Unmanned Aircraft Flight Manual (UFM)

FOR SKY-WATCH FIXED WING UAV SYSTEMS

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DOCUMENT HISTORY/REVISION

Version	Description	Editor	Date
01	This document was developed following the process, content and structure defined in ASTM Specification F2908.	TB, HV, MRL, JSH	02/12/2020
02	Updated according to changes in the autopilot and Sky-Watch Drone Manager	PF	03/03/2021
03	Updated with dual payload gimbal specification (7.1.1.1), still camera specification (7.1.1.2) and precision of headwind launch (2.4)	TB	11/05/2021
05	Updated description of system packaging	PF	28/01/2022
06	Updated description of battery management and Silvus charger	MRL, HB	22/06/2022
07	Minor updates to make sure manual comply with sales info	MRL	01/12/2022

Content

1 Introduction

This UFM document serves the purpose as operator and flight manual for all of Sky-Watch fixed wing UAV systems.

1.1 Applicable UASs

P/N	UAS PRODUCTS
800001001, 800001097, 800001098, 800001099	Heidrun EO/IR UAS
800001097, 800001098, 800001099	Heidrun Mapping UAS
800001003, 800001004, 800001005, 800001006	Heidrun Mapping (433 MHz) UAS
800001110, 800001111, 800001106	Heidrun Radio Relay UAS

1.2 Quality Management System

Sky-Watch is ISO 9001:2015 certified for the scope of Design, Development, Manufacturing, Integration, Sales and Services of UAV systems are all governed by the Sky-Watch ISO 9001:2015 Quality Management System. Sky-Watch's ISO certificate no DK013070 is issued by Bureau Veritas Holding.

ISO 9001
BUREAU VERITAS
Certification

1.3 Abbreviations and Acronyms

AGL	Above Ground Level
APU	Auxiliary Power Unit
BLDC	Brushless direct current
BMS	Battery Management System
BVLOS	Beyond Visual Line of Sight
ESC	Electronic speed controller
GNSS	Global Navigation Satellite System
HVC	Heidrun Video Controller
ICAO	The International Civil Aviation Organization
MBITR	Multiband Inter/Intra Team Radio
MIMO	Multiple Input Multiple Output
MSL	Mean Sea Level
MTOW	Maximum take-off weight

RAL	Return and Land
RTL	Return to Launch
SDM	Sky-Watch Drone Manager
SISO	Single Input Single Output
STOL	Short Take Off and Landing
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UFM	Unmanned Aircraft Flight Manual

1.4 Standards and Regulations

The following standards and regulations are used for the design, development, manufacturing, support, service and training of the Heidrun UAS.

Id	Title	Scope
2019/945/EU	Commission Delegated Regulation (EU) 2019/945 of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft system	Heidrun UAS development is guided by 2019/945/EU, PART 3 – Requirements for a class C2 Unmanned aircraft system.
ANSI/CTA-2063	Small Unmanned Aerial Systems Serial Numbers (ANSI/CTA-2063-A)	Heidrun UAVs produced after June 2020 are compliant with ANSI/CTA-2063.
ASTM F2908	Standard Specification for Unmanned Aircraft Flight Manual (UFM) for an Unmanned Aircraft System (UAS)	This manual follows the intent of the ASTM standard specification F2908-18 for 'Unmanned Aircraft Flight Manual (UFM).
ETSI EN 300 328	Wideband transmission systems; Data transmission equipment operating in the 2,4 GHz ISM band and using wide band modulation techniques; Harmonised Standard for access to radio spectrum	A 2.4GHz radio link compliant with ETSI EN 300 328 is available for Heidrun systems.
IEC 60529	Degrees of protection provided by enclosures (IP Code)	Selected system components are specified and tested against IEC 60529.

Id	Title	Scope
ISO 9001:2015	Quality management systems requirements	Design, development, manufacturing, integration, sales, and service of the Heidrun UAS are governed by Sky-Watch ISO-9001:2015 certified QAS.
MIL-STD-810H	Environmental Engineering Considerations and Laboratory Tests	Heidrun UAS are specified and tested against MIL-STD-810H test methods and procedures.
MISB ST 0601	UAS Datalink Local Set	Heidrun EO/IR video stream is MISB 0601 compliant.
ST/SG/AC.10/11/Rev.6	Recommendations on the Transport of Dangerous Goods – Manual of Tests and Criteria Section 38.3 Lithium metal and lithium ion batteries	Heidrun batteries are UN38.3 compliant.
STANAG 4586	Standard Interface of the Unmanned Control System (UCS) Unmanned Aerial Vehicle (UAV) interoperability	Heidrun UAS are STANAG 4586 Level of Interoperability (LOI) 5 compliant.
STANAG 4609	NATO Digital Motion Imagery Standard	Heidrun EO/IR video stream is STANAG 4609 compliant.
STANAG 4670	Guidance for the Training of Unmanned Aircraft Systems (UAS) Operators	Sky-Watch Heidrun UAS training program is guided by STANAG 4670.

1.5 Manufacturer Address and Contact Information

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Telephone	+45 9686 7666
E-mail	@ Sales: sales@sky-watch.com @ Support: support@sky-watch.com
Customer Support Portal	http://support.sky-watch.com

1.6 References

Document id	Document name
900005672	Sky-Watch Drone Manager Manual
900005685	Heidrun Video Controller User Manual
900005709	Fixed Wing UAV Maintenance & Service Schedule
F2908-18	ASTM Standard Specification for Unmanned Aircraft Flight Manual (UFM) for an Unmanned Aircraft System (UAS)
7488-CD 1993	ICAO Standard Atmosphere Doc. 7488-CD 1993

2 General Information and System Description

2.1 Introduction

The complete UAV system is packed in a single portable case for easy storage, easy transportation and high degree of mobility.

Each UAV system consist of a base set of products and components which are common for all Sky-Watch fixed wing UAVs, and then some additional components which are related to the specific UAV type.

Base products and components in all UAS	1x UAV fuselage 1x Right wing 1x Left wing 2x Wing joiners 1x Elevator (horizontal tail fin) 1x LAN cable (for operator tablet) 1x LAN to USB converter 1x UAV battery (packed in separate blue battery safety box) 1x UAV battery charger, for 2x UAV batteries 1x Operator tablet with Sky-Watch Drone Manager installed 1x Charger, operator tablet 1x Fixed wing field repair kit 1x UAV cradle (4 pieces of foam) 1x LiPo bag (UAV battery safety bag) 1x Micro USB cable (between UAV and tablet) 1x Micro USB reader 1x Wing removal tool
Specific components for Heidrun EO/IR with Compact Ground Station	1x Compact Ground station w/charger 1x Pilot hand controller (for manual control of UAV) 1x EO/IR dual camera (mounted on retract mechanism inside UAV) 1x Video tablet with Heidrun Video Controller installed 1x Charger, Video tablet 1x LAN cable (between Compact Ground Station and Video tablet)

	1x Dual port LAN to USB converter 1x EO/IR payload hand controller
Specific components for Heidrun EO/IR with Silvus Ground Station Radio	1x EO/IR dual camera (mounted on retract mechanism inside UAV) 1x Video tablet with Heidrun Video Controller installed 1x Charger, Video tablet 1x Silvus SC4200 Rugged radio 1x Silvus radio Battery (mounted on Silvus Radio) 1x LAN to USB converter 1X Cable XT60 Connector to 5.5mm DC jack 1X Cable 12/24V Car plug to XT60 connector 1X BTC-70716-1 Desktop Charger for Silvus radio Battery (MBITR Compatible)
Specific components for Heidrun Mapping with Compact Ground Station	1x Ground station or Compact Ground station w/charger 1x Pilot hand controller (for manual control of UAV) 1x Mapping camera (mounted inside UAV)
Specific components for Heidrun Mapping with Silvus Ground Station Radio	1x Silvus SL4200 Rugged radio + cable harness 1x Silvus battery for SL4200 1x Pilot hand controller (for manual control of UAV) 1x Mapping camera (mounted inside UAV)

System packaging

The system is packaged in a hard flight case, well suited for transportation in vehicles, or in a backpack for dismounted operation. Backpacks are delivered in a hard case for transportation and long-term storage.

