.

Integrated ADS-B

Integrated ADS-B for increased coverage with cooperative aircraft.

Collision Avoidance

Avoid collisions with automatically executed, safe, drone maneuvers.

Pilot-In-Command

Report detected intruder aircraft to the ground-station and pilot-in-command in real time*.

Low Size, Weight & Power

Low CSWaP (Cost, Size, Weight, and Power) for easy integration on small UAS platforms.

Autopilot Compatible

Turn-key integration with supported autopilot systems. Supports common commercially available autopilots.

*Requires support from the autopilot and ground-station software being used.

Safety First

Casia X provides additional situational awareness and safety redundancy during UAS operations.

Test all equipment before commencing any UAS mission to ensure that all drone systems are operating correctly.

It is your responsibility to maintain operations in accordance with local aviation regulations.

uAvionix does not take on liability for your UAS operations, regardless of whether uAvionix technology is onboard.

Before commencing any UAV operations, read the limitations and disclaimers section of this document to understand the importance of correct implementation, maintenance, and operation of Casia, and the potential impacts of external factors on its performance.

Components

MODULE

- [ ] 1x Casia Module
- [ ] 1x RS-232 Serial Cable
- [ ] 2x Power Input Cables
- [ ] 1x Serial UART Cable (Pixhawk Standard)

CAMERAS

- [ ] 3-5x GigE Camera Assemblies (with lens caps)
- [ ] 3-5x Lens cloth
- [ ] 3-5x Industrial Ethernet Camera Cables

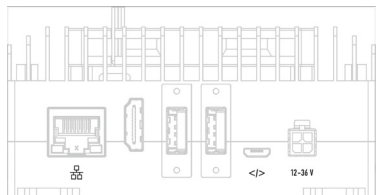
Casia X Module

The Casia X Module is the brains of the DAA system. This is where our software is executed and the cameras connect. It forms the central point of the Casia DAA system and interfaces between all sensors, autopilots, and other systems required to provide DAA safety functionality for BVLOS drone operations.

At the heart of the module is the nVidia Xavier AGX system on module, this is encapsulated in our custom engineered electronics and enclosure to provide easy integration with drone platforms.


CASIA
SERIAL NUMBER
CAMERA STATUS
SYSTEM STATUS
SW
HW
CAN 1
CAN 2
UART 1
UART 2
RS-232 1
RS-232 2
RECOVER
RESET
POWER


CAMERAS


12-36 V


IRIS AUTOMATION™
MICRO SD


103mm
168mm


CASIA
SERIAL NUMBER
CAMERA STATUS
SYSTEM STATUS
CAN 1
CAN 2
UART 1
UART 2
RS-232 1
RS-232 2
RECOVER
RESET
POWER
52.00
188.00

Camera Modules

Do not disassemble the camera body and lens!

These two components are paired and optically calibrated at the time of manufacture, and when taken apart, require factory re-calibration.

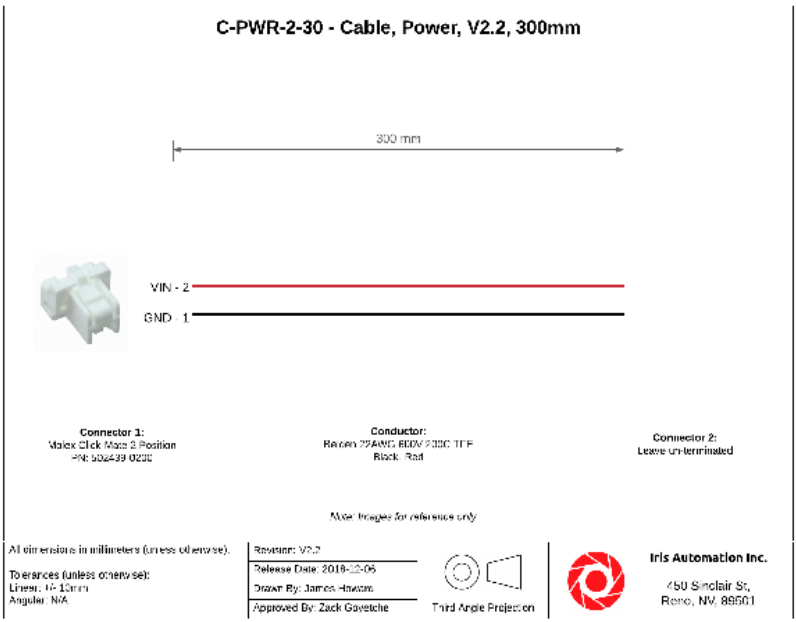
Ensure cameras and lenses comply with the uAvionix safety standards.

Note the white and red dots on the cameras and lenses below. If your system has such dots and they are not cracked or broken, this signifies that your camera and lens comply with the UAvionix safety standards. ***Inspect before each flight.***

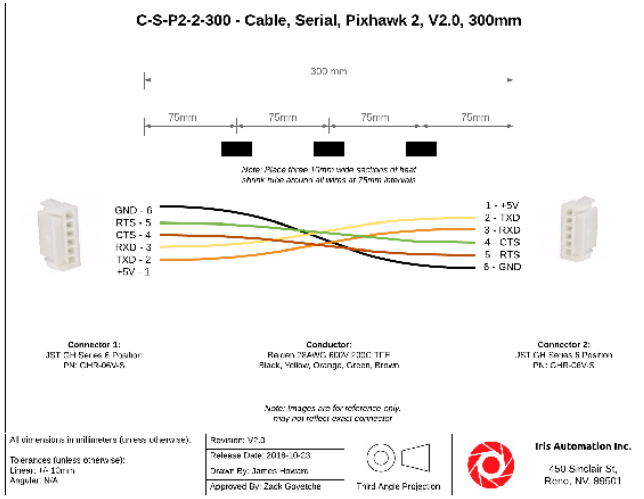
CABLES

We provide all the cables that you need to use Casia, however sometimes it is necessary to use a different length cable or for the cable to be customized in another way. The cable diagrams, part numbers, etc are all provided in this section.

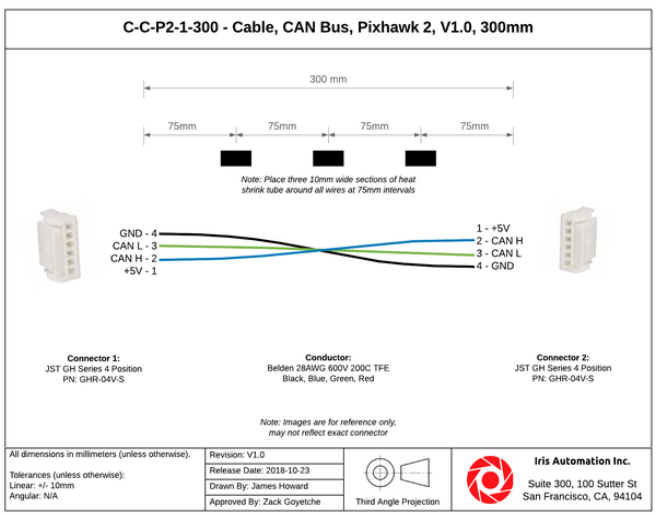
Casia Power Cable



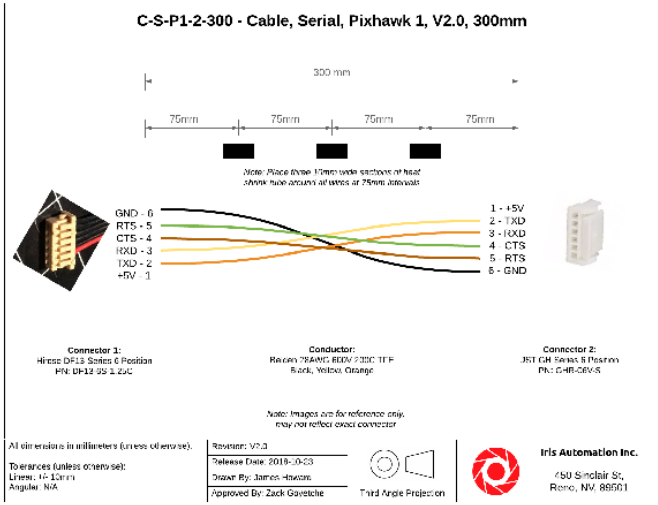
Pixhawk 2 Serial Cable



Pixhawk 2 CAN Bus Cable



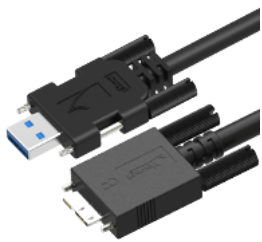
Pixhawk 1 Serial Cable



Pixhawk 1 Serial Cable

Additional cables are extremely difficult to make yourself.

Please find these cables at the following suppliers: FLIR.com, Newnex.com



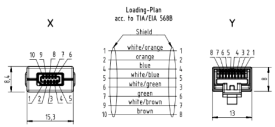
GigE Camera Cable

CCGE-0102 - Cable Camera GigE 1m RJ-45 Screw Locking to ix Type A

Connector 2:
Harting/Hirose ix Type A
PN: 09451812562XL (Harting)
PN: IX31G-A-10S-CV(7.0) (Hirose)

Cable:
CAT6a SF/UTP black, high-flex,
shielded, UV resistant
PN: TFDL5919 (L-Com)

Connector 1:
RJ-45 Straight Side Screw Locking
PN: Unknown



Note: Images for reference only

All dimensions in millimeters (unless otherwise). Tolerances (unless otherwise): Linear: +/- 1mm Angular: N/A	Revision: 0.1 Release Date: 2021-02-10 Drawn By: James Howard Approved By:	Third Angle Projection	**Iris Automation Inc.** 450 Sinclair St, Reno, NV, 89501

Installation

Before You Begin

It is generally advised not to mount electronics close to radio antennas (e.g. C2 radio, GPS receiver, etc) to avoid interference with that equipment.

We recommend that Casia components are mounted away from antennas!

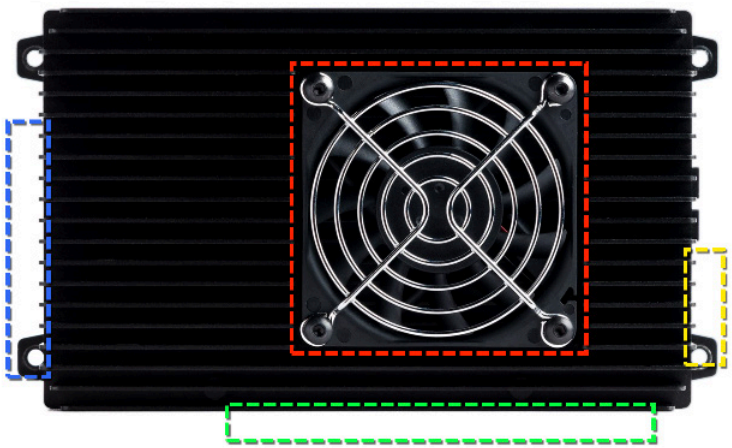
Casia X

CASIA MODULE

Find a suitable location for the Casia modules to be located on your aircraft. As the heaviest component of the Casia system, it is best to mount this as near to the center of mass of the aircraft as possible. For fixed-wing aircraft this is usually in the fuselage. For multi-rotor and helicopter aircraft the best location will be on the central body. Note the following precautions before installation.

- The GigE cables, when connected, protrude from Casia and clearance must be considered to ensure it fits (shown in BLUE)
- Casia has a cooling fan that must be clear of obstructions to allow proper airflow (shown in RED)

- In order to offload flight data, the ethernet port must be accessible to connect an ethernet cable to (shown in YELLOW)
- There are status LEDs critical to pre-flight checks on the front of Casia that must be visible (shown in GREEN)
- Casia is not rated for ingress protection and should be protected adequately from moisture and other water sources.



Mounting

Mount the Casia module securely using the four provided M3 sized mounting feet. It is important to securely mount the module to prevent it from moving during flight and disrupting the center of mass of your drone. See the following image for the dimensions of the mounting hole pattern.

CAMERAS

Positioning

Choosing good mounting locations for the cameras is extremely important to ensure total coverage of the field of view around the aircraft, examples and guidelines are given in this section however, installation will vary depending on the airframe. Following these guidelines is extremely important as this will directly effect the performance of the system if done incorrectly. If at any point during installation you are unsure, please contact support@uAvionixonboard.com for assistance.

In all integration positions, ideally no part of the ownship can occlude the field of view of any camera at any time during flight.

Masking (if a camera is occluded by the aircraft)

False positives can occur when Casia X falsely detects a non-aircraft object as an aircraft which. This can happen if part of the aircraft (e.g. prpeller) is in the field of view of one of the cameras.

uAvionix provides masking capabilities to stop the system triggering on persistent false positives. These capabilities are available via the FlightDeck web application at https://flightdeck.irisonboard.com/.

Log on, navigate to your device and select the ‘Manage Device Masking’ option from the drop down list in the top right corner.

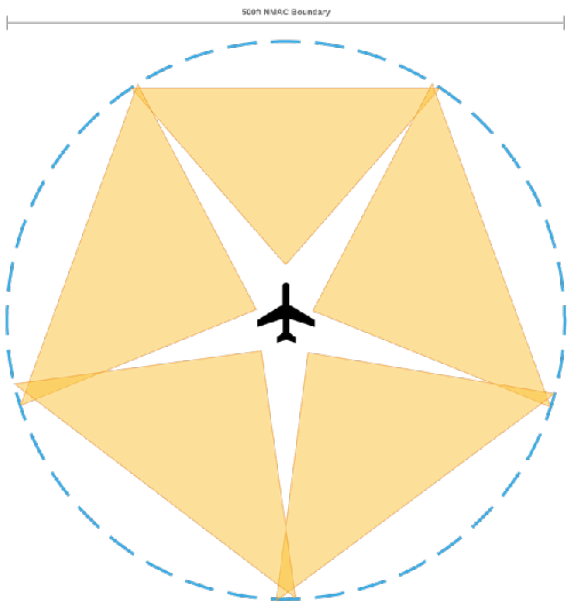
For each camera, mask the area that shows part of the aircraft. If the camera image is outdated, you may want to refresh it by clicking the ‘Refresh Camera Image’ button. If required, please request assistance by emailing support@uavionix.com.

Overlap

It is important that cameras overlap with a minimum of 5 degrees of overlap with neighboring cameras. Larger overlaps should be used to cover areas where there is higher risk of a collision such as the front and rear of the aircraft (where head-on and overtaking collision scenarios are possible). Each camera used with Casia X has an 80 degree horizontal field. Assuming (5) five cameras, this would result in 40 degrees of available overlap within the system, providing adequate flexibility to suite any integration.

Note that when using small degrees of overlap it is important to calculate where the neighboring cameras fields of regard will meet. Smaller angles of overlap will result in longer distances from the ownship before the fields of regard overlap. This can cause blind-spots for the system if not installed correctly.

⚠ To prevent blind spots, all camera's fields of view must overlap with their neighboring camera's fields of regard view within 500ft of the ownship!