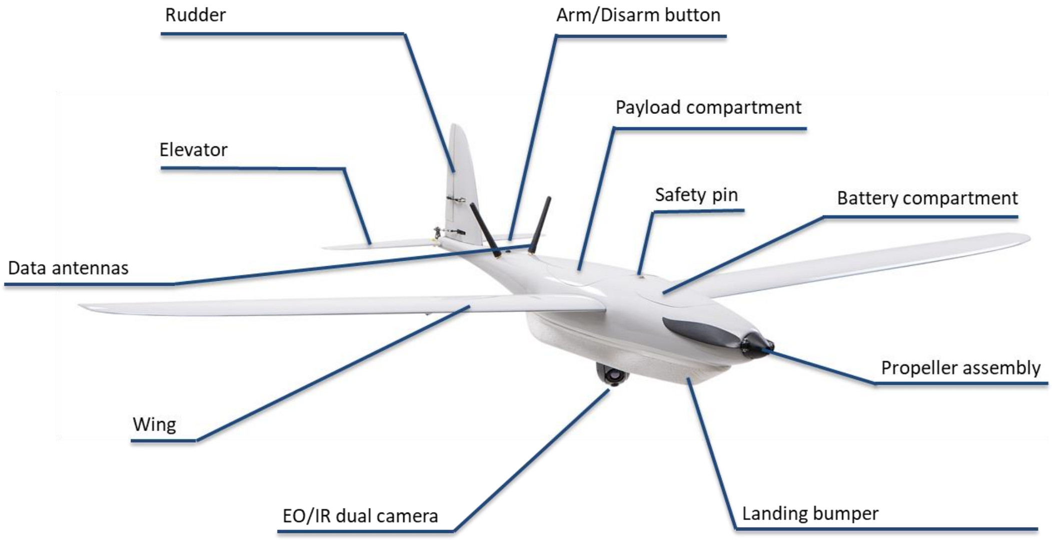
Flight case dimensions	112.2 × 40.9 × 35.5 cm
Backpack dimensions	110 × 40 × 23 cm
Backpack transportation case dimensions	121.2 × 51.4 × 41.7 cm

Picture: Example of complete Heidrun EO/IR UAS kit in a single flight case.

Picture: Example of complete Heidrun EO/IR UAS kit in Backpack.

Picture: Example of Backpack transportation case.

2.2 Aircraft



Picture: Example of Heidrun EO/IR UAV physical component map

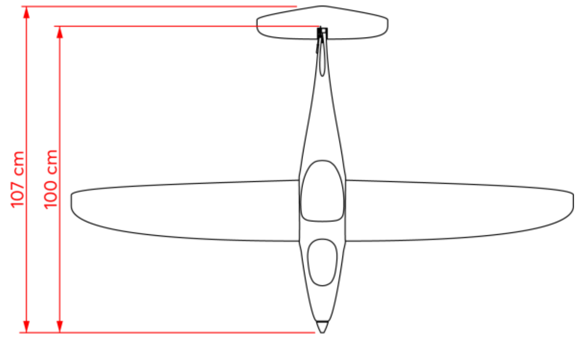
Airframe

Fuselage	Carbon fiber
Wings	Carbon fiber with foam core
Elevator	Carbon fiber with foam core
Rudder	Fiber glass with foam core

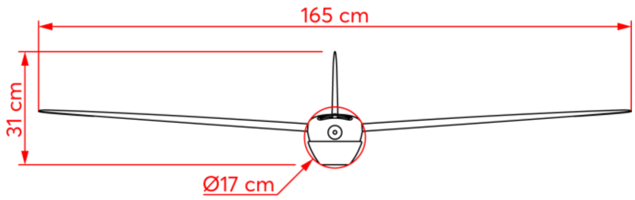
Heidrun EO/IR (front view)	
Heidrun EO/IR (bottom view)	
Heidrun Radio Relay (front view)	
Heidrun Radio Relay (bottom view)	
Heidrun Mapping (front view)	

Dimensions

Wingspan	165 cm
Fuselage length	107 cm (elevator installed)
Fuselage diameter	17 cm



Picture: Top View



Picture: Front View

Weight and Balance

Maximum take-off weight (MTOW)	2.6 kg
Basic empty weight (BEW)	2.1 kg (including battery, excluding removable payload items)
Center of Gravity (CG)	The aircraft center of gravity is marked using a dot under each wing. Center of gravity is verified or achieved by balancing the plane on the two dots under the wings with your fingers. See Section 1877877520.498 Check Center of Gravity for instructions.

Flight Control Surfaces

Elevator and ailerons	KST Digital servo with servo saver
Rudder	KST Digital servo

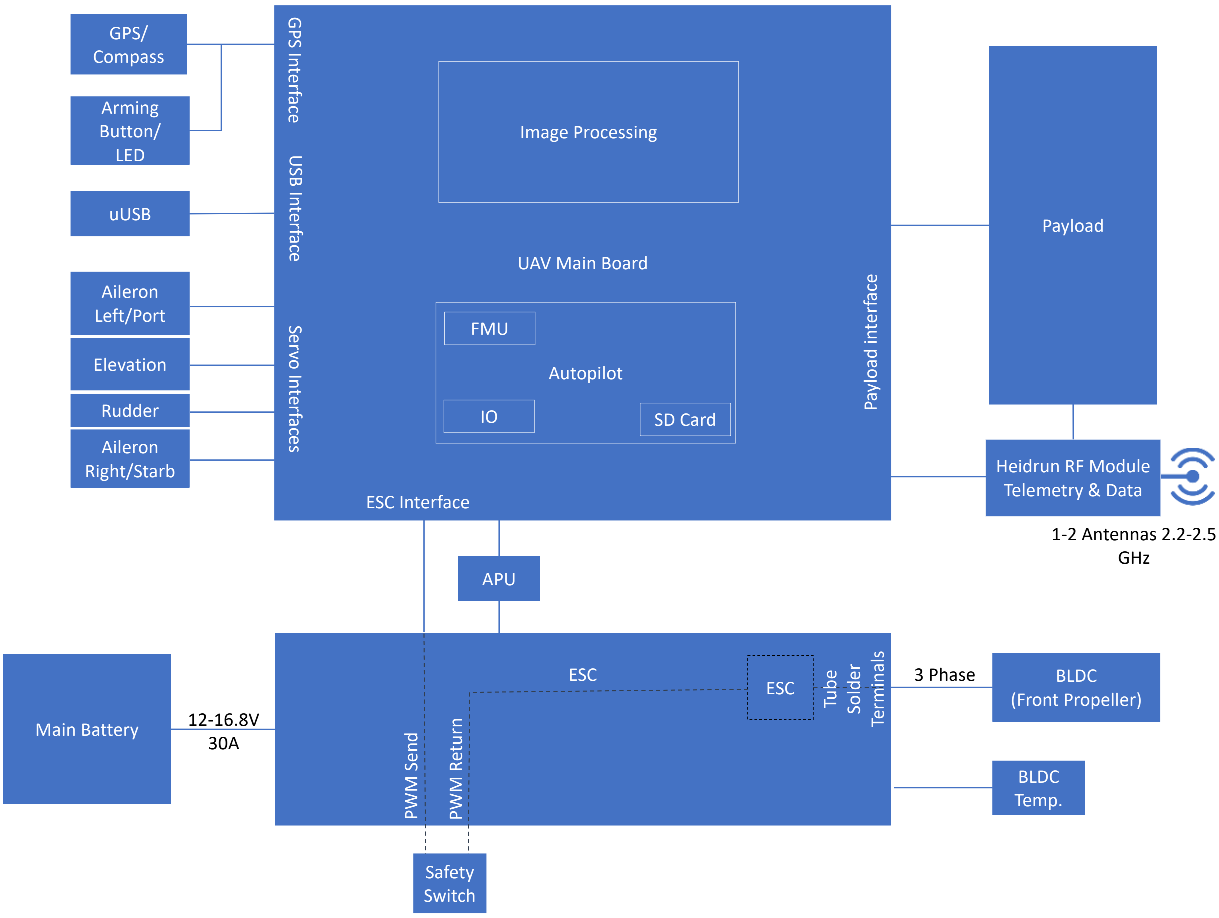
Propulsion, Propellers, and Rotors

Propulsion	3 phase BLDC selected and tested Tiger Motor
Prop size	14 x 8 inches
ESC current rating	40 A slow-burn fused, 60 A FETs
Power in cruise	60 W typical
Power during launch	420 W max

Power

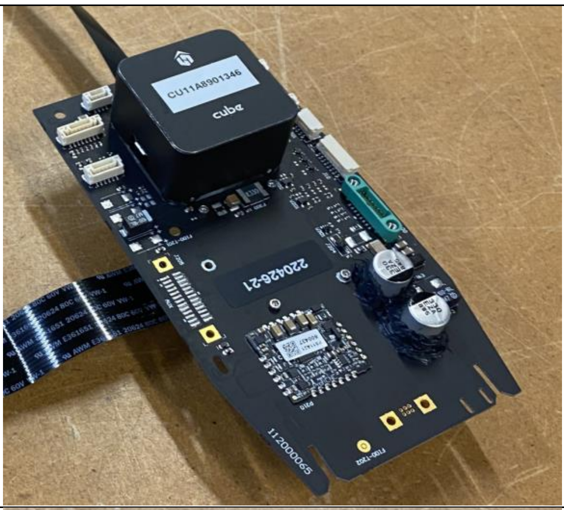
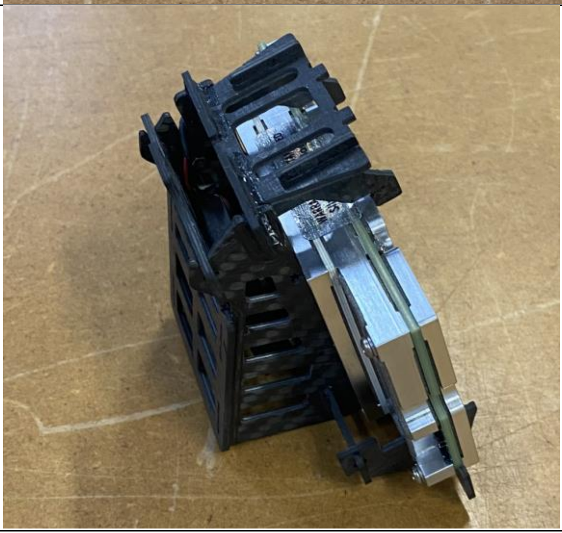
Battery	Sky-Watch Heidrun (P/N p1.020-VV2)
Type	Lithium ion
Voltage	14.8V
Capacity	10,000 mAh
Energy	148 Wh
Weight	650 g
BMS	Yes
Approval	UN38.3

Avionics



INFO: The Auxiliary Power Unit (APU) is currently not fitted on all UAVs.