Multi-Rotor

- Each camera is mounted to avoid having any of the rotors within the field of view and so that it is not subjected to excessive vibration or prop wash
- Front and side cameras are mounted on a boom to extend above or beyond the rotors and in such a way to have a clean field of view and an overlapped field of view in the sides and the front
- Rear cameras are mounted on a boom or fixed landing gear in such a way to have a clean field of view and an overlapped field of view in the rear and sides
- Each camera is mounted so that it is flat in the horizontal plane while the aircraft is in forward flight

Fixed-Wing

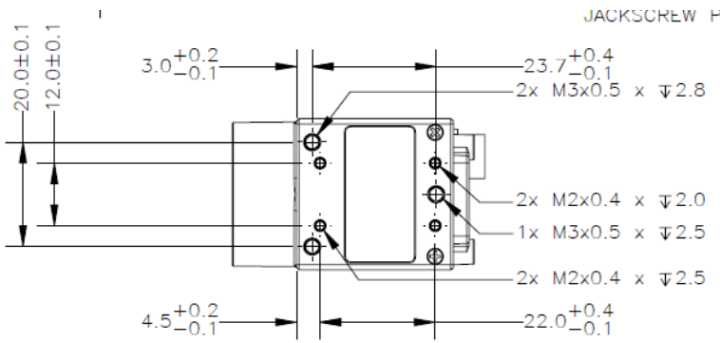
- All the cameras are mounted to avoid having the propeller or other aircraft parts within the field of view
- The front cameras are mounted such that there is overlap at the front of the field of view
- The side cameras are mounted on the ends of the wings to get a clean field of view
- Rear cameras are mounted on the wingtips or the tail of the aircraft to cover the entire field of view around the drone. Cameras should only be mounted on the wings if the wings are rigid enough to prevent excessive vibration in flight
- Cameras should only be mounted on the tail of the aircraft if they can be kept out of the prop wash
- Each camera is mounted flat in the horizontal plane of the autopilot

Helicopter

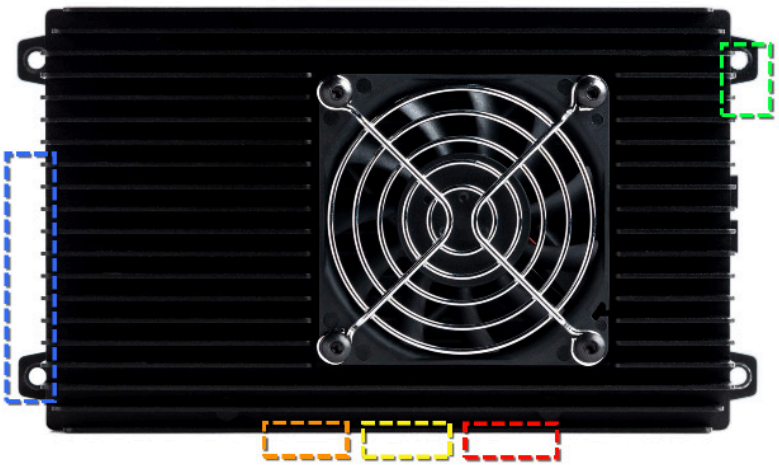
- Front and side cameras mounted low on the body to ensure the rotors are not within the field of view
- Rear cameras mounted on the tail boom to enable complete coverage of the field of view
- Each camera is mounted flat in the horizontal plane of the autopilot

MOUNTING

Mount the FLIR cameras using the three M3 threaded holes on the bottom of the camera, or the four M2 threaded holes on the bottom of the camera. It is important that the cameras are mounted very securely as any movement during flight will cause calibration problems with the DAA system. See the following image for the dimensions of the FLIR camera mounting hole pattern.



SYSTEM WIRING



Power

Power must be supplied to the Casia X module within the specified acceptable input range. For Casia X this is an 12V to 36V supply. Make sure to reference the datasheet for your device and ensure that the power supply can provide an adequate power output to supply Casia.

Power is provided to the Casia X module through the power connector indicated in the image to the right by the GREEN box. Two pre-made power cables are provided with all Casia X modules, however if you lose or damage the cable you can purchase your own components to create a new cable. Please see below for part number information.

- Connector Series: Molex Micro-Fit 3.0
- Mating Connector: 43025-0400
- Crimp Terminals: 43030-0038
- Suggested Wire Gauge: 18 AWG

IMPORTANT: Casia Xpower consumption increased from software release 2.3 to 2.4. It is now 65W nominal and 70W peak.

Data (UART)

The autopilot can be connected to the “UART 1” or “UART 2” port (shown in YELLOW) on the Casia X module using the provided autopilot cables in the Casia module X box. This connector is compliant with the Pixhawk connector standard and can also be used with any other 6 pin Pixhawk connector cable. Information on the specific connectors used is included next:

Note that for Piccolo, an RS-232 converter is required if using these ports, this is detailed in the Autopilots section of this document.

Alternatively, use an RS-232 interface as described below.

- External Markings: UART 1, UART 2
- Connector Series: JST GH
- Mating Connector: GHR-06V-S
- Crimp Terminals: SSHL-002T-P0.2 (Reel)
- Suggested Wire Gauge: 28-30 AWG

Data (RS-232)

The autopilot can be connected to the “RS-232 #1” or “RS-232 #2” port (shown in RED) on each Casia X module using the provided autopilot cables in the Casia X module box. This connector is compliant with the Pixhawk connector standard (this is to stay consistent with the other ports, however Pixhawk does not support RS-232). This interface can be used to directly connect to a Piccolo autopilot without a serial converter as is required for the UART interface. Information on the specific connectors used is included:

- External Markings: RS-232 #1, RS-232 #2
- Connector Series: JST GH
- Mating Connector: GHR-06V-S
- Crimp Terminals: SSHL-002T-P0.2 (Reel)
- Suggested Wire Gauge: 28-30 AWG

Data (CAN Bus)

CAN Bus (ORANGE) is not currently supported but may be enabled in future software updates for autopilot systems that support CAN interfaces.

- External Markings: CAN 1, CAN 2
- Connector Series: JST GH
- Mating Connector: GHR-04V-S
- Crimp Terminals: SSHL-002T-P0.2 (Reel)
- Suggested Wire Gauge: 28-30 AWG

Cameras

The camera and autopilot must be connected to Casia X using the appropriate ports and cables. Casia X communicates to the autopilot using a serial port and to the cameras using GigE ports.

The cameras can be connected to any of the camera ports (shown in BLUE) on each Casia X module using the camera cables provided.

- External Markings: Cameras 1, 2, 3, 4, 5, 6
- Connector Series: CCGE-0102
- Mating Connector: IX Type A

FlightDeck

http://flightdeck.iris.com

FlightDeck is uAvionix's online portal which enables fleet-wide management of Casia devices as well as a host of other features such as:

- Software updates
- Device configuration changes
- Flight data download and analysis

To get Casia setup with FlightDeck follow the instructions in this section.

Getting Started

In order to access FlightDeck you will need a user account. These are created and activated only for customers with an active Casia annual software license or license contract and are assigned at the time of purchase.

Please contact support@uavionix.com if you require an account or account help.

SETUP

To connect Casia to FlightDeck follow these steps.

1. Power up Casia and ensure the camera is connected (if not, the system watchdog will kick in and reboot Casia, preventing FlightDeck connection).

2. Connect Casia to a network with an active internet connection using the RJ-45 Ethernet jack on the back of Casia.

3. Go to https://flightdeck.irisonboard.com and login to your account.

4. Navigate to the device page for your device and wait for the connection status to show “Connected”. This should occur within 30 seconds of step 2.

Casia Software Updates

It is vital that Casia remain updated with the latest version of the Flight Core software as uAvionix is constantly improving the performance of the DAA software, fixing issues and bugs, improving reliability, and adding important features and integrations.

Flight Core software is usually released on a 12 week cadence, however releases will occasionally be on a longer time scale if no significant changes are made within that time period and a release is not deemed necessary.

CHECKING FOR UPDATES

To check to see if your device has an update available for it, navigate to the device page within FlightDeck for your device and check for a yellow colored alert on that page. This alert will give details of the current software installed on the device and any newer versions of software that are available.

If an update is available, follow the steps below to install the newer software.

INSTALLING AN UPDATE

Connect Casia to FlightDeck as described in the previous section, once this is complete navigate to the device page and follow these steps.

1. Click the “Edit Configuration” button.

2. In the top left of the configuration page, select from the drop-down menu the software version you want to push to the device (the newest is at the top).

3. Click the “Save and Push” button to push this change to the device.

4. Wait until the update process completes, you will know this when the status indicators return to “Ready” status.

5. Done!

Note that the device configuration will reset between updates as configuration parameters occasionally change from one version to another.
You must reset your desired parameter values!

IMPORTANT: Before beginning the software upgrade process, ensure your internet connection is stable, and use shore/mains power versus battery. **Do not power cycle your device during the software update process.** Your device may restart several times during the Software Update process, and LED lights may not be displayed for a period of time. FlightDeck will indicate when the update is complete.

TOOLS

FlightDeck provides many tools, this section explains the use of these tools and the data that they can provide.

DATA UPLOAD & BACKUP

Accessing Device Data

Connect Casia to FlightDeck as described in the previous section. Once this is complete navigate to the device page and follow these steps to assess how much data is available for upload on the device.

1. Navigate to the view page of the device that you have connected.
2. Ensure that the device is online and shows “Connected” status.
3. Check the “Available Uploads” field for the number of flights worth of data that are on the device.

Note that a “Flight” is determined by a power-on of the device. FlightDeck will automatically strip any junk data. The total number of flights available after upload may therefore be less than the number indicated here if there is any in-office or bench test data on the device.

Uploading Data

Connect Casia to FlightDeck as described in the previous section, once this is complete navigate to the device page and follow these steps.

1. Navigate to the view page of the device that you have connected.

2. Ensure that the device is online and shows “Connected” status.

3. Click the “Upload Flight Data” button (indicated with an up-arrow icon.)

4. Wait for the data upload to begin. The progress of the upload can then be tracked using the “Upload Transfer Status” field on the device view page. For a more detailed breakdown, click the link in the “Upload Transfer Status” field.

5. Once the data upload is complete, Casia will return to an idle state and can be unplugged and powered off.

6. Any uploaded data will first need to be processed by FlightDeck. Once complete, the flight data will begin to populate in the “Flight History” section of the device view page.

Accessing Data

Casia does not need to be connected to FlightDeck in order to access any data that has already been uploaded. The steps below describe how to access that flight data once it has been uploaded and processed.

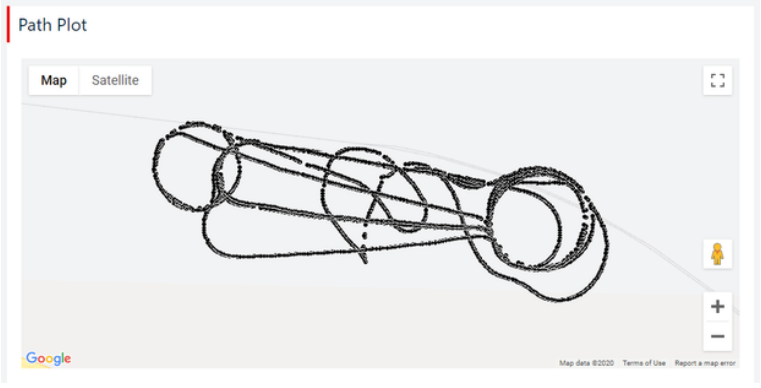
POST-FLIGHT ANALYSIS

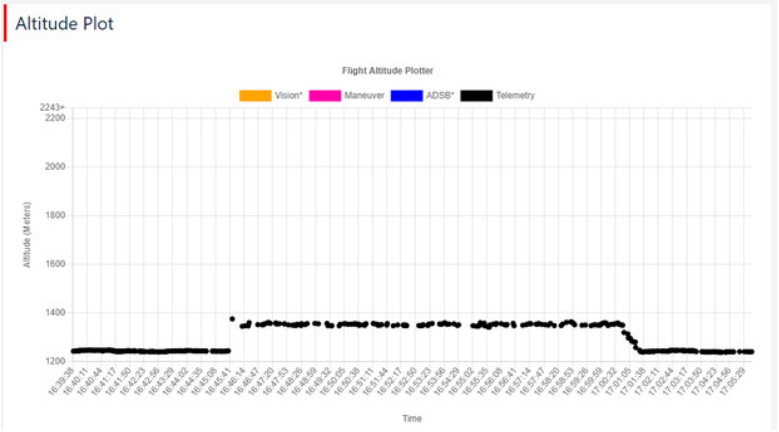
Flight Plotting

The flight can be plotted using two different tools available in FlightDeck. These tools are the Path Plotted and Altitude Plotter. Each offers a different look at the flight from a 2D perspective. The Path Plotter shows a top-down view of the flight with the path of the drone and any intruders and maneuvers plotted along that path and laid on top of a map view of the area. The Altitude Plotter gives a side view of the mission, showing the altitude of the drone during the flight and any intruders and maneuvers plotted on this altitude plot. By using these two tools it is possible to reconstruct the mission and any avoidance maneuvers or intruder intercepts from a high level.

To access the tools, navigate to the Flight View page of the desired flight that you would like to plot. Once there, click on either the “Path Plotter” button or the “Altitude Plotter” button. These buttons are located underneath the video on the Flight View page of the Flight.

Here are some examples of a flight shown on both the Path Plotter and Altitude Plotter.





Video Review

The video recorded by Casia is available once a flight is uploaded for your review. This may or may not be a continuous video clip of the entire flight, newer versions of the Casia FlightCore software do not record all the video during a flight in an effort to minimize the amount of data stored and ultimately transferred to FlightDeck. Data is recorded during a flight when events happen such as an aircraft encounter or at random intervals.

To view the video, navigate to the Flight view page either by first navigating to the device of interest, then by clicking on a flight in the Flight History list, or by navigating to the Flight List page and filtering/selecting one of the flights there. The video is then available for viewing within the FlightDeck interface on this page.

An example of a video playback in FlightDeck.

Note that for Casia X, there are multiple windows available, one for each camera of the system.

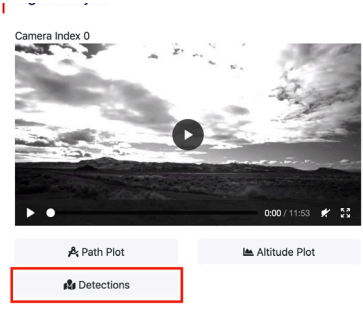
VIEW DETECTED INTRUDER DATA

Intruder aircraft detected by Casia can be viewed in FlightDeck. To access intruder data for a flight:

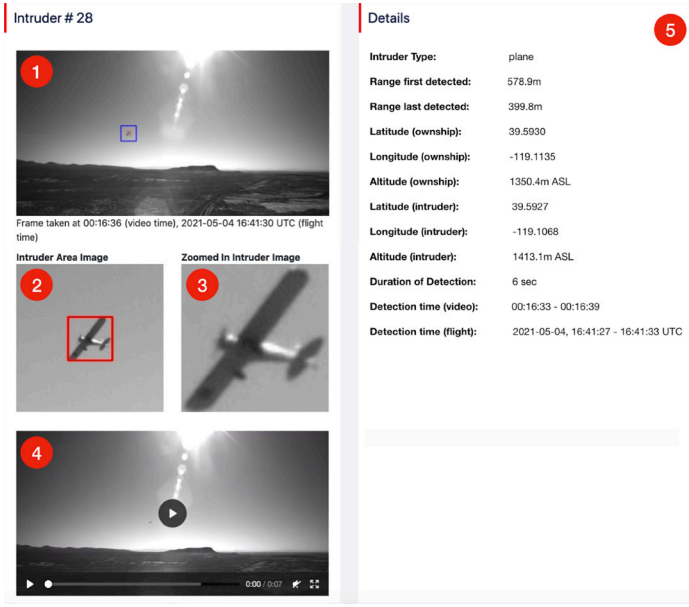
1. Connect your Casia device to FlightDeck (refer to FlightDeck ➔ Getting Started ➔ Setup).
2. Uploaded the flight data to FlightDeck (refer to FlightDeck ➔ Data Upload & Backup ➔ Uploading Data).

When the data upload and batch processing of the flight is finished, the flight will be available.

Navigate to https://flightdeck.iris.com/flights and select your flight from the list. On the right hand side under Flight Analysis, click the Detections button as shown below:



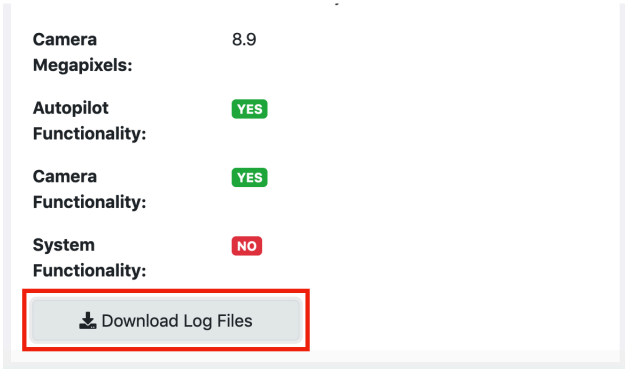
This will take you to the Detections page where you can view any intruder aircraft detected by Casia.
An example of a detected intruder is shown below:



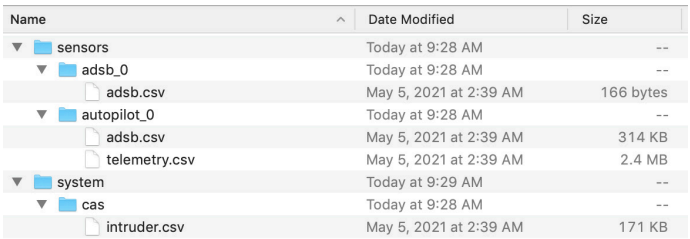
1. A frame is taken from the camera when an intruder is detected. A blue bounding box is added post-flight during the batch process in FlightDeck to make it easier for a person to see where the intruder is. The blue bounding box represents the general area where the intruder is located.
2. The Intruder Area Image is a zoomed-in image of the blue area. A red bounding box is added post-flight to highlight the intruder against the background.
3. The Zoomed-In Intruder Image is a magnified version of the red bounding box area and gives the best possible capture of the detected intruder.
4. A video clip highlights the time when the intruder is first detected and when it disappears from the camera's field of view.
5. Information such as range and the latitude, longitude and altitude of ownship and intruder are provided.

DOWNLOAD INTRUDER AND TELEMETRY DATA

Navigate to https://flightdeck.irisonboard.com/flights and select your flight from the list. Scroll to the bottom of Flight Details and click the Download Log Files button as shown below:



You will be prompted to download a zip file of the flight logs. Download the file to your local device and extract it using a program like WinRAR. You will see a file structure similar to the image below:

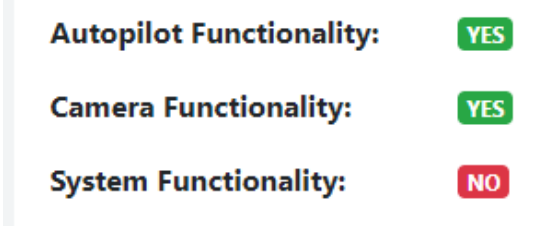


To access the Telemetry Data of the flight, navigate to the autopilot folder and open the telemetry.csv file. To access the Intruder Data of the flight, navigate to the system folder, then to the cas folder and open intruder.csv.

SYSTEM HEALTH

When data is uploaded to FlightDeck from a device, it is automatically processed by FlightDeck. During processing, FlightDeck assesses the health of the Casia system by analyzing logs, ensuring all data is present, and checking for errors and other indicators of poor performance. FlightDeck can then alert the user to issues with their Casia integration or performance.

FlightDeck breaks out its system health check analysis into three sections: Autopilot, Camera, and System. Each of which is then marked with a “YES” or “NO” indicator on the Flight View page. If any errors or issues are detected in these areas, then a “NO” will be displayed, this indicates to the user that there was an issue with a part of their Casia integration. If no issues are found, a “YES” is displayed.



An example showing an internal error was caught in a flight.

When assessing system health, uploads should show all of the status indicators as “YES” for a correctly integrated and functional system. If any “NO” messages are present, please contact uAvionix support at support@uavionix.com for further assistance in correcting the integration of the Casia system.

ADDITIONAL ANALYSIS

uAvionix has additional tools and methods of flight data analysis that are available for certain reasons such as post-incident analysis and for waiver applications. These detailed analysis tools require time from uAvionix to use and to generate a report, if you require these services please contact your account executive to arrange a detailed flight data analysis.

Configuration

Configuration of the Casia system is done through the FlightDeck which can be accessed at the following URL: https://flightdeck.irisonboard.com

ADS-B PARAMETERS

Parameter	Description	Value	Default
adsb__baud_rate	The baud rate (data transfer rate) of the ADS-B interface.	Options: 921600, 460800, 230400, 115200, 57600, 38400, 19200, 9600	57600
adsb__serial_port	The serial interface that is being used for ADS-B.	Options: USB serial port adapter and/or serial ports, Prevent ADS-B from Starting	Prevent ADS-B from Starting

AUTOPILOT PARAMETERS

Parameter	Description	Value	Default
autopilot_interface_address	The physical UART interface to use for autopilot communication.	Options: Serial 2 or several other UART and USB options	Serial 2
autopilot_interface_baud_rate	The baud rate (data transfer rate) of the autopilot serial interface.	Options: 921600, 460800, 230400 115200, 57600, 38400, 19200, 9600	57600
autopilot_type	The type of autopilot connected.	Options: Ardupilot, PX4, Piccolo, VN-200, UAVNav	Ardupilot
autopilot_telemetry rate_hz	The rate to request autopilot/ sensor to send telemetry	Units: Hz	15
autopilot_resume_waypoint_id	*Piccolo Only The ID used for the resume waypoint in the waypoint list.	Geater than 0, Less than 1000	999
autopilot_maneuver_waypoint_id	*Piccolo Only The ID used for the maneuver waypoint in the waypoint list.	Geater than 0, Less than 1000	998

COLLISION AVOIDANCE PARAMETERS

Parameter	Description	Value	Default
avoid_vertical_distance	When aircraft are detected within this vertical distance from the ownship, avoidance will be initiatedif enabled.	Units: Meters Greater than 0m	304.8m
avoid_horizontal_distance	When aircraft are detected within this horizontal distance from the ownship, avoidance will be initiatedif enabled.	Units: Meters Greater than 0m	3000m
avoid_rangefinder_max	The maximum range of the installed ground ranging device. If the aircraft is above this altitude, the system will default to using takeoff altitude reference for altitude calculations.	Units: Meters Greater than 0m, less than 122m	0m
avoid_maneuver_clearance_altitude	A minimum altitude at which the aircraft will loiter when descending. This is a safety value to prevent loitering at too low of an altitude.	Units: Meters Greater than 0m, less than 122m	61m
avoid_adsb_enabled	Allows the system to direct avoidance maneuvers based off of ADS-B targets.	Options: Enabled, Disabled	Disabled
avoid_vision_enabled	Allows the system to direct avoidance maneuvers based off of vision targets.	Options: Enabled, Disabled	Disabled
avoid_maneuver_enabled_altitude	An altitude beneath which a collision avoidance maneuvers will not be executed. This is a safety value to prevent avoidance maneuvers during take-off and landing. If avoid__coordinate_frame is **AMSL**, this value needs to be an altitude above mean sea level, not above ground.	Units: Meters Greater than 0m, less than 122m	91m
avoid_target_altitude	The altitude for the collision avoidance loiter maneuver. This is value is used in different ways depending on the avoid__target_altitude_reference parameter. A **relative** avoid__target_altitude_reference necessitates a **negative** value for a descent. An **absolute** avoid__target_altitude_reference necessitates a **positive** value dependent on avoid__coordinate_frame. If avoid__coordinate_frame is **AMSL**, this value needs to be the altitude above mean sea level to loiter.	Units: Meters	15.24m

COLLISION AVOIDANCE PARAMETERS

Parameter	Description	Value	Default
avoid__coordinate_frame	The altitude reference used when conducting collision avoidance maneuver. **ATO**: Relative altitude from take-off point. **AGL**: Above Ground Level altitude, requires laser altimeter or other ranging device integration with autopilot. **AMSL:** Above Mean Sea level altitude reference. **ATL:** : Above terrain level altitude reference. ATO not supported by the Piccolo autopilot ATL is only supported by the ArduPilot **IMPORTANT**:Fixed wing aircraft avoid by descending and loitering. The descent will account for terrain level at the point when the avoidance maneuver is triggered and convert the target loiter altitude to AMSL. Once the aircraft has descended to the AMSL loitering altitude, the AMSL loiter altitude will be maintained until the mission is resumed. The gradient of the terrain and the radius of the loiter should therefore be taken into account for safety purposes.	Options: ATO, AGL, AMSL, ATL	ATO
avoid__target_altitude_reference	The way in which the avoid__target_altitude parameter is used when conducting a collision avoidance maneuver. **Absolute**: The drone will go to the altitude specified by the avoid__target_altitude parameter in the altitude reference frame specified by avoid__coordinate_frame. **Relative**: The drone will change its altitude by the avoid__target_altitude amount, relative to the altitude the drone was flying at when the maneuver was executed (e.g. will descend by X feet from current altitude).	Options: Absolute, Relative	Relative
avoid_autoresume_timeout	Duration of time since last detection of intruder before mission is resumed.	Units: Seconds Greater than 0s	60 seconds

COLLISION AVOIDANCE PARAMETERS

Parameter	Description	Value	Default
avoid__autore-sume_enabled	Return the aircraft to autonomous flight after a specified avoid_autoresume_ timeout after an avoidance maneuver is triggered. This is misspelled as cas_send_resume_ manevuer in V0.21.2	Options: Enabled, Disabled	Disabled
avoid_autore-sume_timeout	Duration of time since last detection of intruder before mission is resumed.	Units: Seconds Greater than 0s	60 seconds
avoid_autore-sume_waypoint_ enabled	**Piccolo Only** If enabled, after an avoidance maneuver the autopilot will proceed back to where an avoidance maneuver started, using the resume waypoint, before resuming the mission	Options: Enabled, Disabled	Enabled
avoid_loiter_ra-dius	**Piccolo Only** Loiter radius when performing an avoidance maneuver	Units: Meters	100

CAMERA PARAMETERS

Parameter	Description	Value	Default
camera_pitch_angle	**Casia I Only** The pitch angle that the camera is mounted on the drone relative to the autopilot XY plane. This is used for tuning the physical mount of the camera to the telemetry data provided by the autopilot. Positive is nose up, negative is nose down.	Units: Degrees Greater than -15 deg, less than 15 deg	0 deg

NOTIFICATION PARAMETERS

Parameter	Description	Value	Default
constant__notify_horizontal_distance	Aircraft detected within the horizontal distance specified by this parameter will generate alerts.	Units: Meters Greater than 0m	10000m
constant__notify_vertical_distance	Aircraft detected within the vertical distance specified by this parameter will generate alerts.	Units: Meters Greater than 0m	1200m

DATA CAPTURE PARAMETERS

Parameter	Description	Value	Default
data_capture__ random_trigger_ enabled	When enabled, Casia will collect random data throughout the flight. Disable to minimize the flight data storage usage.	Options: Enabled, Disabled	Enabled
data_capture__ random_trigger_ duration_percent	Percentage of frames within the trigger window length that will send triggers. For example, if this value is sent to 10 percent, then 10% of all frames send a trigger to force video capture. Note: A single trigger can cause up to 3x the size of recorded video segments.	Options: 100 Percent, 10 Percent	10 Percent

DETECTION PARAMETERS

Parameter	Description	Value	Default
detection__classification_model	Selects which deep learning classifier model to use, a new preview model, or the stable release version.	Options: Stable, Preview	Stable
detection__below_horizon_enabled	When enabled, allows detections below the horizon.	Options: Enabled, Disabled	Disabled
detection__camera_count	The number of cameras connected to the device.	Greater than 0	1 for Casia I, 5 for Casia X

Configuration Management

It is essential for safety systems to have a configuration management tool that allows for detailed record keeping and assessment of the equipment itself in accordance with operating procedures and manuals.

For Casia, configuration management is achieved through the FlightDeck system, the tools and controls provided by FlightDeck are described here.

ACCESS CONTROL

Access to the Casia device configurations is restricted to those that have a user account on the FlightDeck system with the adequate permissions.

In order to be able to access and modify the configuration of the Casia device, a user must have the following in addition to access to the Casia device itself.

- A FlightDeck user account
- Be registered as a user of the organization that owns the device
- Have the Device Manager user role

Initial users for an organization are configured by the uAvionix Support Engineering team when a new Casia device is purchased.

New users can be designed to have the above listed permissions and they should be carefully chosen and controlled by the organization in order to limit the access control of Casia devices to personnel who are authorized to have such access.

User Roles

Organization Administrator

Organization Administrators have the following abilities and permissions.

- View, create and manage users within the organization
- View and manage all devices within the organization

Device Manager

Device Managers have the following permissions.

- View and manage all devices within the organization

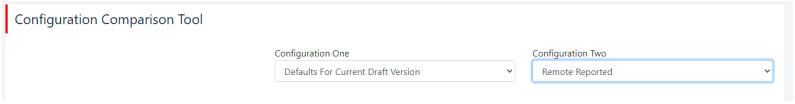
Verification

Configuration verification is performed using the configuration comparison tool within FlightDeck. This tool allows a user to view and compare device configurations with one another.

To enter the configuration comparison tool, click the button with the double arrow icon as shown above. This button is located on the device view page.

These configurations can be sourced from the device itself, from historical configurations of the device, or from default configurations for particular software versions.

When viewed side by side, two configurations can then be compared. Each configuration parameter is shown as it is configured within the selected configuration and any changes or differences between the two selected at the time are highlighted.



In this example, the default configuration values for the device are compared with the values reported from the device at present.

This highlight allows the user to see and verify that the specific settings they desire are configured as such on a device or changed since the last update to the device configuration.

Here it is possible to see the difference between the default value and the remotely reported value for this parameter.

Change Approval

Changes to devices cannot be made without several steps which require the user to approve those changes before they are pushed to the device, the steps described here prevent users from accidentally changing configuration parameters without knowingly doing so.

When making configuration changes to the device, the user must enter the device configuration tool page of the device management interface. On this page they can draft changes to the device before they are pushed and executed on the device itself. The user can select the desired software version as well as configuration parameter values.

Note that none of these selections alters the device at this draft stage!

Once the user has configured their selects as they desire, these selections can be saved as a draft. Drafts are not pushed to or executed on the device and exist solely within the FlightDeck online portal. These drafts can also be made without the device being connected at the time, this gives another layer of protection ti the device for accidental changes.

If a draft is approved by the user to be the desired device configuration, the user must then push these changes to the device itself. Once pushed, the device will execute the desired changes, including any alterations in software version, that are necessary from its current configuration at the time.

Once a configuration is pushed to a device, the device will attempt to complete these changes until it has finished. It is important to allow this process to complete and the device status to return to a “Ready” state to ensure that the changes were executed correctly and completely before operating the device again.

Change Tracking

At all times changes to devices are tracked by FlightDeck, each device has a history that can be viewed on the device view page of the site. All changes are timestamped, the user that made the changes is logged, and the specific details of the configuration and the parameters is also logged. These logs are kept indefinitely once a device leaves uAvionix's facility and is shipped to the customer for traceability.

Historical changes made to the device can also be viewed in detail using the configuration comparison tool described in the "Verification" section above in this document. By doing this it is possible to see precisely the differences between the device as it was at any point in time, including the present configuration.

If un-desired changes or alterations are detected, the responsible party can be easily identified along with timestamp information, and specifics on the changes made by that user.

Note that other user metadata is also accessible in the case of an incident that can be extracted by uAvionix staff upon request.

Verification & Validation

The procedures in this section detail how an integration of Casia onto your aircraft is verified and validated for use in regular operations.

These procedures and checks must be completed before Casia can be used for regular flight operations.

GROUND TESTING

Ground testing is performed to validate the following elements of the installation with your drone. Once these elements have been tested it is safe to fly for the first time with the Casia system installed, however this will be a limited flight in order to complete validation of the system components and tests that can only be performed in flight.

- Power and data connections to all cameras
- Data connection to the autopilot
- Casia software configuration
- Internal Casia systems and software

Procedure

1. Install the Casia system as described in the Installation section of the User guide.

2. Take detailed photos of the installation showing the following:
   - Overall drone shot
   - Close-ups of the Casia module(s)
   - Close-ups of the camera(s)

3. In your office, power on the drone. Make sure to remove all propellers and other systems that may cause injury!

4. Follow the Pre-Flight Checklist part of the User guide.

5. Leave the system to run for 5 to 10 minutes and gather some data.

6. Remove power and re-power the drone and repeat this process two more times.

Data Review

By following the procedure in the previous section data is generated and logged by Casia that is used to determine the validation of this step. The data needs to be uploaded and inspected by an uAvionix Support Engineer in order to proceed further, please follow these steps to complete this step.