The physical implementations of the main components are seen below

UAV Main board	
ESC Electronic Speed Controller	
Radio module and Fixture For EO/IR	

Guidance, Navigation and Control (GNC)

Autopilot hardware	Pixhawk 2.1 Cube (Pixhawk 1 in older UAVs) integrated in Sky-Watch custom industry grade avionics (PCB's, wire harness, and power management) to ensure maximum safety, reliability, and robustness.

Autopilot software	Sky-Watch custom flight control software based on the opensource PX4 Autopilot. The software is tailored and optimized for the Sky-Watch UAV platforms including flight modes, protection of critical flight functions, envelope protection, abnormal and emergency modes.

Flight Modes

AUTO	Execution of mission items. Starting from Take-off -> n mission items -> Land.
LOITER	Autonomous loiter. The autopilot will maintain steady flight in a loiter pattern above a coordinate. The autopilot can either circle around a coordinate with a user defined radius or fly in a user defined figure 8 pattern centered above a coordinate. This mode can be used to climb/descend if the user defines new altitudes for the loiter pattern.
RAL	(Return and Land) Execute the last part of the planed mission which contains the landing sequence. Flight to the first wp of the landing sequence can be configured to be performed at either, current altitude, at max planned mission altitude, or in a direct slope towards wp entry altitude.
RTL	(Return to Launch) If the mission memory is corrupted during mission execution, direct flight towards launch will be performed in 100 [m] altitude and LOITER will be performed around launch at 50 [m]. The pilot will from then be responsible for navigation to a safe landing position with CRUISE MODE or reupload a new mission.
CRUISE MODE	The autopilot will maintain altitude (ATO) and course over ground. Altitude and course over ground can be corrected by the pilot via the pilot hand controller.
EMERGENCY LAND	The autopilot will perform a deep-stall landing initiated at the current position. The actual landing position will depend on drop distance, velocity, and wind. Terminal velocity is reached at around 10 meters drop, but accuracy is decreased as altitude of deep stall is increased beyond 30 meters.
GPS Denied RTL	(GNSS Denied Navigation – Return To Launch) The autopilot will perform navigation towards launch based on compass, last known GNSS position, wind conditions and estimated time to fly back to launch position. The autopilot will perform a RAL if GNSS is recovered. During GPS Denied RTL the operator is to take manual control using CRUSE MODE or enable GPS denied flight.

Protection of Critical Flight Functions

The Autopilot performs initial diagnostics of sensors, parameters and mission before allowing autonomous operation. This is done to ensure correct operation, and ability to operate all flight modes.

Autopilot Pre-flight Sensor Validation

The autopilot has redundancy on the following components

	Pixhawk 2.1	Pixhawk 1
Number of Gyroscopes	3	2
Number of Accelerometers	3	2
Number of Magnetometers[1]	4	2
Number of Barometers	2	1
Number of GNSS	1	1
Number of processors[2]	2	2

For every sensor type, a sanity check is performed, based on comparison of n sensors of the same type. Where n > 2 a majority voting algorithm is used to select which sensor is used. If n=2 a primary sensor will be appointed, and the secondary is used for validation and fallback in case of failure of the primary.

The Autopilot stores deep-stall critical parameters in non-volatile memory. Because the deep-stall process is used as a possible failsafe option (EMERGENCY LAND), the autopilot performs parameter validation of these parameters.

Deep stall can be performed even if the primary flight computer malfunctions.

Autopilot Pre-flight Mission Validation

Before a take-off is allowed the autopilot performs mission validation. Mission validation contains the following topics

- Take-off feasibility
- Distance to first waypoint < 900 [m]
- Mission item support
- Landing feasibility

The autopilot does a sanity check of battery voltage levels and requires a minimum of 25% capacity for launch.

Autopilot Inflight Adaption and Protection

Under autonomous flight the autopilot will adjust throttle based on the following constraints:

- Forward velocity (ground speed) > 4.5 [m/s]: Prevent reverse flight and fly-away caused by high head wind
- Airspeed < 18 [m/s]: Protection of actuation surfaces.

Forward velocity protection dominates high airspeed protection

Battery Protection and Failsafe

Battery protection is enforced based on both capacity estimation and voltage level.

At 25% remaining the user is informed that the battery is low and encouraged to execute RAL Navigation.

[1] Including one external
[2] Main processor and co-processor

At 10% the Autopilot will force RAL Navigation. This process can be overruled by further user input. If the Pilot asses that navigation to an alternate landing location is safer, this can be performed by CRUISE MODE and eventually execute EMERGENCY LAND.

Because the battery has an internal BMS system with a low voltage protection at 10.7V (2,675V/Cell), the autopilot will execute EMERGENCY LAND if the battery voltage drops below 11.2V (2.8V/Cell).

Loss of Power

Sky-Watch UAV systems fitted with an Auxiliary Power Unit (APU) has the following additional battery failsafe.

If the main battery is lost, the APU will power the flight controller and servo actuators for the time needed to execute EMERGENCY LAND. If the APU is exhausted before the UAV reaches ground the UAV will lose all actuation and active control, but still be mechanically stable and maintain controlled stall in near level attitude.

Loss of Communication

After 60 [s] communication dropout, the autopilot will force RAL mode. If communication is regained, the autopilot will stay in RAL until the pilot commands otherwise. The pilot has the option of disabling this failsafe at the pilot's own responsibility and if local legislation allows.

Loss of GNSS

After 3 [s] of lost 3D fix, the autopilot will initiate EMERGENCY LAND unless GPS Denied RTL is configured by the pilot, at the pilot's own responsibility and if local legislation allows.

Autopilot Main Processor Failure

Autopilot main processor failure is initiated by the co-processor in case of missing heartbeat every 1 [s]. The co-processor will initiate EMERGENCY LAND.

Flight Mode Validation

The autopilot does periodic feasibility validation of the present flight mode. In the event the required state estimation or sensor output becomes invalid, the autopilot will force a mode change to EMERGENCY LAND.

Loss of State Estimation Caused by IMU Sensor Malfunction

The autopilot will initiate EMERGENCY LAND.

Envelope Protection

To enforce envelope protection the autopilot enforces the roll, pitch, climb and decent constraints defined in Section 3.1 Flight Characteristics.

The constraints are tested and validated by Sky-Watch.

Communications Equipment

Heidrun UAV's w/ Silvus Ground Station Radio

Radio	Embedded radio module 2.2-2.5 GHz MIMO.
Antennas	2x external UAV antennas (MIMO)

Heidrun UAV's w/ Compact Ground Station Radio

Radio	Embedded radio module 2.3, 2.4 or 2.5 GHz MIMO or SISO depending on configuration.
Antennas	1x external UAV antenna (SISO) 2x external UAV antennas (MIMO)

Heidrun 433 MHz UAV's

Radio	Telemetry radio 433 MHz.
Antennas	1x UAV embedded telemetry antenna.