1. Contact support@uavionix.com and mention that you would like to validate the ground tests of your Casia installation. Include the photos you took of the drone during the procedure above.

2. Connect your Casia to FlightDeck and upload data from the device for inspection as detailed in the FlightDeck section of the User guide.

3. Receive confirmation from uAvionix Support that you can proceed, or advice on any changes or fixes that need to be completed. Repeat these steps and work with your support representative until confirmation is received to proceed.

Flight Testing

Flight testing is performed to validate the following. Once this is completed it is possible for uAvionix trained personnel to give a final sign-off of the installation and for the Casia system to be used for regular operations. At this point the installation is complete!

- Camera positioning
- Camera calibration and focus
- Camera settings
- Autopilot connection
- Internal Casia systems and software
- Casia configuration

Procedure

1. Setup your drone to fly an automated simple short range flight lasting 5 to 10 minutes total. A recommended flight pattern is shown to the right.
2. Setup your drone and prepare for flight. Follow the Pre-Flight Checklist part of the User guide.
3. Take-off and allow the drone to complete the flight pattern.
4. Complete the Post-Flight Checklist part of the User guide.
5. Remove power and re-power the drone and repeat this process two more times.

Data Review

By following the procedure in the previous section data is generated and logged by Casia that is used to determine the validation of this step. The data needs to be uploaded and inspected by an uAvionix Support Engineer in order to proceed further, please follow these steps to complete this step.

1. Contact support@uavionix.com and mention that you would like to validate the flight tests of your Casia installation.

2. Connect your Casia to FlightDeck and upload data from the device for inspection as detailed in the FlightDeck section of the User guide.

3. Receive confirmation from uAvionix Support that you can proceed, or advice on any changes or fixes that need to be completed. Repeat these steps and work with your support representative until confirmation is received to proceed.

SIGN-OFF

Final sign-off on an installation is given by an uAvionix Support Engineer or a trained representative with the authorization of uAvionix to make this determination. Only once final sign-off has been received is the Casia system integration complete and can be used for regular flights including BVLOS operations.

Autopilots

This section describes how to configure your autopilot to correctly support the Casia system. Ensure that you reboot the autopilot after changing these settings before flying the aircraft as some settings require a reboot before they take effect!

ARDUPILOT

BENEFITS

Textual Alerts

ArduPilot supports forwarding of text alerts from Casia to the Ground Control Station software. This enables Casia to make positive alerts to the RPIC of intruder aircraft detections, avoidance maneuver execution, and in-flight detected errors. These informational and situational awareness capabilities are highly recommended for all drone operations and may be required for some regulatory compliance reasons.

LIMITATIONS

Heartbeat Monitoring

ArduPilot does not support the heartbeat monitoring that other autopilot platforms such as PX4 support. This means that if during flight there is an error or hardware failure that causes Casia to no longer be able to communicate with the autopilot, the autopilot and RPIC will not be alerted to the loss of heartbeats from the Casia system. This would result in the flight continuing even though DAA functionality is no longer available. It may be required for some regulatory compliance reasons that this feature is supported, if this is the case please work with uAvionix support and regulations teams to determine the best course of action for your CONOPS.

Note that heartbeat monitoring is required by the ASTM DAA Minimum Operational Performance Standard!

ArduPlane Telemetry Reliability

We have observed on the majority of ArduPlane releases over the last two years that the telemetry provided by the autopilot to Casia can be extremely slow and unreliable. Casia requests frequent telemetry updates from the autopilot (at approximately 30Hz) however ArduPlane does not appear to be able to provide telemetry at a rate more than approximately 3Hz, in comparison to other firmware versions such as ArduCopter and PX4 that do not have trouble with this. We recommend that during integration you work closely with uAvionix support staff to verify and validate your integration if using ArduPlane firmware.

Parameter	Value	Description
SERIAL_X_BAUD	57	Serial baud rate for the Casia connected serial port X (Where X can be 1, 2, 3, 4, or 5 for Pixhawk 2.1). Note that the value of 57 represents an actual baud rate of 57600.
SERIAL_X_PROTO-COL	1	MAVLink version used for serial port being used by Casia, replace X with the serial port being used (Where X can be 1, 2, 3, 4, or 5 for Pixhawk 2.1)
WP_LOITER_RADIUS	-	Sets the radius at which the drone will loiter around the collision avoidance point. Should be a **POSITIVE** value to ensure that the aircraft loiters in a clockwise direction in accordance with aviation right-of-way standards. This parameter is aircraft specific and only applies to fixed-wing type aircraft, set this to an appropriate value for your aircraft.
LIM_ROLL_CD	-	Sets the maximum bank angle of the aircraft when in a turn. This will override the WP_LOITER_RADIUS if the aircraft cannot turn at the desired radius, causing too high of a bank angle. This parameter is aircraft specific and only applies to fixed-wing type aircraft, set this to an appropriate value for your aircraft.
MIS_RESTART	0	Configures the behavior of the drone when exiting a collision avoidance maneuver and returning to the automatic mission. When set to 0 the mission will be resumed, when set to 1 the mission will be started again from the first waypoint which for long missions may cause significant detour!
ADSB_ENABLE	1	Enables intruder aircraft ground-station notification from the Casia device.

Parameter	Value	Description
AVD_ENABLE	0	Disables the automatic ADS-B avoidance from the intruder ground notification downlink message and ensures that Casia maintains avoidance control during an encounter with another aircraft.
ADSB_LIST_RADIUS	2000	Filters out intruder aircraft that are further away than the defined distance (in meters), we recommend a distance of 2km to ensure that and ADS-B tracks from distant aircraft and not visible and do not clutter the groundstation interface.
Q_GUIDED_MODE	1	Only applies to hybrid VTOL aircraft. This setting enables the use of VTOL mode (hovering) when in guided flight mode (as is the case during a collision avoidance maneuver). If this is not enabled, the aircraft will transition to forward flight when the avoidance maneuver is commanded! When enabled, the aircraft will always transition into VTOL mode when the collision avoidance maneuver is commanded.

Setting SRx Parameters for ArduPilot 4.x and Above

Casia requests telemetry messages at a certain frequency using the MAV_CMD_SET_MESSAGE_INTERVAL command. Telemetry messages requested by MAV_CMD_SET_MESSAGE_INTERVAL may conflict with telemetry stream rates configured via the firmware's SRx parameters. The numeric value after the SR roughly corresponds to the telemetry port on the PixHawk itself, so that SR2_* parameters represent the stream rates of telemetry served from the PixHawk's telem2 port.

If connecting Casia to the telem2 port on the PixHawk, **set all SR2_* parameters to 0**

For more information about the SRx parameters, see https://ardupilot.org/dev/docs/mavlink-requesting-data.html

PX4

BENEFITS

Heartbeat Monitoring

PX4 does support heartbeat monitoring for onboard controllers and other peripheral devices installed on the drone and connected to the autopilot. This means that if during flight there is an error or hardware failure that causes Casia to no longer be able to communicate with the autopilot, the autopilot and RPIC will be alerted to the loss of heartbeats from the Casia system by the autopilot and appropriate actions can be taken to mitigate this failure. It may be required for some regulatory compliance reasons that this feature is supported.

This alert will take the form of a textual alert to the ground control station that the autopilot generates. These alerts are displayed as described in the Ground Control Stations section of this document. Currently in PX4 the alert is generated only once when the lost heartbeat is first detected, the ground control station will not be alerted more than once for a single heartbeat failure. If the heartbeats resume and then are lost again, another failure alert is sent to the ground control station by the autopilot.

Note that heartbeat monitoring is required by the ASTM DAA Minimum Operational Performance Standard!

LIMITATIONS

Textual Alerts

PX4 does not support forwarding of text alerts from Casia to the Ground Control Station software. This feature enables Casia to make positive alerts to the RPIC of intruder aircraft detections, avoidance maneuver execution, and in-flight detected errors. These informational and situational awareness capabilities are highly recommended for all drone operations and may be required for some regulatory compliance reasons, if you are using PX4 please work with uAvionix support and regulations teams to determine the best course of action for your CONOPS.

CONFIGURATION

Parameter	Value	Description
MAV_X_CONFIG	0 - Disabled 6 - UART 6 101 - TELEM 1 102 - TELEM 2 103 - TELEM 3 104 - TELEM 4 201 - GPS 1 202 - GPS 2	MAVLink version used for serial port being used by Casia, replace X with the serial port being used. Set the value to one of the defined numbers corresponding to the physical port on the Pixhawk being used for Casia communication
MAV_X_FORWARD	1 - Enabled	If enabled, forward incoming MAVLink messages to other MAVLink ports if the message is either broadcast or the target is not the autopilot. This allows for example a GCS to talk to a camera that is connected to the autopilot via MAVLink (on a different link than the GCS).
MAV_X_MODE	0 - Normal	The MAVLink Mode defines the set of streamed messages (for example the vehicle's attitude) and their sending rates. A value of 0 sets this to normal mode.

Parameter	Value	Description
MAV_X_RATE	7200	Configure the maximum sending rate for the MAVLink streams in Bytes/sec. If the configured streams exceed the maximum rate, the sending rate of each stream is automatically decreased. (7200 Bytes/s is 57600 bits/s divided by 8 bits/Byte)
SER_TELX_BAUD	57600	Serial baud rate for the Casia connected serial port X (Where X can be 1, 2, 3, 4, or 5 for Pixhawk 2.1).
NAV_LOITER_RAD	-	Sets the radius at which the drone will loiter around the collision avoidance point. Should be a **POSITIVE** value to ensure that the aircraft loiters in a clockwise direction in accordance with aviation right-of-way standards. This parameter is aircraft specific and only applies to fixed-wing type aircraft or VTOL aircraft that are flying in fixed-wing mode at the time of the avoidance maneuver being issued, set this to an appropriate value for your aircraft.
NAV_TRAFF_AVOID	0 - Disabled 1 - Groundstation Warning	Sets the automatic ADS-B avoidance from the intruder ground notification downlink message and ensures that Casia maintains avoidance control during an encounter with another aircraft. 0 - Disables the features, 1 - will issue a groundstation warning only.

PICCOLO

BENEFITS

This autopilot is the only autopilot supported by some drone manufacturers.

LIMITATIONS

Aircraft Location Indication

The Piccolo autopilot by default does not support the ability for onboard equipment to transmit intruder aircraft location information to the ground control station without modification of the ground control station software. This means that positional information of detected aircraft intruders are not available to the ground control station operator.

While not supported currently, this feature can be developed. Please contact your account executive to discuss pricing.

CONFIGURATION

Parameter	Value	Description
COMX Baud	57600	Serial baud rate for the Casia connected serial port X (Where X can be 1, 2, 3, 4, or 5 for Pixhawk 2.1).
COMX Protocol	Comm No Timeout Refresh	Specific method the autopilot uses to handle communications on this port. If not set to this value, the autopilot will not initiate a lost C2 link failsafe as messages from Casia are interpreted in such a way as to trick the autopilot into thinking it still has a C2 connection with the ground control station.

UAV NAVIGATION

Benefits, limitations and conguration information coming soon. Contact support@uavionix.com for details.

HARDWARE INTERFACE

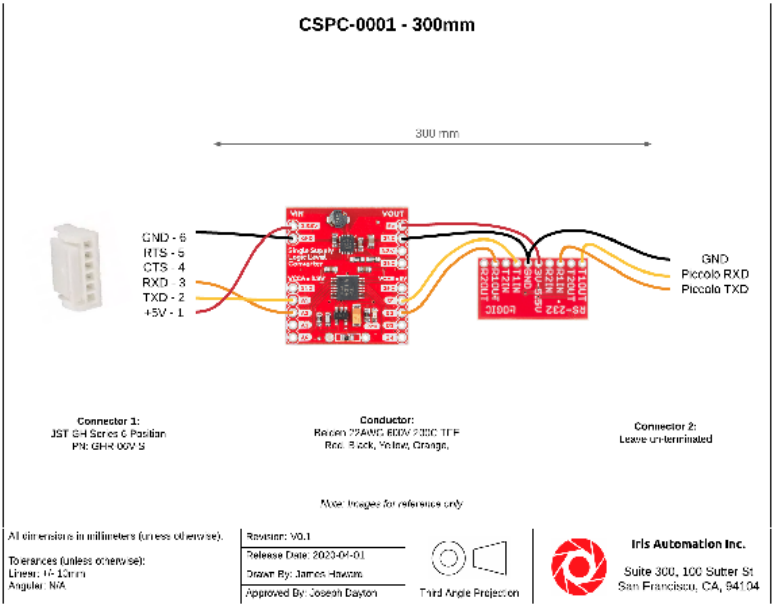
The Piccolo autopilot uses an RS-232 serial interface to communicate with on-board equipment. Casia X is only equipped with a TTL UART serial interface and therefore must be used with a UART to RS-232 converter when configured with Piccolo. These converters are available from uAvionix or can be developed guidance from uAvionix.

It is important to note that Casia operates the TTL UART serial ports at 3.3V, most off the shelf RS-232 converters operate at 5.0V!

The converters that uAvionix provides use the 5.0V supply from the UART port and convert it to 3.3V before applying the RS-232 conversion.

The following wiring diagram details how to build one of these converters yourselves. The required parts are linked below:

- Sparkfun Single Supply Logic Level Converter
- Sparkfun RS-232 Converter



This harness needs to be connected to the appropriate pins on the Piccolo autopilot interface connector. The specifics of the interface used by Casia are as follows, and can also be found in the Piccolo hardware documentation.

Interface: Payload/Serial

TXD Pin: 34

RXD Pin: 33

GND Pin: 4

Since there is a single connector on the Piccolo side, the customer is responsible for terminating the wires from the uAvionix cable harness to the Piccolo autopilot connector.

AVOIDANCE MANEUVER SPECIFICS

The Piccolo autopilot does not have “modes” in the same way that the PX4 and Ardupilot autopilots do. Because of this, the way avoidance maneuvers are handled on Piccolo are different to the way that they are handled on the other two autopilots. This section details the specifics of how avoidance maneuvers have been implemented on the Piccolo autopilot without the ability to use modes.

Entering Avoidance

When an avoidance maneuver is deemed necessary, two new waypoints will be created in the Piccolo flight plan. A waypoint is created for the location of the desired avoidance maneuver, and another is created at the current location of the aircraft when the avoidance was created so that it can resume at the correct location. Once these waypoints have been injected into the flight plan, the autopilot will be directed to immediately target the avoidance maneuver waypoint instead of its current mission.

Piccolo has a limited number of waypoints that can be used for a mission. Because of this Casia will by default use the same waypoint numbers in the “reserved” section of the waypoint list as described below. These values are configurable for your use case however, please see the Configuration section of the user guide for more details, see autopilot_maneuver_waypoint_id and autopilot_resume_waypoint_id.

Waypoint ID Default	Name	Description
998	Maneuver Waypoint	This is the waypoint that the drone is directed to in order to execute the configured collision avoidance maneuver according to the collision avoidance parameters.
999	Resume Waypoint	This is the waypoint that the drone is directed to when resuming a mission after the configured avoidance maneuver has been completed. This is only used if the autopilot_use_resume_maneuver parameter is true.

In order to prevent conflicts with mission planning, you must leave waypoint locations 998, and 999 (or those IDs configured by the parameters in the configuration section) free from any mission waypoints!

If this is not done then the mission waypoints will be over-written in flight to enable the collision avoidance maneuver.

Exiting Avoidance

Once the avoidance maneuver has been completed, the autopilot will be directed to resume the maneuver (if the resume feature is being used).

If the autopilot_use_resume_maneuver parameter is set to true then the drone will go back to the resume waypoint (at the location where the avoidance happened) before going to continue on with the rest of the mission. It will be directed to target the resume waypoint. This waypoint's "next waypoint" parameter is configured to target the waypoint that the drone was traveling to before the avoidance maneuver was executed. It is in this way the drone is directed back onto the mission it was previously following without disruption.

If the autopilot_use_resume_maneuver parameter is set to false, then instead of heading back to the location where it started the avoidance maneuver, the drone will be directed to go to the next waypoint in the mission that it was heading to before the avoidance began.

Note that the maneuver and resume waypoints are not deleted from the mission plan after an avoidance is executed. If another avoidance is required, the same waypoints will be used but updated to the new avoidance locations.

Ground Control Stations

The procedures in this section detail how an integration of Casia onto your aircraft is verified and validated for use in regular operations.

These procedures and checks must be completed before Casia can be used for regular flight operations.

QGroundControl

QGroundControl is commonly used with the PX4 autopilot, however does also support other MAVLink compatible autopilots such as ArduPilot.

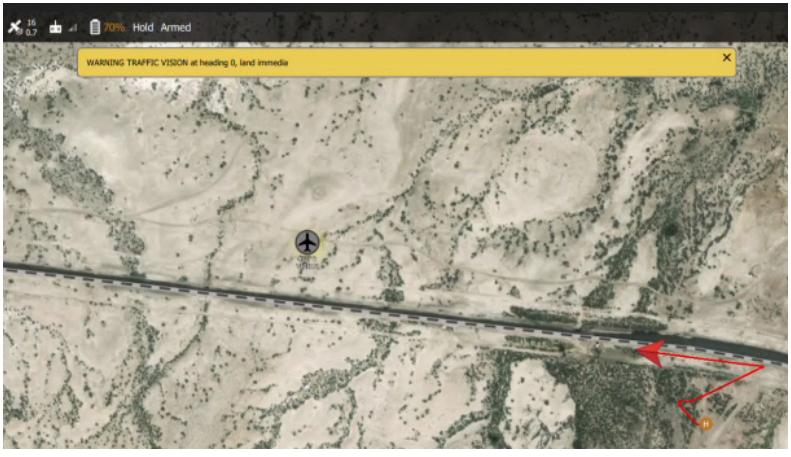
BENEFITS

Alerts

During flight Casia generates several alerts that must be displayed to the RPIC for safety, situational awareness, and sometimes regulatory compliance reasons. QGroundControl implements these alerts as visual and auditory pop-ups within the user interface which are very clear for the RPIC to notice and utilize in their decision making.

This is in contrast to the alert display in some other ground control station software such as Mission Planner, because of this, QGroundControl is the preferred ground control station software that uAvionix recommends.

An example of one of these alerts is shown below. Additionally these alerts are converted to speech by the software and provide an auditory warning.

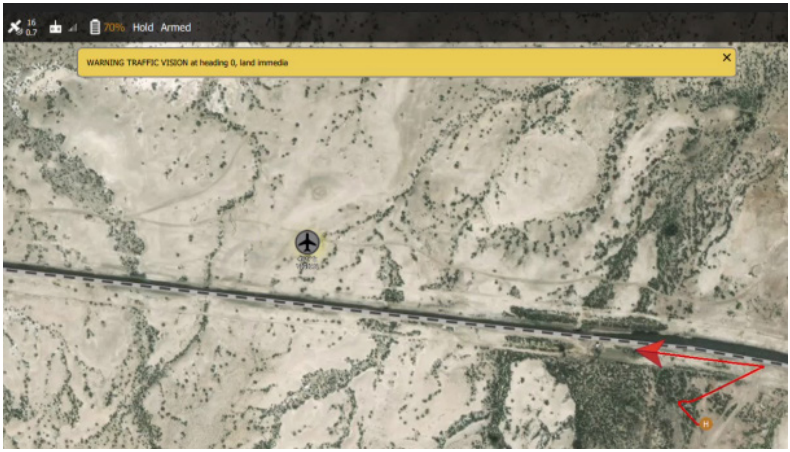


USAGE

Intruder Display

When intruder aircraft are detected by Casia they will be forwarded to the autopilot. The autopilot then sends this information to the ground control station for display to the remote pilot.

QGroundControl implements this display as a small aircraft icon within the user interface as demonstrated in the next image (where the red arrow is the ownship and the grey airplane icon is the detected intruder).



QGroundControl also displays the callsign of the intruder and the MSL altitude of the intruder below the icon in small white text.

Note that the callsign “VISION” is used by Casia when communicating intruders detected using the vision system.

Avoidance Maneuver

When an avoidance maneuver is issued by Casia, the RPIC is alerted to this by the mode change of the autopilot which is displayed within the ground control station software and can additionally be configured to be an auditory alert.

The autopilot mode is displayed within the top bar of the QGroundControl interface, as shown in the images on the right the mode changes from Auto to Hold when the avoidance maneuver occurs.

Mission Planner

Mission Planner is commonly used as the primary ground control station for the ArduPilot autopilot software.

LIMITATIONS

Alerts

During flight Casia generates several alerts that must be displayed to the RPIC for safety, situational awareness, and sometimes regulatory compliance reasons. Mission Planner implements these alerts as a small textual output hidden in a sub-tab of the user interface and displayed amongst other output messages from the autopilot during flight. Additionally, it is not possible to have these messages read out to the RPIC in an auditory manner meaning that if the textual message is missed, there will be no other opportunity to communicate the alert.

This is in contrast to the alert display in some other ground control station software such as QGroundControl, because of this, Mission Planner is not recommended as the GCS of choice by uAvionix.

An example of one of these alerts is shown below in the small white text on the bottom left.

USAGE

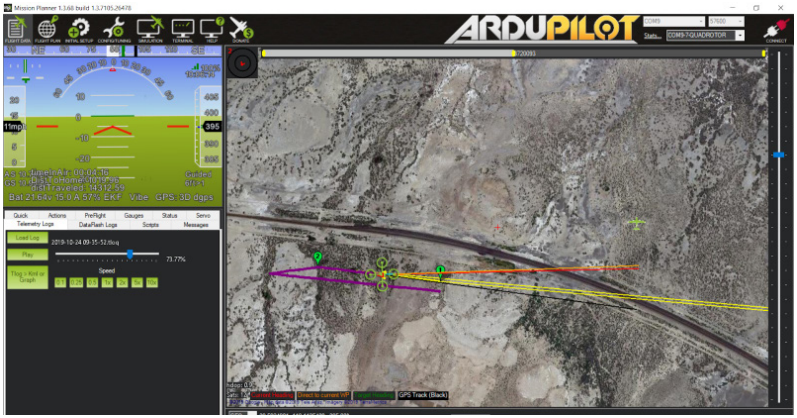
Intruder Display

When intruder aircraft are detected by Casia they will be forwarded to the autopilot. The autopilot then sends this information to the ground control station for display to the remote pilot.

Mission Planner implements this display as a small aircraft icon within the user interface as demonstrated in the image below (where the green multi-rotor icon is the ownship and the green airplane icon is the detected intruder).

Mission Planner also displays the callsign of the intruder if the intruder icon is clicked on in the user interface.

Note that the callsign “VISION” is used by Casia when communicating intruders detected using the vision system.



Avoidance Maneuver

When an avoidance maneuver is issued by Casia, the RPIC is alerted to this by the mode change of the autopilot which is displayed within the ground control station software and can additionally be configured to be an auditory alert.

The autopilot mode is displayed within the heads up display of the Mission Planner interface in the bottom right of this UI section in white test, as shown in the images on the right the mode changes from Auto to Guided when the avoidance maneuver occurs.

APM Planner

APM Planner is officially supported by the ArduPilot community however is untested by uAvionix due to its low usage within the industry. While it is likely that many features that MissionPlanner implements are also supported on APM Planner, it is not supported by uAvionix and the operator must confirm themselves that it is adequate.

ADS-B Receivers

The following ADS-B receivers are supported by Casia. This section details instructions for their use

uAvionix PingRX

Instructions coming soon To leverage a uAvionix's PingRX ADS-B receiver with Casia X, connect it to the UART 1 or UART 2 ports using the native cabling. The Flightdeck configuration must match the port being used as well as the correct baud rate specified by the ADS-B receiver.
Once connected, Casia will pass along the received packets to your autopilot. See the ADS-B and Avoid Parameters sections of the Configuration chapter of this user guide for guidance on available parameters which can be set in Flightdeck.

uAvionix PingRX Pro

The integration of uAvionix's PingRX Pro ADS-B receiver with Casia is the same as with uAvionics PingRX.

uAvionix Ping2020

The integration of uAvionix's Ping2020 ADS-B receiver with Casia is the same as with uAvionics PingRX. While uAvionics Ping2020 ADS-B receiver has not been specifically tested with Casia, it should work just fine. However, we recommend you test fully.

Test this integration fully.

Aerobits TID-Aero

The integration of Aerobits TID-Aero ADS-B receiver with Casia is the same as with uAvionix's PingRX. While Aerobits TID-Aero ADS-B receiver has not been specifically tested with Casia, it should work just fine. However, we recommend you test fully.
The baud rate for this device is 115200 rather than the default 57600 and this needs to be specified in the Casia configuration for the device to function correctly. See the ADS-B and Avoid Parameters sections of the Configuration chapter of this user guide for guidance on available parameters which can be set in Flightdeck.

Test this integration fully.

OPERATING INSTRUCTIONS

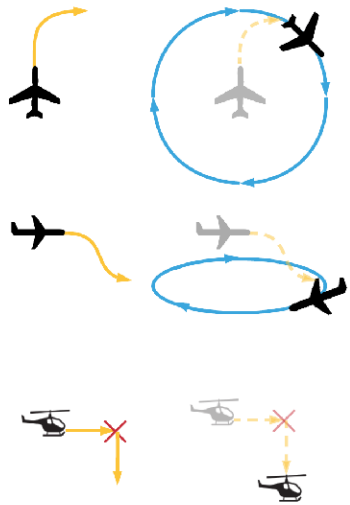
Collision Avoidance Behavior

Physical Avoidance Maneuver

Casia uses a standardized avoidance maneuver for all intruder encounter scenarios. This maneuver has been validated through simulation and flight testing to provide the best balance between simplicity and ease of implementation and support by different autopilots, as well as maximizing the ability to maintain separation between the drone and the intruder aircraft.

This maneuver is a “descend and loiter” maneuver, however depending on the specific airframe of your drone platform, this may be initiated by the autopilot system in different ways. Please see the following table for what the avoidance maneuver will be for your specific aircraft type.

Airframe Type	Maneuver
Fixed-Wing	Descending right hand turn loiter May vary depending on Autopilots support, flight mode, and configuration
Fixed-Wing VTOL	Descending right hand turn loiter May vary depending on Autopilots support, flight mode, and configuration
Multi-Rotor	Stop, descend, and loiter
Helicopter	Stop, descend, and loiter



Avoidance Workflow

INTRUDER DETECTION

Casia can detect intruder aircraft through a number of different sensing modalities, these intruder detections are then passed on to the Collision Avoidance Subsystem for processing.

Casia uses a computer vision system as the primary means of cooperative and non-cooperative aircraft detection but can also process and use intruder data from ADS-B information received by the autopilot (e.g. from sensors such as the uAvionix Ping).

ENTERING AVOIDANCE

When intruders are detected the GCS will immediately be notified via the Autopilot. These alerts are processed and presented to the user in different ways for different Ground Control Station software packages, please see the Ground Control Stations page in the user guide for more information on this.

Once an intruder aircraft is within the distance defined by the "*Avoidance Boundary*" , defined at 3000 meters horizontal and 304.8 meters vertical of the drone, an avoidance maneuver will be executed immediately.

The specific maneuver that is constructed and executed is built form the current telemetry from the autopilot and the rules defined in the collision avoidance parameters from the Casia configuration, please see the Configuration section of the user guide for more details.

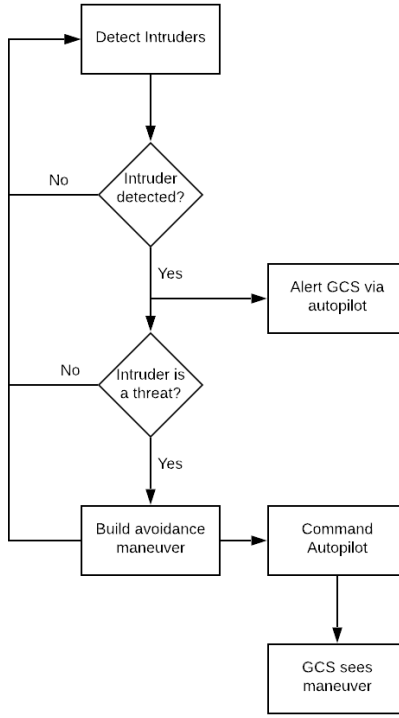
Once an avoidance maneuver is built, this maneuver is immediately commanded to the autopilot for execution. There is no opportunity for a "human in the loop" setup that would first ask for the operator's approval. This is intentionally designed to ensure that the system can maintain complete functionality even in the event of a GCS connection loss, and to work around the inherent un-reliability and delay of requiring human input in fast-paced and uncertain environments.

GCS connection loss, and to work around the inherent un-reliability and delay of requiring human input in fast-paced and uncertain environments.

The GCS operator is then notified that an avoidance maneuver has taken place by monitoring the mode of the autopilot. When avoiding a collision the autopilot will switch into the mode used by Casia for avoidance as defined by the following table.

Autopilot	**Avoidance Mode**
ArduPlane	“Guided” Mode
ArduCopter	“Guided” Mode
PX4	“Hold” Mode
Piccolo	N/A - A new avoidance waypoint will be injected in the flight plan

The complete flow-chart for initiating an avoidance maneuver is displayed below.


Detect Intruders
Intruder detected?
No
Yes
Alert GCS via autopilot
Intruder is a threat?
No
Yes
Build avoidance maneuver
Command Autopilot
GCS sees maneuver

EXITING AVOIDANCE

Manual

The remote pilot may exit the avoidance maneuver at any time and continue the mission by switching the aircraft back into another flight mode such as “Auto” or “*Fly-By-Wire*”.

Note that if you have enabled the automatic mission resume described below, it is possible that Casia will command the autopilot to go into “Auto” mode even if the remote pilot has already commanded it into another mode such as “*Fly-By-Wire*”.

Automatic

When the automated mission resume feature is enabled, Casia will return to the automated mission being flown before the avoidance maneuver was initiated. This allows for hands-free automation of the entire flight without requiring any remote pilot intervention even in the case that an avoidance is required during the flight. Additionally, this ensures that in certain edge cases where communications are lost during and avoidance maneuver that the aircraft will return to standard operations autonomously and not become “stuck” in an avoidance maneuver waiting for manual intervention.

To enable this feature set the cas_send_resume_maneuver parameter of the Casia Configuration section of the user guide.

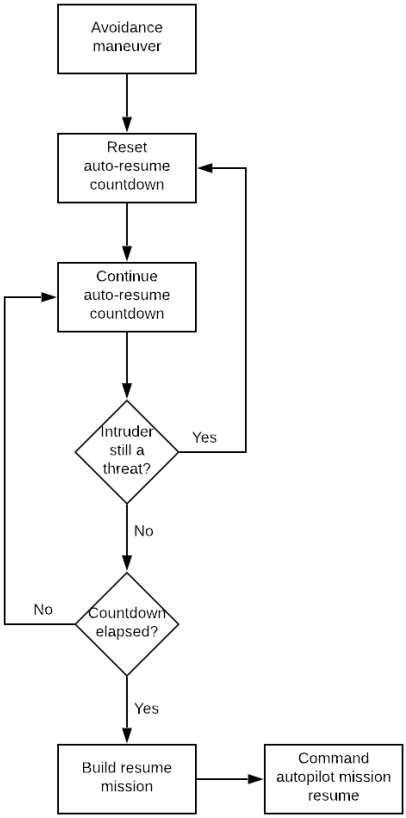
This feature allows Casia to automatically resume a mission if the resume maneuver timeout elapses. This timeout is continuously reset as Casia continues to detect the intruder aircraft, or if it re-detects the intruder aircraft at any time while maintaining the avoidance maneuver. The timeout parameter should be set to allow enough time for the intruder aircraft to continue on its way and exit the vicinity around the drone and defaults to one minute.