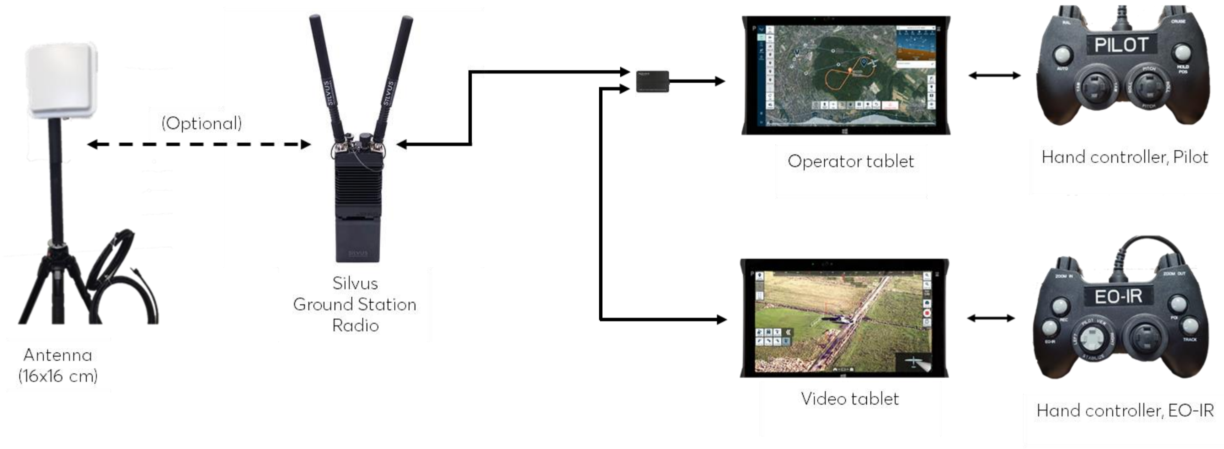
Other avionics

Arming button/LED	Autopilot arming button with LED status indication.
Safety Switch	Main motor safety switch.
GNSS/Compass	GNSS/Compass module with integrated GNSS antenna and LED status indication.
APU	Auxiliary Power Unit (APU) for loss of power failsafe. The APU is fitted on selected customer UAVs.
Micro USB	External USB connector for easy access to autopilot flight logs.
SD Card	SD Card with flight logs installed in the Autopilot.
BLDC Temp	Main motor (BLDC) temperature monitor.

Control station

Heidrun EO/IR UAS w/ Silvus Ground Station Radio

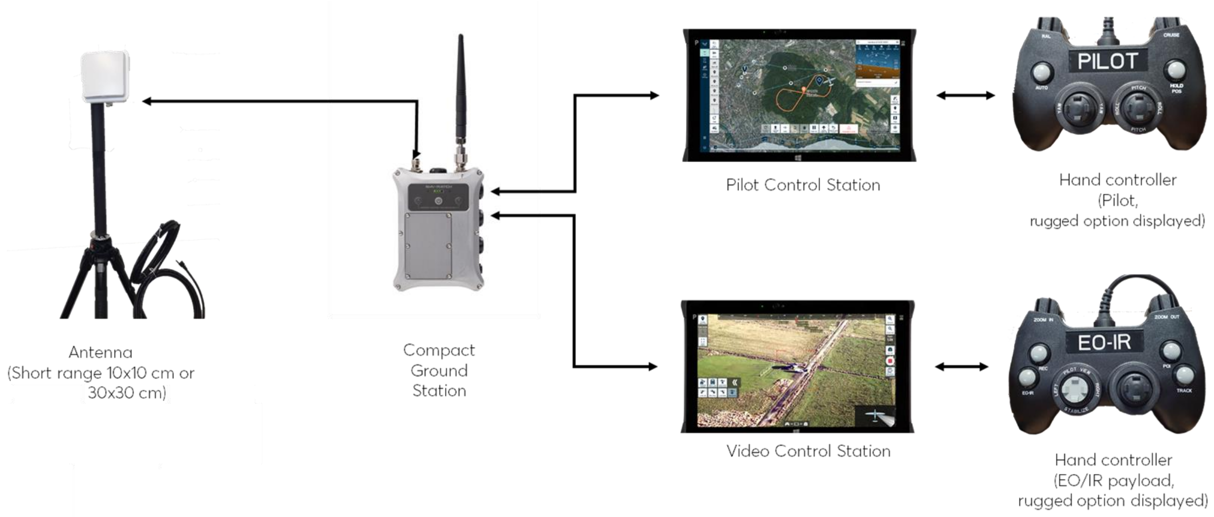
Heidrun EO/IR	1x Silvus Ground Station Radio 1x Ground antenna (16x16cm) 1x Operator tablet with Sky-Watch Drone Manager (SDM) installed 1x Video tablet with Heidrun Video Controller (HVC) installed 1x Dual port LAN to USB converter 1x Pilot hand controller 1x EO/IR payload hand controller



Picture: System diagram for Heidrun EO/IR with Silvus Ground Station Radio and optional 16x16cm antenna.

Heidrun EO/IR UAS w/ Compact Ground Station

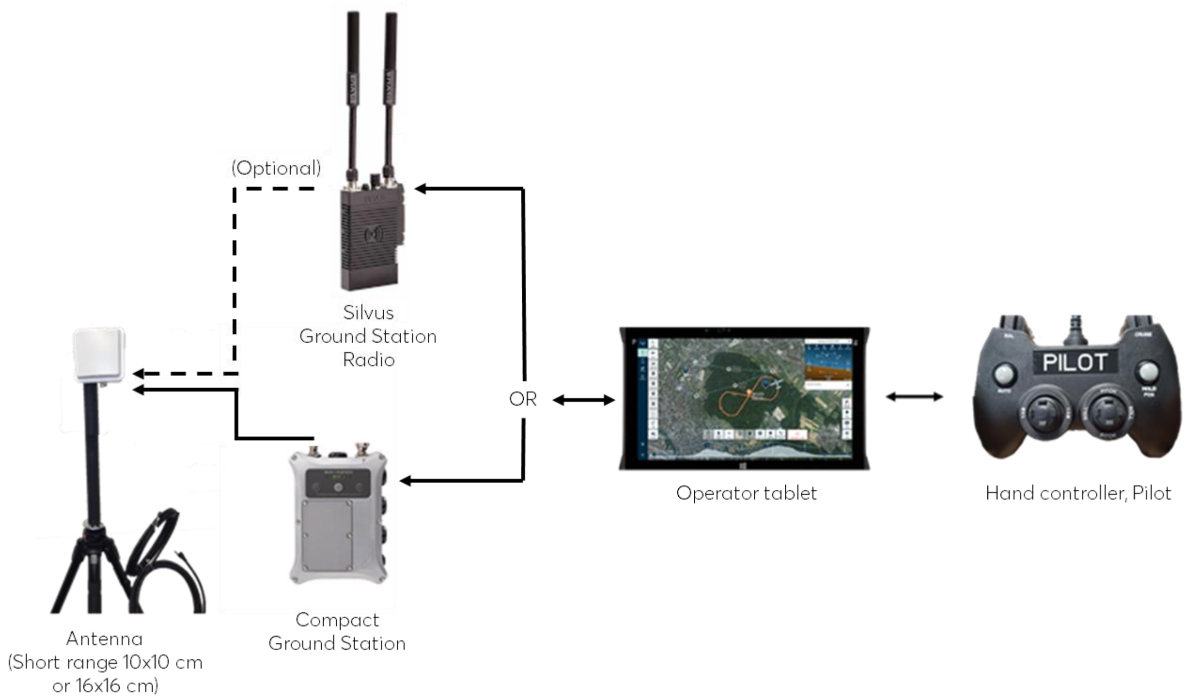
Heidrun EO/IR	1x Compact Ground station 1x Ground antenna (10x10cm or 30x30cm) 1x Operator tablet with Sky-Watch Drone Manager (SDM) installed 1x Video tablet with Heidrun Video Controller (HVC) installed 1x Pilot hand controller 1x EO/IR payload hand controller



Picture: System diagram for Heidrun EO/IR with compact Ground Station (here with a short-range 10x10 cm antenna option).

Heidrun Mapping UAS, Heidrun Radio Relay UAS

Heidrun Mapping Heidrun Radio Relay	1x Compact ground station OR Silvus Ground Station Radio 1x Ground antenna 1x Operator tablet with Sky-Watch Drone Manager (SDM) 1x Pilot hand controller



Picture: System diagram Heidrun Mapping / Heidrun Radio Relay

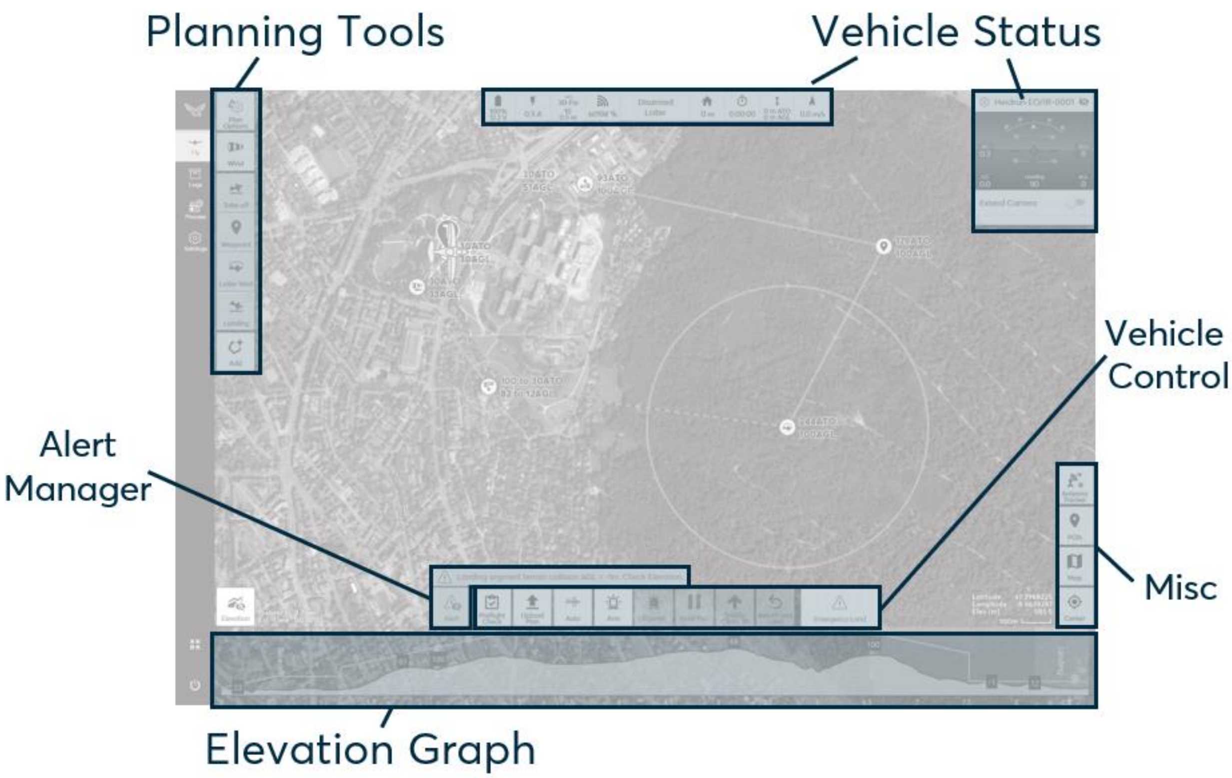
Heidrun Mapping 433 MHz

Cumulus	1x Ground station (USB dongle) 1x Ground antenna on base plate 1x Pilot tablet with Sky-Watch Drone Manager (SDM) 1x Pilot hand controller

Picture: System diagram for Cumulus

Information Displays

Sky-Watch Drone Manager (SDM) provides all the information needed to perform a safe flight with Sky-Watch UAVs.



Picture: Sky-Watch Drone Manager Flight screen overview

Other than the essential flight information (required to fly your vehicle safely) the SDM also lets you customize a panel of additional flight Information to suit your specific needs.

Based on the selected **Vehicle Type** you will also be provided with **Payload Information and Control**.

The default list of information and configuration of information displays are at any time documented in the Sky-Watch Drone Manager manual (document id 900005672).

User Interfaces

Tablets

Model	Panasonic CF-20 (2-in-1 tablet with keyboard) 
Performance	Win 10 Pro, Intel® Core™ i5-7Y57 vPro™, 8GB RAM, 256GB disc
Physical	10.1" WUXGA, 800 nit 272 mm x 233.0 mm x 33.5 mm 1.9 KG
Environment	Operating: -29° C to +60° C Storage: -51° C to +71° C IP65
Battery	11.4V, 2600mAh (each battery), 2 batteries (1 in tablet, 1 in keyboard)
Applications	Ground Control Station software: Sky-Watch Drone Manager Heidrun Video Controller
SDM features	Flight planning, flight operation, UAV control, flight logs, data post processing
HVC features	Live video stream, EO/IR payload control and operation, video POI management

Model	Mobile Demand T-1600/T-1680 (tablet) 
Performance	T-1600: Win 10 Pro, Intel® Core i5-5200U, 4GB RAM, 256GB disc T-1680: Win 10 Pro, Intel® Core i5-8250U, 8GB RAM, 256GB disc
Physical	11.6″ screen, 500 nit

	298.5 mm x 191.8 mm x 20.1 mm 1.6 KG
Environment	Operating: 0° C to +60° C Storage: -33° C to +71° C IP65 (dust and water)
Battery	86Wh, 11.1V, 7800mAh XL battery pack
Applications	Ground Control Station software: Sky-Watch Drone Manager Heidrun Video Controller
SDM features	Flight planning, flight operation, UAV control, flight logs, data post processing
HVC features	Live video stream, EO/IR payload control and operation, video POI management

Hand Controllers

Type	Pilot
	Manual control of UAV
Features	YAW left/right, Roll left/right, Pitch up/down, Hold Position, Cruise, Auto, Return and Land (RAL)
Standard Pilot hand controller	
Ruggedized Pilot hand controller (add-on option)	 Environment: IP54

Type	EO/IR payload operator
Application	Manual control of EO/IR dual camera

Features	Zoom in/out, Record video, switch between EO and IR mode, set POI, activate object tracking, camera view (pilot view, stabilize, look left/right)
Standard EO/IR payload hand controller	
Ruggedized EO/IR payload hand controller (add-on option)	 Environment: IP54

Interoperability Between Control Station and Multiple Aircraft Types

Control of multiple aircrafts using one control station is not possible.

Any of the listed tablets above can be used with any of the Sky-Watch fixed wing UAV types.

2.3 Command and Control (C2) Link

ATTENTION: Radiofrequency transmitters can potentially produce adverse thermal effects on the human body. To avoid hazards:

- Avoid walking or standing in front of high gain antennas (patch antennas)
- Turn off equipment before disconnecting RF cables

Silvus Ground Station Radio – Heidrun EO/IR

Link description	C2 Telemetry and payload (payload control & video downlink)
Frequencies	2.2 - 2.5 GHz, 2X2 MIMO
Transmission power	Up to 36 dBm (4.0 W)
Modulation bandwidth	10 MHz
Antenna gain	UAV and ground omni antennas: 2.1 dBi MR antenna (16x16cm): 12 dBi
Range	Omni antennas: up to 12 km LOS MR antennas: up to 25 km LOS

Encryption	256bit AES encryption
Certifications	FCC (class B digital device), CE Mark

INFO: The Silvus Ground Station radio has a pre-set configuration that is compliant with standard Wi-Fi limitations (ETSI EN 300 328). The configuration is accessible in SDM.

Use this configuration (2G4 20dBm) to avoid hazards from high power RF transmission.

Silvus Ground Station Radio – Heidrun Mapping

Link description	C2 Telemetry and payload (payload control & video downlink)
Frequencies	2.2 - 2.5 GHz, 2X2 MIMO
Transmission power	Up to 30 dBm (1.0 W)
Modulation bandwidth	5 MHz
Antenna gain	UAV and ground omni antennas: 2.1 dBi MR antenna (16x16cm): 12 dBi
Range	Omni antennas: up to 10 km LOS MR antennas: up to 16 km LOS
Encryption	256bit AES encryption
Certifications	FCC (class B digital device), CE Mark

Compact Ground Station (Heidrun EO/IR and Heidrun Mapping)

Link description	C2 Telemetry and payload (payload control & video downlink)
Frequencies	Tree options 2.304 - 2.390 GHz, 2X2 MIMO 2.402 - 2.478 GHz, 2X2 MIMO or SISO 2.500 – 2.570 GHz, 2X2 MIMO
Transmission power	Up to 30 dBm (1.0 W) for SISO, up to 27dBm for MIMO
Modulation bandwidth	4 MHz

Antenna gain	UAV and ground omni antennas: 2.1 dBi SR antenna (10x10cm): 8 dBi MR antenna (30x30cm): 17 dBi
Range	Short range antenna: up to 12 km LOS Antenna tracker antenna: up to 25 km LOS
Encryption	128bit AES encryption
Certifications	FCC, Industry Canada for 2.4GHz modules

Heidrun Mapping 433 MHz

Link description	C2 Telemetry
Frequencies	433.920 (433.050 to 434.790 Frequency Hopping Spread Spectrum (FHSS))
Duty cycle	Min 10% up to 100% depending on license
Transmission power	Up to 20 dBm (100 mW)
Modulation bandwidth	35 kHz
Antenna gain	0 dBd
Range	Up to 10 km LOS
Certifications	CE

2.4 Launch and Recovery

The aircraft is hand-launched and always in headwind direction and recovered by a single person. Recovery is done by an autonomous 'deep stall' landing method at the planned landing zone.