Once the timeout elapses, Casia will send a command to the autopilot to switch back into autonomous mode and continue on to the last waypoint that was previously being targeted before the avoidance maneuver was initiated (note that for some autopilots this behavior must be set in the autopilot configuration, please see the Autopilots section in the user guide for detailed information).

The specific mode that the autopilot is commanded to return to depends on the type of autopilot being used and is defined in the following table.

Autopilot	**Avoidance Mode**
ArduPlane	“Auto” Mode
ArduCopter	“Auto” Mode
PX4	“Mission” Mode
Piccolo	N/A - The resume waypoint or the destination waypoint prior to avoidance will be re-targeted depending on Casia’s configuration.

The complete flow-chart for exiting an avoidance maneuver automatically is displayed below.



Note that if an intruder is detected immediately after resuming a mission, this is treated as if a new avoidance maneuver is being initiated, please see the section above on the behavior that would occur.

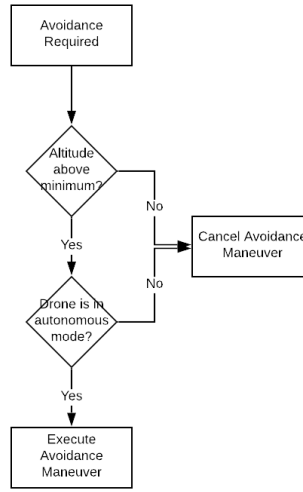
Safety Interlocks

Casia will engage an avoidance maneuver only when ALL of the following criteria have been met.

1. The drone is above a preset, autopilot-reported, altitude known as the "*Minimum Maneuver Altitude*" present in the Casia system Configuration .

2. The drone is in autonomous mission flight mode, as defined by the following table.

Autopilot	**Avoidance Mode**
ArduPlane	"Auto" Mode
ArduCopter	"Auto" Mode
PX4	"Mission" Mode
Piccolo	N/A - Avoidance is always active when within the specified operating altitudes

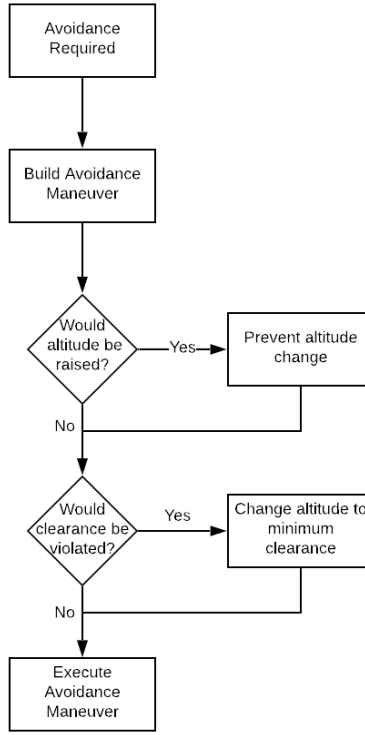


Safety Limits

When initiating a maneuver, Casia has certain limitations on its behavior that prevent unwanted behavior by the avoidance maneuver function.

1. It will not command a descent below a specified "*Minimum Maneuver Clearance*" altitude which is present in the Casia system Configuration , even if this would result in an altitude change of less than the programmed altitude change parameter. This is used to keep a buffer zone between the drone and the ground at all times, and is designed to prevent the avoidance maneuver from commanding the drone to fly into the ground or another obstacle.

2. No change in altitude is executed if the calculated maneuver, or configuration of parameters, would result in the drone raising its altitude from its current position. Instead, the maneuver will be initiated without an altitude change. This is to prevent the drone from making a collision with the intruder more likely, as drones primarily operate at altitudes below that of crewed aviation it is imperative that an avoidance maneuver not direct the drone to a higher altitude.


Avoidance Required
Build Avoidance Maneuver
Would altitude be raised?
Yes
Prevent altitude change
No
Would clearance be violated?
Yes
Change altitude to minimum clearance
No
Execute Avoidance Maneuver

Alert Behavior

Only ArduPilot autopilots forward the required message to the Ground Control Stations at this time. Therefore only ArduPilot autopilots currently support these alerts.

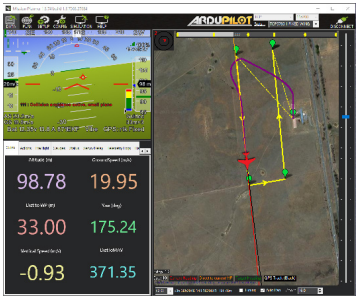
ALERT: **“Collision avoidance active”**

Description

The system detected an intruder within the avoidance boundary and will execute an avoidance maneuver.

Will be sent a maximum of every 10 seconds while an intruder is within the avoidance boundary.

Mission Planner Behavior



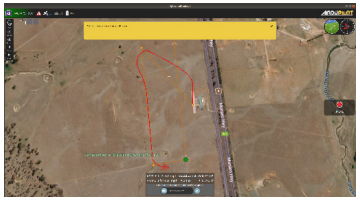
Version 1.3.74+

- Displays in HUD and Messages tab
- Aurally reported if speech enabled

Version below 1.3.74

- Displays in Messages tab
- Aurally reported if speech enabled

QGroundControl BehavioR



QGround Control

- Displays in Alert popup box, along with Messages console
- Aurally reported if speech enabled

ALERT: **“Do manual avoid immediate, auto disable”**

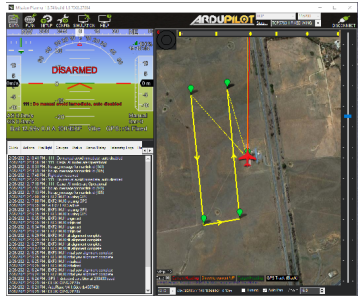
Description

The system detected an intruder within the avoidance boundary, but the system will not execute an avoidance maneuver (this could because avoidance is disabled, its already in avoidance, its below safe altitude, etc. If it can’t avoid for some reason, it this message indicates it detects an intruder but will not direct the autopilot to do anything).

Will be sent a maximum of every 10 seconds while an intruder is within the avoidance boundary.

Note that if an avoidance maneuver is being executed and an intruder is detected, this messgae will be sent.

Mission Planner Behavior



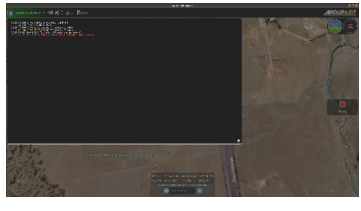
Version 1.3.74+

- Displays in HUD and Messages tab
- Aurally reported if speech enabled

Version below 1.3.74

- Displays in Messages tab
- Aurally reported if speech enabled

QGroundControl BehavioR



QGround Control

- Displays in Alert popup box, along with Messages console
- Aurally reported if speech enabled

ALERT: **“Aircraft at safe distance, small plane/helicopter”**

Description

The system detected an intruder, but it is outside of the avoidance area, so no maneuver will execute since its at a safe distance

Will be sent a maximum of every 30 seconds while the intruder is still detected and remains outside the avoidance boundary.

Mission Planner Behavior

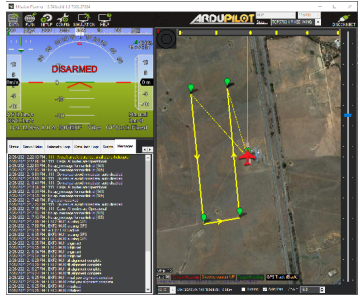
Note message below is not highlighted in Mission Planner, done below for emphasis.

Version 1.3.74+

- Displays in Messages tab

Version below 1.3.74

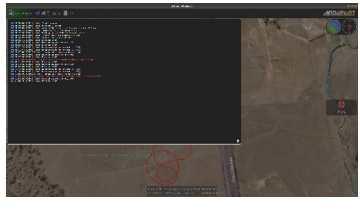
- Displays in Messages tab



QGroundControl Behavior

QGround Control

- Displays in Messages console



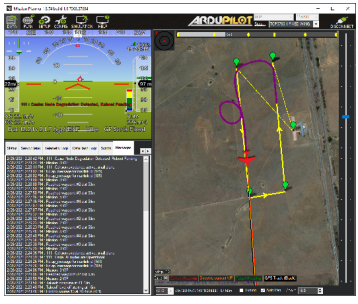
ALERT: **“Casia: Node Degradation Detected, Reboot Pending”**

Description

The watchdog has detected that a node is down based on missing heartbeats and that a reboot is pending. Indicates the system is going to reboot soon.

Will be sent a maximum of every 10 seconds until the system reboots or resumes full functionality.

Mission Planner Behavior



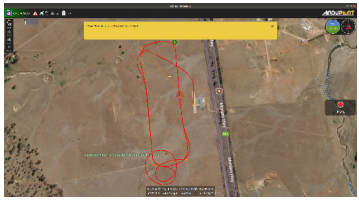
Version 1.3.74+

- Displays in HUD and Messages tab
- Aurally reported if speech enabled

Version below 1.3.74

- Displays in Messages tab
- Aurally reported if speech enabled

QGroundControl Behavior



QGround Control

- Displays in Alert popup box, along with Messages console
- Aurally reported if speech enabled

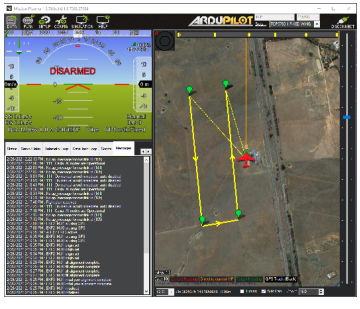
ALERT: **“Casia: All nodes are Operational”**

Description

All expected nodes are sending heartbeats to the watchdog. This will show up initially after boot once the watchdog has received a heartbeat from all nodes it is monitoring. It will also show up if a node is perceived to go down, then able to recover itself somehow. Once the node is thought to be down, the status is changed in the system (usually indicated by the above reboot pending message). If for some reason suddenly the node starts sending heartbeats again (“recovers”) and all heartbeats are being received, this message will come up again.

Will only be sent once each time the system reaches full functionality.

Mission Planner Behavior



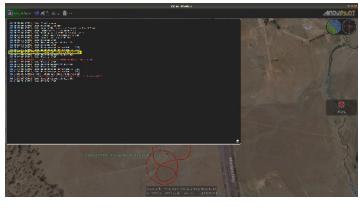
Version 1.3.74+

- Displays in HUD and Messages tab

Version below 1.3.74

- Displays in Messages tab

QGroundControl Behavior



QGround Control

- Displays in Messages console

WatchDog Behavior

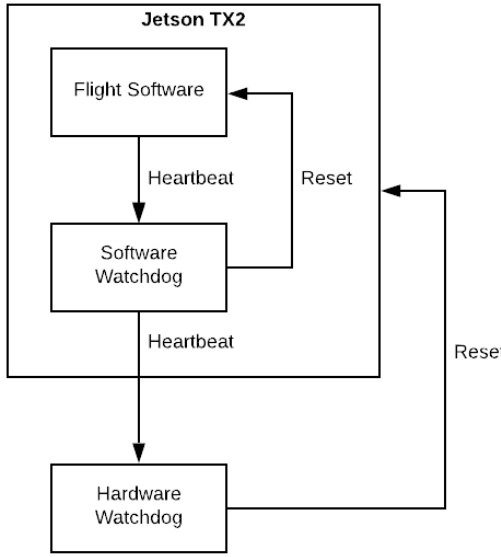
Watchdog system

Casia includes a Watchdog System that allows it to detect and recover from errors while in operation. The way this system is designed and functions is described in this document.

The Casia watchdog system works on the basis of continued positive affirmation of functionality and time-outs to detect failures within the system. This prevents the possibility of a silent failure being un-detected as is possible in other watchdog configurations. There are multiple layers of watchdogs built into Casia in order to capture and recover from all potential internal failures of the system.

All elements of the Casia FlightCore software report constantly to the Software Watchdog that they are still functional. If one of these elements stops reporting, the Software Watchdog will assume a failure and reset the entire software system allowing it to start from scratch and recover from the error.

It is possible that the error encountered was due to some underlying software systems or due to a hardware error meaning that a reset of the software would not enable the system to recovery completely. Therefore we have also installed a Hardware Watchdog that monitors the entire hardware system. If it stops receiving affirmations from the software system then it will reset the entire platform.



Software Watchdog

The software watchdog functions by monitoring heartbeats from each individual component of the software on Casia. These heartbeats constantly confirm to the Software Watchdog that each component is still functional. If everything is still considered function, the Software Watchdog will send heartbeats to the Hardware Watchdog (see the next section of this document) to confirm that the software system in Casia is healthy.

When a heartbeat is lost for a certain period of time, the component sending that heartbeat is considered to have failed in some manner and the Software Watchdog will log an error and take corrective action to recover the system from that failure. It is possible that a component

will have slowed down or encountered a temporary issue that it can self-recover from and so it takes several heartbeat intervals to cause a complete timeout of the Software Watchdog.

Once a timeout occurs the heartbeats to the Hardware Watchdog will immediately stop being sent (which begins the Hardware Watchdog timeout) and the recovery action of the Software Watchdog is executed. This will exit and re-launch the entire Casia software stack to clear out any potential issue and start from a clean beginning. This effectively begins the cycle of monitoring again.

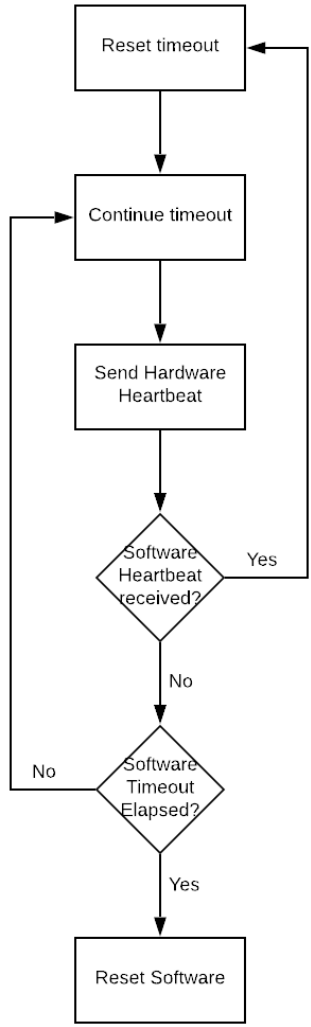
Additionally, once heartbeats from a software component are not received and the timeout has elapsed, the Software Watchdog will indicate to the user that this has occurred through flashing LED B.

Once all software components report that they are started up and running correctly, the Software Watchdog will resume sending the heartbeats to the Hardware Watchdog to report that the system has recovered from the error.

If the software components do not report that they have started up correctly within a certain initialization time, the Software Watchdog will again initiate a software reset under the assumption that the issue was not resolved and the cycle repeats again.

The specific time-outs are listed here:

Timeout	**Duration**
Software Component Heartbeat (before indication and reset)	1s
Software Reset Initialization Wait	30s


Reset timeout
Continue timeout
Send Hardware Heartbeat
Software Heartbeat received?
Yes
No
Software Timeout Elapsed?
No
Yes
Reset Software

Hardware Watchdog

The Hardware Watchdog functions by monitoring for software stack functionality by listening to the heartbeats from the Software Watchdog as described in the previous section. The Hardware Watchdog is a completely independent hardware and software from the main Casia processor and is able to therefore independently monitor the performance of Casia and recover the system from potential underlying hardware or system level failures the Software Watchdog cannot recover the system from.

As heartbeats are received, the Hardware Watchdog continuously resets a timeout, preventing it from taking any corrective action when the system is functioning as normal.

When heartbeats from the Software Watchdog stop being received, the Hardware Watchdog timeout will no longer be reset and will eventually elapse. The timeout duration is set slightly longer than the Software Watchdog initialization time to allow the Software Watchdog a chance to re-initialize the system without having to resort to a hard reset. This is because a software reset is much faster than a hard reset and if it is possible to reset in software that is preferable to minimize the Casia down-time during an event.