Take-off Profiles

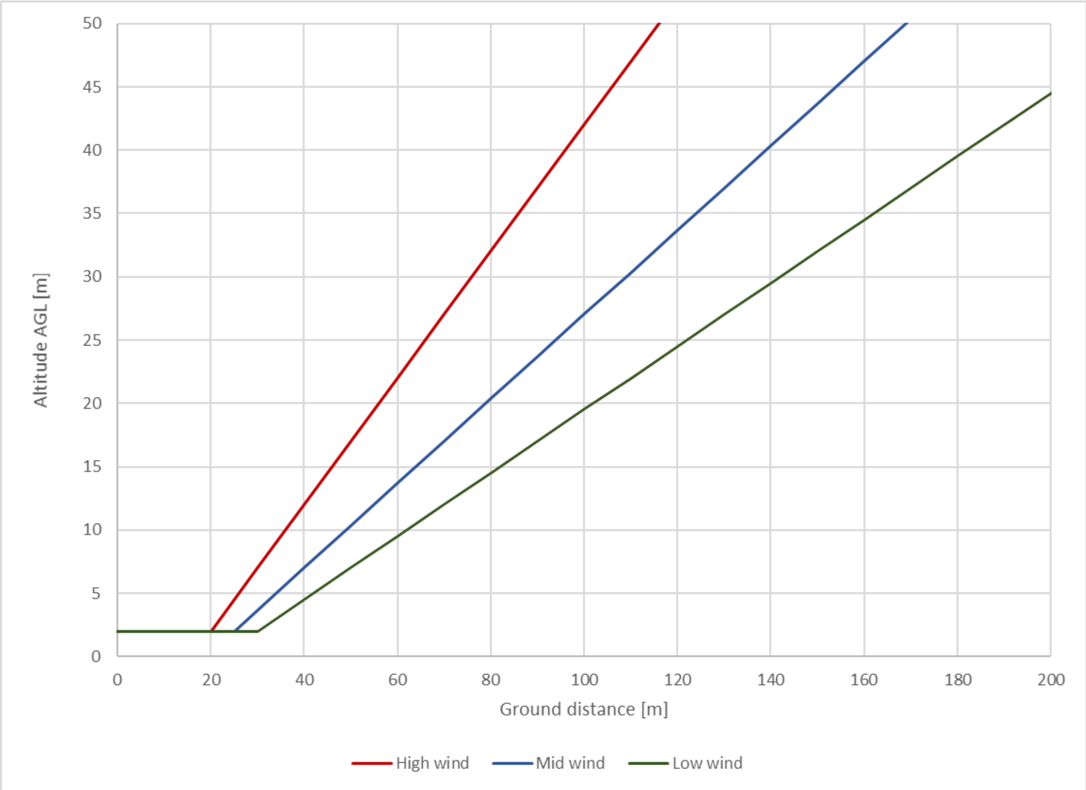
The launch profiles and scenarios presented in this section, are representative of a Sky-Watch certified operator capable of launching the UAV with at least an acceleration of 25 m/s^2 in the forward direction.

All specifications mentioned are in relation to the ICAO Standard Atmosphere.

In such conditions, with a worst-case scenario of zero headwind, the conservative launch distance to launch height can be calculated as:

d [m] = 30 [m] + 4 x launch altitude AGL [m]

Example take of profiles for low wind (<4 [m/s]) mid wind (4-8 [m/s]), and high wind (>8 [m/s]) scenarios are depicted below. The UAV is launched by a typical pilot at 2 [m] AGL in a standard atmosphere.



Climb rate during the take-off segment is limited by an air speed calculation of the flight controller, typically 5 [m/s] – denoted climb-out. Throttle is always 100% in take-off segment.

To optimize energy (battery) efficiency and flight stability software settings limits climb and decent rates to 1.5 [m/s].

As with any other fixed winged aircraft, the lift depends on air density, linearly, and the air density varies with absolute pressure and absolute temperature. This must be considered, when launching in high temperature or high-altitude missions.

Landing Profiles

The land profile of the UAVs consists of three elements. A loiter point for reducing altitude from mission altitude, flight to landing approach path and the approach path vector itself.

The landing is a deep-stall type landing where the UAV pulls itself into a stabilized stall, allowing STOL missions.

Deep stalls can be initiated from any altitude up to 100m AGL. However, the landing precision is decreased with increased deep stall altitude.

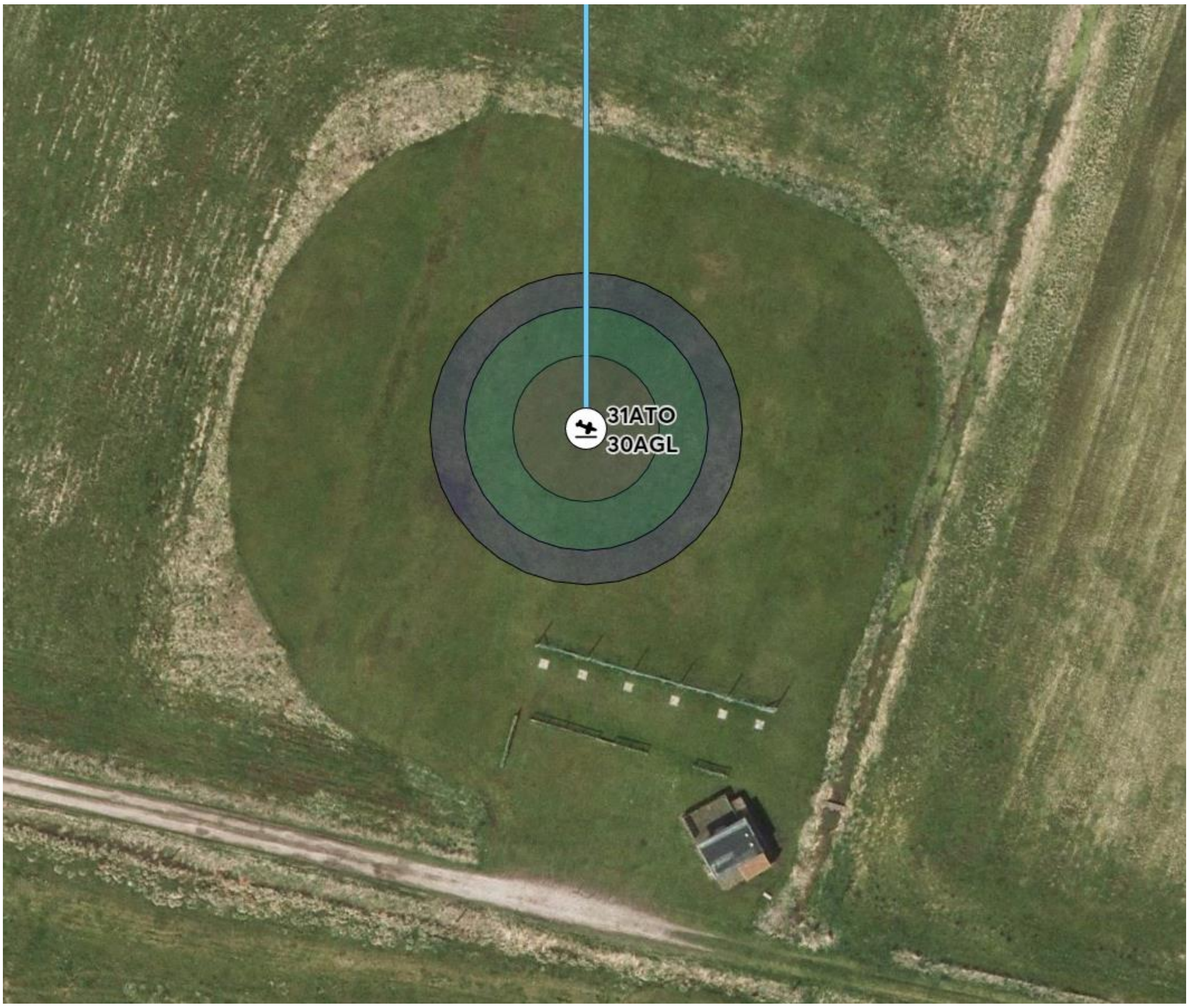
The standard landing precision, from a 30 [m] deep stall altitude, is defined using circles of uncertainty:

Inner circle: 7.5 [m] radius, 65% likely

Mid circle: 12.5 [m] radius, 30% likely

Outer circle: 16.0 [m] radius, 5% likely

See illustration below.



Landing precision illustrated in SDM

INFO: The landing precision will vary with wind alignment, deep stall altitude above ground and the air pressure (e.g., high absolute altitude decreases air density, which makes descent faster).

It is always recommended that the pilot scopes the area and keeps personnel and bystanders aware of UAV operation, and possibly marks the landing area.

Generally, the landing will, within the stated precision radii, overshoot the center of the landing spot in low wind conditions and undershoot in high wind conditions in the direction of the wind.

Example Mission

An example mission from the Sky-Watch Drone Manager, SDM, is depicted below:

A mission consists of segments:

Take-off Segment

The take-off is started from the take-off position. The UAV will climb in a straight line in the direction it is launched until reaching the fast climb altitude (20 [m] AGL. 17 [m] in this example). The UAV will then climb towards the ascend circle and stay in the ascend circle until reaching the exit altitude (75 [m] AGL. 76 [m]).

Mission Specific Segments

Depending on the mission and vehicle type, different segments can be inserted, such as waypoints and area scan segments. In this example a standard waypoint, which is using normal flight envelope, will increase height to 130 [m] AGL

Landing Segment

The aircraft will initiate the landing segment from the descend circle. It will descend to the deep stall altitude. The approach WP is used to make sure that the aircraft performs the deep stall landing with head wind at the specified landing position.

INFO: Detailed descriptions of all segments, and how to create flight plans can be found in the SDM manual (document id 900005672).