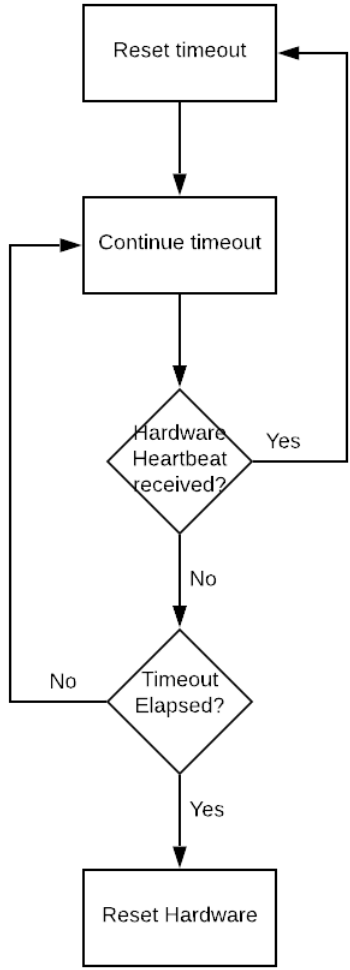
Additionally, the Hardware Watchdog will indicate to the user via LED A that it has stopped receiving heartbeats even before a reset is initialized. This will occur within a specified time (see table below) of the heartbeats being lost.

Once the timeout has elapsed however, the Hardware Watchdog will trigger a full system hard reset of Casia, causing not only the software to restart, but the entire Casia device and all power systems as well. Once a reset has been initiated, the Hardware Watchdog waits for the hard reset initialization time to allow the system to boot and the Software Watchdog to once more begin reporting that everything is functional.

If this is not the case, and the hard reset initialization timeout is reached without receiving a heartbeat from the Software Watchdog, the Hardware Watchdog will again issue a hard reset of the system, repeating this cycle again.

The specific time-outs are listed here:

Timeout	Duration
Software Watchdog Heartbeat (before indication)	5s
Software Watchdog Heartbeat (before reset)	35s
Hard Reset Initialization Wait	75s


Reset timeout
Continue timeout
Hardware Heartbeat received?
Yes
No
Timeout Elapsed?
No
Yes
Reset Hardware

LED Indicators

LED	System	Indication
HW	Hardware Watchdog	Solid On • Ready for Flight • Receiving heartbeats from Software Watchdog to Hardware Watchdog Slow Blink • Booting Up/Initialization wait time Fast blink • Error, lost heartbeats from Software Watchdog • Will reset after timeout finished
SW	Software	Solid On • Ready for Flight • Receiving heartbeats from all software components Slow Blink • Booting Up/Initialization wait time Fast blink • Error, lost heartbeats from one or more software components • Will reset after timeout finished
'!'	Autopilot Connection	Solid On • Ready for Flight, actively receiving messages from autopilot Blink • No autopilot connection detected, no messages being received

Pre-flight checklist

The following checks must be performed before flight to ensure that the Casia system is functioning correctly. If any of these checks fail, the issue must be corrected and the checklist started again.

Lenses

- ⬭ The anti-tamper paint on all lenses is not cracked or damaged in any way
- ⬭ Lens cap is removed from all lenses
- ⬭ Inspect lenses for dust, particulates, liquids, fingerprints, or other blemishes
- ⬭ Clean all lenses with a microfiber cloth and lens cleaning fluid

Power

- ⬭ Power status LED on Casia X module shows solid green

Casia Status

- ⬭ Casia System '!' LED on Casia module shows solid green
- ⬭ Casia SW LED on Casia module shows solid green
- ⬭ Casia HW LED on both Casia module shows solid green

In older Casia devices the Hardware Watchdog status indicator (LED A) will show a “heartbeat” blinking pattern to indicate correct operation.

If this is the case please contact support@uavionix.com to update your software!

In versions of Casia Flight Core software before V1.0 LED C has no function. Please update your software as described in the FlightDeck.

LED	System	Indication	Time Frame
HW	Hardware	Solid On - Ready for Flight Slow Blink - Booting Up Fast blink - Error, Resetting	1 minute
SW	Software	Solid On - Ready for Flight Slow Blink - Booting Up Fast blink - Error, Resetting	1 minute
‘!’	System	Solid On - Ready for Flight Blink - No autopilot connection	1 minute

Camera Status

- LED on the back of all camera bodies are solid and not flashing in any way
- LED on the back of all camera bodies are green in color

System Status

- [ ] GCS has received the “Casia: All nodes are operational” message

In-Flight Procedures

Detection

Detection of crewed aircraft intruders is done on-board the aircraft by the FlightCore running on Casia. These detections are made within the images from the camera, however the detection system is then able to output the 3D position of the intruder aircraft to additional systems down-stream which are used for the Alert and Avoid functionality described further in this article.

This article will not dive into the function of the Detection aspect of Casia, however it is important to know the outputs of this algorithm so that the further Alert and Avoid functions can be understood.

Alert

Once a detection is made by Casia, alerts are generated for the remote Ground Control Station and the remote Pilot in Command. These alerts are informational to both keep the GCS and PIC informed of the airspace safety and situational awareness of the airspace around the drone, as well as to inform of collision avoidance maneuvers that are executed automatically (as described in the avoidance section below) by the system when breaches of airspace are detected.

Several different alerts are generated during an encounter, these are detailed below along with instructions on the action needed by the GCS operator or PIC when these are initiated.

Note that the language used in the alerts generated by Casia are compliant with FAA Advisory Circular AC 25.1322-1, however Ground Control Station software support for other aspects of this advisory may vary.

Note that Casia will only send the same type of alert once every 30 seconds. This is to avoid spamming the operator with alerts during an encounter. This functionality does not prevent more important alerts from not being sent as an intruder aircraft approaches since a different type of alert is sent at different breach levels.

Note that alerts are not supported by the Piccolo autopilot.

Intruder Location

Immediately when an intruder is detected, and at all times during an encounter with an intruder aircraft, Casia will relay to the GCS and PIC the location of the detected intruder. This aircraft and location information is then displayed on the GCS software interface (as described in the Ground Control Stations page in the User guide).

This intruder location alert is maintained and updated for airspace awareness of the GCS operator and PIC, however it is not necessary with Casia installed to take any action when the intruder aircraft icon is displayed alone. Actions may be needed when accompanied by other alerts which are detailed in the following sections.

Note that intruder position location alerts are not supported by the Piccolo autopilot.

Detection Alert

As soon as an intruder is detected by the computer vision system a Detection Alert will be sent if that intruder is outside of the Avoidance Distance, if it is within that distance then an immediate Breach Alert will be sent instead, please see the following section for details on that alert. The detection alert is used to notify the PIC/GCS that an intruder aircraft is within the airspace around the drone but is not currently at a threat of collision.

This intruder location alert is maintained and updated for airspace awareness of the GCS operator and PIC, however it is not necessary with Casia installed to take any action when the intruder aircraft icon is displayed alone. Actions may be needed when accompanied by other alerts which are detailed in the following sections.

A detection alert is worded as shown in the following example:

CAUTION: Aircraft at safe distance small plane/helicopter

Breach Alert

Immediately when the aircraft crosses the avoidance boundary and a collision avoidance maneuver is needed to avoid a collision, then a breach alert is generated. The alert is used to notify the GCS/PIC that a maneuver has begun being executed for an intruder aircraft.

CRITICAL: Collision avoidance active small plane/helicopter

Note that if the avoidance maneuver cannot be executed due to other limitations (such as being below the pre-programmed safe altitude for performing avoidance maneuvers, or that the autopilot is not in the correct mode to execute an automated avoidance maneuver) then the following alert is sent instead. This warns the PIC/GCS that a manual intervention is required to perform an avoidance maneuver since the automated system is not able to be engaged.

WARNING: Do manual avoid immediate auto disabled

Avoidance

Intruder aircraft avoidance is initiated by Casia automatically to ensure timely and effective maintenance of airspace separation between the drone and the intruder crewed aircraft. The specifics of the maneuver are notified to the PIC and GCS operator at the time the avoidance takes place to ensure they are informed of the change in the flight characteristics of the drone.

Detailed information on the avoidance can be found at the Collision Avoidance Behavior page of the User guide. Specific instructions on how the GCS operator or PIC should respond during an avoidance are detailed below.

Post-Flight Checklist

The following checks must be performed after a flight to ensure that the Casia system remains correctly functional once the drone has landed.

Lenses

- [ ] The anti-tamper paint on all lenses is not cracked or damaged in any way
- [ ] Inspect all five lenses for dust, particulates, liquids, fingerprints, or other blemishes
- [ ] Clean all five lenses with a microfiber cloth and lens cleaning fluid
- [ ] Lens cap is placed back on all five lenses

Camera Status

- [ ] LED on the back of all camera bodies is solid and not flashing in any way
- [ ] LED on the back of all camera bodies is green in color

Power

- [ ] Power status LED on Casia module shows solid green

Casia Status

- HW LED on Casia module shows solid green
- SW LED on Casia module shows solid green
- System (!) LED on Casia module shows solid green

In older Casia devices the Hardware Watchdog status indicator (HW LED) will show a “heartbeat” blinking pattern to indicate correct operation.

If this is the case please contact support@uavionix.com to update your software!

In versions of Casia Flight Core software before V1.0 LED C has no function. Please update your software as described in the FlightDeck.

LED	System	Indication	Time Frame
HW	Hardware	Solid On - Ready for Flight Slow Blink - Booting Up Fast blink - Error, Resetting	1 minute
SW	Software	Solid On - Ready for Flight Slow Blink - Booting Up Fast blink - Error, Resetting	1 minute
‘!’	System	Solid On - Ready for Flight Blink - No autopilot connection	1 minute

Maintenance Plan

uAvionix recommends its users to incorporate regular maintenance of Casia into their internal maintenance schedule to ensure the system continues to operate at its peak performance. Provided below are the recommended maintenance actions to be made at different intervals and an explanation of each of these procedures.

Maintenance should be performed by individuals certified by the user's internal standard operating procedures or by those that have received training from uAvionix. Certain maintenance activities require uAvionix staff to perform them and there may be requirements to return your hardware to us on occasion for these tests to be performed.

If subjected to a crash or heavy impact, Casia may incur damage that is not detectable via visual inspection. Casia devices that may have received impacts beyond standard operating conditions should no longer be used. Contact support@uavionix.com for further advice.

25 Flight Hour Interval

CLEANING

This is done to remove any built up particulate that may ingress into the body of the system over time and to make it easier to perform the inspections required for the 25 hour maintenance. Special care should be taken on the lens of the camera to ensure the lens is completely free of any particulate that may have a detrimental affect on the quality of imagery and performance of the system. Additionally, ensuring the fins of the heat sink on the Casia module will guarantee that enough cooling is available to the module at all times.

Before Beginning

- ⬭ Prepare a microfiber cloth and cleaning fluid such as isopropyl alcohol
- ⬭ Ensure that Casia is completely powered off (isopropyl alcohol is conductive and could short components!)

Procedure

- ⬭ Clean the Casia module to remove any dust or debris, pay particular attention to the cooling fins
- ⬭ Clean the camera module to remove any dust or debris
- ⬭ Clean the lens optics to remove any dust or debris, pay particular attention to not leave behind any dust or marks on the lens after cleaning.

INSPECTION

Dents or scratches on the hardware bodies can be an indication that the hardware is positioned in too vulnerable of a location on the airframe. There are no moving parts on the Casia hardware, so most deformation to the body can be considered superficial. If there is deformation at or near the screw heads or other connections points on the aluminum body, there could be cause for concern as these act to rigidly affix the internal electronics that could have a shorter lifespan without proper mechanical support. Contact the uAvionix support team for an assessment should you be concerned.

Casia relies on a stable connection both the camera and autopilot to function while in flight. UAS platforms are a somewhat inhospitable environment for cabling due to the high amount of vibration and factors related to outdoor operations. Much of these risks can be mitigated by ensuring the cabling is rigidly affixed and routed through the interior of the airframe. Cables with thumbscrews should be snugly tightened. Cables to be checked include the power, autopilot, camera, and fan cables. Contact the uAvionix support team to replace any worn or damaged cabling.

Camera focus is key to maintaining good performance on Casia. uAvionix has a process for focusing and calibrating each camera before it is shipped to the user. This focus and calibration will be affected by any shift of the aperture ring, focus ring, or mechanical connections of the camera assembly. Assess each by checking for breaks in the tamper paint.

If there is no tamper paint on your camera/lens assemblies, contact support@uavionix.com and do not fly with Casia on board until the issue is resolved.

Before Beginning

- [ ] The cleaning part of this maintenance procedure is complete

Procedure

- [ ] Inspect Casia module and camera for any dents or scratches
- [ ] Inspect cabling for any cuts, frayed wires, or loose connections
- [ ] Inspect camera focus rings and threaded connections for movement indicated by the anti-tamper markers
- [ ] Check for dents, scratches, or other blemishes to the lens optics

SOFTWARE UPDATE

uAvionix makes regular software updates that improve the detection and avoidance performance of Casia as well as fixing bugs and making improvements to features. We advise that when performing maintenance that the latest version of software available for your device is downloaded and updated to. This may even be a regulatory requirement depending on your CONOPS and operating environment if certain performance requirements are put in place.

Please follow the software update procedures described in the FlightDeck section of the User Guide.

IMPORTANT: Before beginning the software upgrade process, ensure your internet connection is stable, and use shore/mains power versus battery. **Do not power cycle your device during the software update process.** Your device may restart several times during the Software Update process, and LED lights may not be displayed for a period of time. FlightDeck will indicate when the update is complete.

FOLLOW-UP

Should there be evidence that the system has failed any of these checks contact the uAvionix support team at support@uavionix.com for assistance before flying again.

50 Flight Hour Interval

CLEANING

This is done to remove any built up particulate that may ingress into the body of the system over time and to make it easier to perform the inspections required for the 50 hour maintenance. Special care should be taken on the lens of the camera to ensure the lens is completely free of any particulate that may have a detrimental affect on the quality of imagery and performance of the system. Additionally, ensuring the fins of the heat sink on the Casia module will guarantee that enough cooling is available to the module at all times.

Before Beginning

- [ ] Prepare a microfiber cloth and cleaning fluid such as isopropyl alcohol
- [ ] Ensure that Casia is completely powered off (isopropyl alcohol is conductive and could short components!)

Procedure

- [ ] Clean the Casia module to remove any dust or debris, pay particular attention to the cooling fins and the status indication LEDs
- [ ] Clean the camera module to remove any dust or debris
- [ ] Clean the lens optics to remove any dust or debris, pay particular attention to not leave behind any dust or marks on the lens after cleaninG

INSPECTION

Dents or scratches on the hardware bodies can be an indication that the hardware is positioned in too vulnerable of a location on the airframe. There are no moving parts on the Casia hardware, so most deformation to the body can be considered superficial. If there is deformation at or near the screw heads or other connections points on the aluminum body, there could be cause for concern as these act to rigidly affix the internal electronics that could have a shorter lifespan without proper mechanical support. Contact the uAvionix support team for an assessment should you be concerned.

Casia relies on a stable connection both the camera and autopilot to function while in flight. UAS platforms are a somewhat inhospitable environment for cabling due to the high amount of vibration and factors related to outdoor operations. Much of these risks can be mitigated by ensuring the cabling is rigidly affixed and routed through the interior of the airframe. Cables with thumbscrews should be snugly tightened. Cables to be checked include the power, autopilot, camera, and fan cables. Contact the uAvionix support team to replace any worn or damaged cabling.

Camera focus is key to maintaining good performance on Casia. uAvionix has a process for focusing and calibrating each camera before it is shipped to the user. This focus and calibration will be affected by any shift of the aperture ring, focus ring, or mechanical connections of the camera assembly. Assess each by checking for breaks in the tamper paint.

If there is no tamper paint on your camera/lens assemblies, contact support@uavionix.com, and do not fly with Casia on board until the issue is resolved.

Before Beginning

- ⬭ The cleaning part of this maintenance procedure is complete

Procedure

- [ ] Inspect Casia module and camera for any dents or scratches
- [ ] Inspect cabling for any cuts, frayed wires, or loose connections
- [ ] Inspect camera focus rings and threaded connections for movement indicated by the anti-tamper markers
- [ ] Check for dents, scratches, or other blemishes to the lens optics

ASSEMBLY CHECK

The body of the Casia module acts as a frame to mechanically affix the internal electronics to prevent them from being damaged by shock or vibration. There are 8 screws to be checked for snugness; 4 screws securing the fan, 4 screws in the top of the module. Check each of these screws by gently tightening each. The 4 screws securing the fan take a M4 hex driver and the 4 screws matching the enclosure take an M3 hex driver.

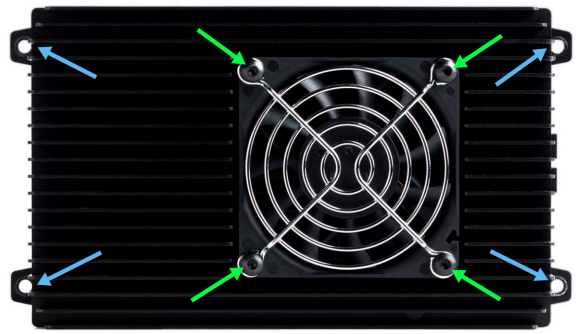
Any screws that are loose should be re-torqued to 4Nm with Loctite 242 threadlocker (blue) and any screws that may be missing can be replaced by contacting the uAvionix support team.

Before Beginning

- [ ] Prepare an M4 hex screwdriver
- [ ] Prepare an M3 hex screwdriver
- [ ] Prepare the adequate screwdriver for the Casia mounting screws

Procedure

- [ ] Gently torque the 4x M4 screws securing the fan in place to ensure they are snug (shown in GREEN)
- [ ] Gently torque the 4x M3 screws on the bottom of the Casia enclosure to ensure they are snug (shown in PURPLE).
- [ ] Gently torque the 4x screws used to mount Casia to the airframe through the Casia mounting feet to ensure they are snug (shown in BLUE)



CONNECTOR CHECK

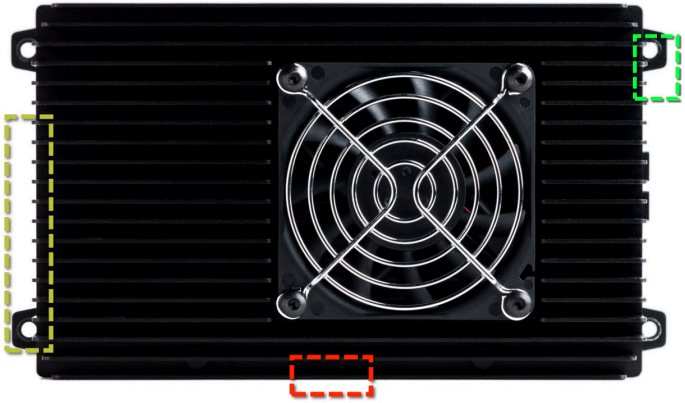
The connectors on the Casia module face the same challenges present for the cabling mentioned in the 25 hour service plan. Each connector, especially those in heavy use should be inspected for damage. Gentle pressure should be placed on each connector to validate that it is still firmly seated on its respective board. If any connector appears to be loose, contact the uAvionix support team for assistance.

Before Beginning

- [ ] Prepare a small flathead screwdriver

Procedure

- [ ] Apply gentle pressure to the Casia power cable connector, ensure it is snug and secure (shown in GREEN)
- [ ] Apply gentle pressure to the Casia autopilot serial cable connector, ensure it is snug and secure (shown in RED)
- [ ] Apply gentle pressure to each Casia camera cable connector, ensure it is snug and secure (shown in YELLOW)
- [ ] Gently torque each screw on each Casia camera cable connector with the flathead screwdriver, ensure they are tight and secure (shown in YELLOW)



CAMERA FOCUS CHECK

Focus of the camera is extremely important for Casia functionality to be at its peak. Even though we now place anti-tamper paint on all lenses for Casia camera modules, it can occasionally occur that the camera lens comes out of focus from the factory due to a variety of factors such as regular temperature fluctuation, high vibration environments, or other accidental damage.

In order to assess that the camera is still in focus, some footage from the camera must be assessed against a standard camera calibration target by uAvionix.

This check is extremely important and must be completed at regular intervals to ensure the Casia DAA system is still functioning correctly. If not done, Casia may not detect any intruders at all!

Procedure

The easiest procedure to follow for systems already integrated onto a drone is as follows:

- Ensure that the pre-flight integration verification checks have been performed (with help from uAvionix if needed) to ensure a successful first flight.
- Take the drone to a location where it can be safely flown at altitudes of 300ft - 400ft (90m - 120m) above ground, and where it has enough operational area to fly for ~30 seconds at a time in a straight line at cruise speed.
- Follow your normal operating procedures, and the Casia pre-flight procedures to launch the drone to the chosen operating altitude within the altitude band described above.
- Fly in a straight line for 30 seconds at normal cruise velocity. Turn the drone around and fly in another straight line in the opposite direction for another 30 seconds. Repeat this 3-4 times.
- Land the drone and follow normal post-flight procedures and Casia post-flight procedures.
- Upload the flight logs from the Casia device to FlightDeck and notify Support Engineering that you have uploaded the requested data (support@uavionix.com).

SOFTWARE UPDATE

uAvionix makes regular software updates that improve the detection and avoidance performance of Casia as well as fixing bugs and making improvements to features. We advise that when performing maintenance that the latest version of software available for your device is downloaded and updated to. This may even be a regulatory requirement depending on your CONOPS and operating environment if certain performance requirements are put in place.

Please follow the software update procedures described in the FlightDeck section of the User guide.

IMPORTANT: Before beginning the software upgrade process, ensure your internet connection is stable, and use shore/mains power versus battery. **Do not power cycle your device during the software update process.** Your device may restart several times during the Software Update process, and LED lights may not be displayed for a period of time. FlightDeck will indicate when the update is complete.

FOLLOW-UP

Should there be evidence that the system has failed any of these checks contact the uAvionix support team at support@uavionix.com for assistance before flying again.

To arrange maintenance, please contact the uAvionix support team at support@uavionix.com.

Troubleshooting

If you encounter an issue with the Casia device, follow these steps to help diagnose and fix the problem.

POWER SYSTEMS

POWER STATUS LED

If the Power Status LED does not turn on solid green when power is applied to Casia this indicates a few potential issues with either the power source or the device, please ensure the following and attempt re-powering the Casia once complete.

- The power connector and cable are not damaged in any way and are securely seated and fixed.
- The input voltage being supplied is within the acceptable range printed on the Casia device (11V minimum to 40V maximum).
- The power source is capable of delivering the required power for Casia (70W maximum draw, therefore >70W is recommended).

If none of these are the issue, there may be an internal malfunction to the Casia device due to corrosion, extreme vibration, wear, defect, or other causes. Please contact uAvionix support for assistance.

COOLING FAN

COOLING FAN WON'T SPIN

The cooling fan on the Casia module will only spin when the device is hot enough to require it. If you believe this is the case and are experiencing heat related issues, such as reboots, and the fan is not spinning this may be because of several reasons, please ensure the following:

- The fan is not stuck of clogged, check that it can spin freely by blowing on it and watching it spin. Additionally, you can turn the fan by hand and feel for grit within the fan.
- Check that the fan power cable is plugged in properly to the Casia device fan port and that the connector and wires are not damaged or frayed in any way.
- Make sure that the fan has not been subjected to water or other liquids by checking for stains or other residue.

If there are signs of damage or the above checks are completed without issue contact uAvionix support and a replacement fan can be sourced.

WATCHDOGS

HW LED STUCK IN FAST BLINK

This indicates that there is a persistent error detected by the Casia hardware watchdog. Errors here occur because of un-met dependencies on external systems, or errors with internal systems.

Note: In older Casia devices the Hardware Watchdog status indicator (LED A/HW) will show a "heartbeat" blinking pattern to indicate correct operation.

- Please ensure that all the system configuration parameters are set correctly for external devices such as the ADS-B receiver, Camera, and Autopilot.
- Additionally, check that all cables to these external devices are plugged in, un-damaged, and securely fastened.
- Ensure also that the external devices are powered on by checking their respective status indication LEDs or with a multi-meter if required.
- Ensure that for each connected camera, the corresponding green led is solid (indicating that the connection is good) and orange led is blinking (indicating data transfer). If not, check connections are solid and cables are not damaged.
- Once these steps are complete, attempt power cycling the Casia device.

SW LED STUCK IN FAST BLINK

This indicates that there is a persistent error detected by the Casia software. Errors of this type occur because there are un-met dependencies on external systems that are either not configured correctly or not plugged in or powered up.

Please ensure that all the system configuration parameters are set correctly for external devices such as the ADS-B receiver, Camera, and Autopilot.

Additionally, check that all cables to these external devices are plugged in, un-damaged, and securely fastened.

Ensure also that the external devices are powered on by checking their respective status indication LEDs or with a multi-meter if required.

Once these steps are complete, attempt power cycling the Casia device.

BOTH HW AND SW LEDs STUCK IN BLINK

This indicates that there is a persistent error detected by the Casia software. Errors of this type occur because there are un-met dependencies on external systems that are either not configured correctly or not plugged in or powered up.

- Please ensure that all the system configuration parameters are set correctly for external devices such as the ADS-B receiver, Camera, and Autopilot.
- Additionally, check that all cables to these external devices are plugged in, un-damaged, and securely fastened.
- Ensure also that the external devices are powered on by checking their respective status indication LEDs or with a multi-meter if required.
- Ensure that for each connected camera, the corresponding green led is solid (indicating that the connection is good) and orange led is blinking (indicating data transfer). If not, check connections are solid and cables are not damaged.
- Once these steps are complete, attempt power cycling the Casia device.

System '!' LED STUCK IN FAST BLINK

This indicates that the communication between Casia and the autopilot is non functional and Casia has identified that this is the case. Please assess the following points to solved the issue.

Ensure the cables between Casia and the autopilot are un-damaged and are correctly connected (See Casia X Datasheet for connector pinouts).

Through FlightDeck, check that the Casia autopilot settings are correctly configured for your autopilot (See Casia configuration section of this document)

Check that the configuration of the autopilot is correct to allow communications to Casia (See autopilot configuration section of this document)

FLIGHT BEHAVIOR

MANEUVER NOT EXECUTED

If a maneuver is not executed during an encounter with an intruder aircraft this may be because of many reasons. Please follow this checklist to ensure that Casia is functioning correctly.

Camera Problems:

- The lens cap was removed during flight.
- The lens was not obscured or damaged.
- The camera was correctly connected and capturing images.

The above items can be checked for past flights by reviewing the flight footage in the online portal.

System Configuration:

- Ensure that the enable maneuvers parameters are set to “Enabled”.
- Ensure that the configuration is pushed to the device by checking the “Configuration Status” is up to date.
- Check that the latest version of software is installed, this will give the best collision avoidance performance possible.
- Ensure that the correct autopilot system and autopilot interface is configured in the system configuration.

Autopilot Configuration:

- Check that the serial port settings for the autopilot are correct for the Casia device.
- Ensure that the autopilot software is of a supported version according to the table in the datasheet for Casia.
- Check that the autopilot was operating within “Auto” or “Mission” mode.
- Make sure that the autopilot hardware is not damaged.
- Ensure that adequate power is being supplied to the autopilot.

Physical Problems:

- Check that the interface cables between the Casia and the autopilot are undamaged, seated well, and are fixed.
- Ensure that the Casia power systems are correctly functioning and supplying the Casia with the correct voltage and adequate power.

MANEUVER NOT AS EXPECTED

When a maneuver is executed it follows the setup in the system configuration and the setup parameters of your autopilot system. Please ensure that all system configuration settings are to your liking for the desired avoidance maneuver outcome and reference the descriptions of these settings and parameters in this document. If these settings are not clear please contact uAvionix Support for additional assistance.

INTRUDER NOT DISPLAYED ON GROUNDSTATION

Groundstation display of intruder aircraft requires specific versions of supported groundstation software only. Please ensure that you are running a recent version of either Mission Planner, APM Planner, or QGroundControl with an autopilot firmware version that supports the ADSB_VEHICLE message. Additionally ensure the following.

- The correct autopilot type is configured in the Casia system configuration.
- The autopilot cable and connector are not damaged, are properly seated, and fixed.
- The autopilot parameters are set correctly to forward MAVLink messages to the groundstation.

FURTHER ASSISTANCE

Please contact uAvionix support for further assistance at support@uavionix.com.

Limitations & Disclaimers

Setup and maintenance of Casia must be performed as per the Casia user guide to ensure that Casia performs optimally. Setup of the Casia System must be verified by an uAvionix Engineer. Contact support@uavionix.com for assistance.

Incorrect camera focus or installation can affect Casia performance:

- If the camera is not focused correctly, Casia will not detect as specified.
- If the field of view of the camera is partially obscured - for example - by a propeller, wing, or other part of the UAS, or any other object including bugs and water droplets, Casia will not detect as specified.
- Elevation and bearing accuracy of Casia will vary based on the precision of integration of Casia cameras.

Pre and post-flight checks must always be performed as specified in the Casia user guide.

uAvionix leverages artificial intelligence and machine learning to ensure Casia 'learns' to correctly interpret its environment. Casia has been trained to identify small piloted aircraft and helicopters, and is designed for use in low risk airspace, some distance away from airports. The performance and limitations of the Casia system should be understood by the pilot in command before using Casia as part of a layered air risk mitigation approach.

- If Casia has not been 'trained' in an environment similar to yours, performance - including the frequency of false positives - may vary from that specified.
- Casia has been optimized for low risk airspace, away from airports. If Casia 'sees' larger aircraft (e.g. Boeing 747) several miles away, it may report a smaller aircraft at a closer range.
- Casia was not trained to detect powered parachutes, balloons, large planes/jets, other aircraft or other objects. This should be considered by the operator when evaluating air risk.
- Casia may not detect every aircraft in all environments under all circumstances, and may not detect all intruders early enough for an avoidance maneuver to be successfully performed. This must be considered during air risk assessment.
- The time taken for Casia to detect uncooperative piloted aircraft can vary due to environmental conditions, distance, aircraft size, clutter, smoke, and other factors.
- Depending on the performance (turn radius, cruising speed, ascent/descent rates, acceleration/deceleration rate) of your UAS, the time taken to avoid a detected intruder aircraft will vary. This must be considered during air risk assessment.
- Casia does not detect static objects.
- The stated time between false detections excludes birds as the number of birds varies dramatically from environment to environment. If you are operating in an area with an extremely high population of birds, you may see higher false positive rates.

Casia has been trained and tuned to identify and classify small GA aircraft. The specified results are specific to the detection of small GA aircraft (small planes and helicopters). Casia I will not perform to the above level when the intruder aircraft are small drones. This is the case even when aircraft scale is considered, as there are many factors involved in Casia detecting crewed aircraft.

The specified Casia performance was based on actual encounters with piloted aircraft intruding from above the skyline. Performance below the skyline is still being assessed and should therefore be presumed to be significantly lower.

EMI from Casia may interfere with range and performance of C2 systems. This should be fully evaluated by the operator and, if necessary, advice sought from support@uavionix.com.

Reliability / average uptime of the Casia System is under evaluation. Casia should be rebooted between flights to maximize performance.

Following a heavy crash or impact, your Casia system should be replaced or returned to uAvionix for evaluation and repair.

If you believe Casia may not be performing correctly, it should NOT be used and support@uAvionixonboard.com should be contacted for guidance.

For regulatory guidance, please contact sales@uavionix.com.

Ensuring no two aircraft collide mid-air.

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