2.5 Ground Operational Area Set Up

Security of Flight Crew Positions and Personnel

- Always keep safety pin installed in UAV when not flying

Picture: Safety pin installed in aircraft

- Always approach the aircraft from behind
- Keep fingers away from propeller
- Do not fly aircraft in mean wind > 12m/s and never exceed the Environmental limitations
- Keep any bystanders away (on safe distance) from the landing zone (see 2.4.2) when the aircraft is performing its deep stall landing
- Once the aircraft has completed its deep stall landing, immediately install the safety pin
- Never fly the aircraft with damaged material/components, and always perform pre-flight check before launching the aircraft

3 Performance and Limitations

3.1 Flight Characteristics

Endurance	Heidrun EO/IR: Up to 100 min Heidrun Radio Relay: Up to 120 min Heidrun Mapping: Up to 150 min
Cruise Speed	16 m/s (air speed)
Never exceeded speed (NVE)	30 m/s (air speed)
Min Speed	12 m/s (air speed)
Stall Speed	11 m/s (air speed)
Glide ratio	1:32.2
Max roll angle	Roll angle < 50° Roll angle > -50°
Max pitch angle	Pitch angle < 20° Pitch angle > -20°
Rate of climb	1.5 m/s
Rate of descent	1.5 m/s
Turn radius	Min: 70 m
Deep stall velocity	Typical 10 m/s (depending on air density)

All specifications mentioned are in relation to the ICAO Standard Atmosphere.

3.2 Environmental Limitations

Operational Limitations

Max wind tolerance	12 m/s (mean wind)	Operationally verified
Maximum operating altitude	5,100 m MSL	Operationally verified
Maximum landing altitude	3,000 m MSL	Operationally verified
Operating temperature*	-20° C to +45°C	MIL-STD-810H, Method 501.7, Procedure II (constant) MIL-STD-810H, Method 502.7, Procedure II
Thermal shock	+20°C to +45°C	MIL-STD-810H, Method 503.7, Procedure I-C
Dust	10.6±7g/m3 up to +55°C; Front and tail exposed 8.9m/s	MIL-STD-810H, Method 510.7, Procedure I
Foreign object protection	≥ø12.5mm	IEC60529-2002, IP2x
Humidity	93±3%RH; 40°C	MIL-STD-810H, Method 507.6, Procedure I (Storage and Transit)

* Pre-flight Cooling Unit must be used at pre-flight check at high ambient temperatures.

Complete UAV and Control Station assembled with batteries installed including Compact Ground Station, tablets, controllers and ground antenna. Additional limitations on payloads may apply, see Section 3.2.1.1.

ATTENTION: Absolute maximum temperature limitation on UAV battery is 65°C at which the BMS protective circuit will cut power.

Operational Payload Limitations

EO/IR	-20° C to +55°C	MIL-STD-810H, Method 501.7, Procedure II (constant) MIL-STD-810H, Method 502.7, Procedure II
R10C	-10° C to +45°C	Operationally verified
Map 24	-10° C to +45°C	Operationally verified
Radio Relay	-20° C to +55°C	Supplier specifications

Storage and Transportation

Storage temperature	-20 C° to +60 C°	MIL-STD-810H, Method 501.7, Procedure I (constant temperature) MIL-STD-810H, Method 502.7, Procedure I
Vibrations	5-500Hz; xyz rms 2.24/1.45/1.32	Method 514.8, Procedure I (Category 4 - CWV)
Rain and Dust	IP67 (In flightcase) IP43 (Backpack in transportation case)	IEC60529-2002

Complete system in transportation case

3.3 Acoustic Noise Profile

Condition of motor	Test setup	Distance [m]	Measurement [dBA]@distance
Launch	Test bench stationary (stalled propeller)	1	82
Launch	Flight launch	1	69
Cruise	Test bench stationary (stalled propeller)	1	69
Cruise	Flyby	30	46
Cruise	Flyby	50	42
Cruise	Flyby	100	38 (*)

Noise Level Measurements. (*) 38dBA was around background level

4 Normal Procedures

4.1 Pre-flight Planning

Launch Site Selection

When choosing the launch site, you should ensure that the area in the take-off direction (head wind) in front of you is free of obstacles like trees, tall building, masts, wires, poles etc.

You should ensure a clear path of min. 75-150m (depending on high/mid/low wind conditions) from the take-off position in the take-off direction as the aircraft will climb from launch height to 30m AGL (standard climb height if not changed in SDM) before it will continue to the next way point in the uploaded flight plan. Please see section 2.4.1 for take-off profiles for more details.

ATTENTION: The take-off position is used for synchronizing the flight plan altitudes with the vehicle. Always launch the vehicle from this position.

INFO: The flight plan assumes that the vehicle is launched in head wind. The first part of the flight track is therefore locked according to the wind direction and assumed the aircraft is armed in the same direction and shown with a dashed line in SDM. It is possible to arm and launch the vehicle in other directions. In such cases the vehicle will not follow the flight track in SDM until reaching the fast climb altitude. It is recommended to always arm and launch the vehicle in the direction that is given by the wind direction.

Landing Site Selection

Evaluation of Landing Site

When choosing a landing spot, special care should be taken to find a site that is: soft, flat and even. If no options are available at the planned destination an option could be to move the landing site to a new position and fly the aircraft to the new landing zone instead.

Planning for landing is a crucial part of the flight preparations and time should be set aside to scout for suitable areas.

Evaluating a site for landing, requires the operator to take different issues into consideration which are described further below.

The desired landing conditions should be available for the entire landing radius (95% of all landings will be within a radius of 12.5m. Please see section 2.4.2 for more details for landing profiles) and a thorough search should be conducted to ensure that the area is suitable and safe.

The evaluation of the approach path of the aircraft into the landing zone is also crucial as this should be clear of buildings, trees, poles, masts etc. as the aircraft decent down to the altitude of default 30m AGL which is the altitude when the deep stall is initiated (deep stall altitude can be changed in SDM by the pilot).

Things to look out for at the landing zone:

Isolated anomalies such as poles, stones, holes etc. Remove stones if necessary or move to another landing spot

Overhanging branches, communication masts, wires or antennas

Unexpected traffic such as: pedestrians, vehicles or livestock. The entire landing area should be visible and observed during flight and landing

Operational Environment

To correctly choose a suitable landing site, some environmental factors should be taken into consideration.

Altitude

The altitude above mean sea level (MSL) must be observed for the landing site. As altitude increases, air density will decrease. A decrease in air density will increase the impact velocity of the aircraft and therefore put more stress on the mechanical construction of the aircraft. E.g., at 2,500m the impact velocity could increase as much as 50% compared to sea level landings. At present the maximum MSL for landing is 3,000m and if landings are made above 1,500m special care should be exercised in finding an ideal landing site.

Temperature

As temperature increases, air density will decrease. A decrease in air density will increase the impact velocity of the aircraft and therefore put more stress on the mechanical construction of the aircraft. If flying in temperatures above 40 degrees C., extra attention should be directed at finding ideal landing sites. Although temperature has a noticeable effect on landing speed, altitude remains the most important factor.

Wind

The vehicle is designed to handle landings in 0-12 m/s. head wind. As wind increases the importance of planning an approach directly into the wind gets more important. Always land the aircraft head wind. Failing to land in had wind can cause instability and can lead to damage, especially if the landing site is less than ideal.

Combination of Less-Than-Ideal Conditions

While a landing at 3,000m MSL can be carried out safely, extra care should be taking, if other problematic conditions are also present. As an example: a planned landing at 3,000 m MSL at 45 degrees C and heavy turbulence is likely to cause risky landings, even though each factor on its own is acceptable.

Landing site conditions

The condition of the ground on which the aircraft is landing is by far the most important factor in a successful landing. The conditions the operator should be looking for are: As soft as possible, as even as possible, as level as possible and finally the available horizontal space available for safe landing.

Ground Hardness

Ground properties can vary from hard concrete to very soft grass fields. The operator's goal should always be to find the softest possible conditions in the area.

Geometry of Ground

The landing site should be flat or very close to flat. A slope, hill or hole will affect the impact point on the aircraft and could cause damage.

While hills or slopes are easy to identify, special care should be taking when looking at the micro conditions of the landing site. A site with stones of a diameter above 5 cm, will have the same effect as a hill side if the plane impacts just on the edge.

This could cause the wing tip to impact first and result in damage. The same is true for wheel tracks on a dirt road which comparably could have a local inclination steeper than a hill side.

Avoid landing in thick grass, thick straws or crops, as the hard straws may damage the payload or puncture the wings when landing.

Airspace Environment

It is the responsibility of the UAV Pilot/Operator to know the local and national airspace rules and legislation applicable to fly and operate the UAV in the specific mission area.

It is recommended to have contact to aviation authorities and/or closest aviation tower to ensure they are informed of UAV flight, and you have knowledge of other flight activities in the mission area.

Radio Frequency (RF) Environment

It is the responsibility of the UAV Pilot/Operator to know the local and national radio frequency rules and legislation in relation to flying and operating the UAV in the mission area.

For missions with Heidrun EO/IR UAS it is furthermore important to check for any possible radio interference or jamming from communication network and/or equipment in the mission area as this can influence the data/communication link to the UAV and cause lower video quality or disturbance of the telemetry data. The assessment should lead to the use of a radio frequency suited for the mission.

Use of Launch and Recovery Equipment

No equipment is required for launch and recovery of the aircraft as it is hand launched and uses "deep stall" landing method.

Distance to Control Station

No special requirement other than the control station (running the SDM software) must have a connection to the ground station radio (e.g. connection via LAN cables).

4.2 System Assembly and Pre-flight Inspection check

ATTENTION: Before or during the assembly of the aircraft it is important to inspect all aircraft components to ensure that no damages are present which can have an impact on flight performance or safety.

Assembly of UAV Cradle

Attach the 4 foam pieces together to a cradle

Place fuselage in cradle (UAV nose head wind direction)

Picture: 4 cradle foam pieces

Picture: Assembled foam cradle

Attach Elevator (Horizontal Tail Fin)

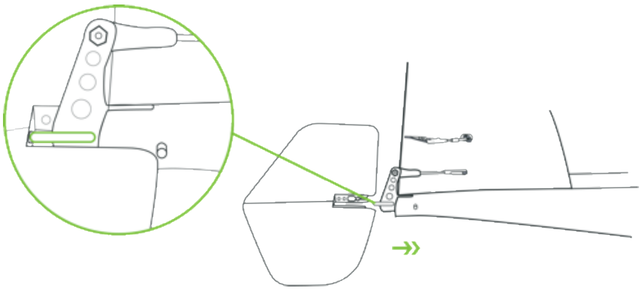
Make sure the fuselage is positioned in the cradle.

Hold the rear of the fuselage with one hand and the elevator with the other hand

Place the elevator on the bell crank

Make sure the elevator bell crank enters in the hole in the horizontal tail

Push forward until both sides click into place



Picture: how to attach elevator

ATTENTION: Before flying always check that the elevator is properly clicked in place in both sides. Check is done by holding the UAV (without UAV battery and without wings installed) in a firm hand grip around the fuselage below the rudder, with two fingers hold the elevator (centre wise) and carefully loosen the hand grip of the fuselage. If mounted properly you will be able to lift the UAV by its elevator.

Picture: Check elevator mounting with caution

Attach Wings (left and right)

Please be aware that two wing connection designs are released and in use and both assembly instructions are described below. The two wing connection designs are:

- Wing connection with wired connection
- Wing connection with un-wired click-on connection

Attach Wings – "Wing connection with wired connection"

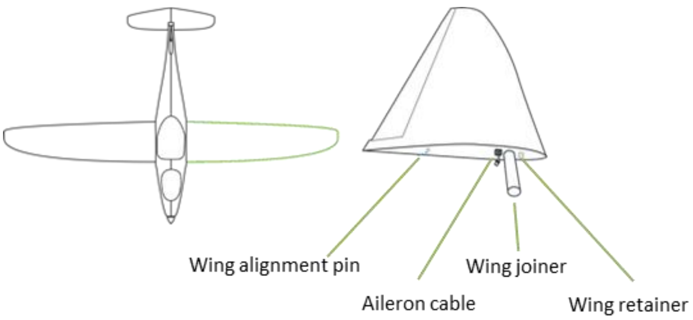
Insert wing joiner into wing

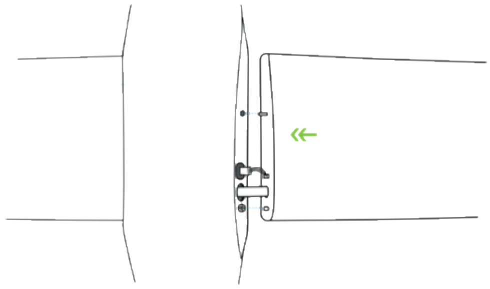
Hold the aircraft with one hand and the wing with the other

Connect the wing cable firmly to the connector on the fuselage, observing orientation

Gently push the wing towards the fuselage to engage wing retainer.

Be careful that the cable is not pinched between the wing and fuselage. Click the wing into place.





Picture: wing connection points

Picture: how to attach wing and cables

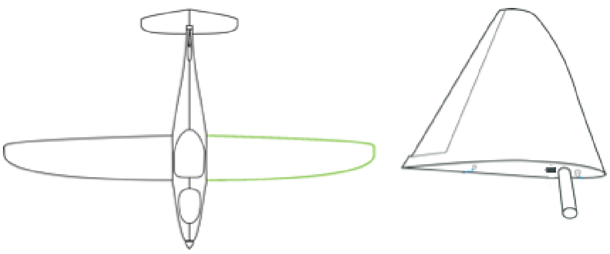
Attach Wings – "Wing connection with un-wired connection"

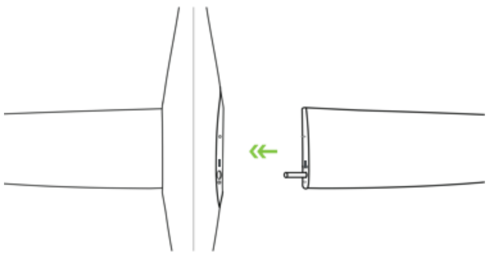
Insert wing joiner into wing

Hold the aircraft with one hand and the wing with the other.

Gently push the wing towards the fuselage to engage wing retainer

Finally push the wing to click on to the wing connector





Picture: wing connection points

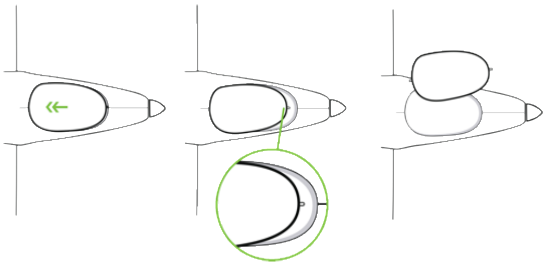
Picture: how to attach wing

Open Front Hatch and Install Battery

With your thumbs gently push the centre of the hatch down so the sides flip up

Slide the hatch slightly back

When the fixture pin is visible: Lift the hatch slightly and slide the hatch forward to remove it

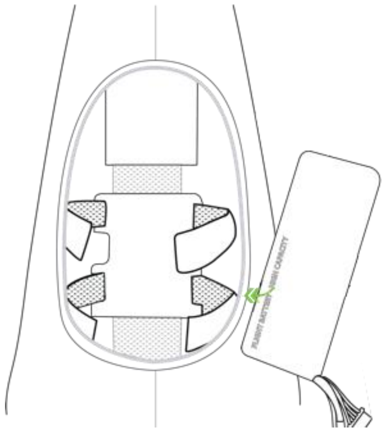


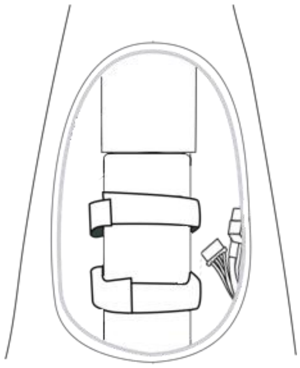
Picture: how to remove hatch from battery compartment

Insert new battery between the two foam blocks (place the battery with its cables facing tail direction)

The battery must have a tight fit between the foam blocks – if not replace the foam blocks

Fix the two Velcro-straps around the battery





ATTENTION: Always ensure the safety pin is installed when UAV battery is connected to the aircraft.

INFO: Do not connect the UAV battery cable until you need to establish a connection between the aircraft and the Ground Station.

Check Center of Gravity

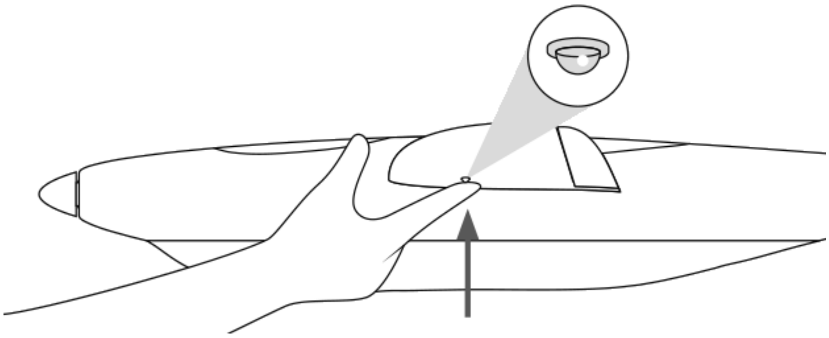
After payload, battery, Wings and elevator have been properly installed, make sure the aircraft is in balance

Use the small transparent balancing points underneath the wings

Place one finger on each balancing point

The aircraft should be in perfect balance.

If not, adjust the battery position by adjusting and/or modifying the battery foam blocks



Picture: how to balance aircraft

INFO: Preferable balancing should be done indoor, to make sure that the aircraft is not not affected by winds during this procedure.

Assemble Ground Antenna and Ground station

The procedure to assemble ground antenna and ground station varies between the systems:

Heidrun EO/IR – Silvus Ground Station Radio Setup

Unfold the tripod and extend the legs (tripod must be levelled and stabile on the soil)

Mount the Silvus Ground Station Radio on the extended tripod pole

OPTIONAL: Attach the patch antenna on top of the tripod pole

OPTIONAL: Detach one antenna from the Silvus Ground Station Radio and use the coax antenna adapter and cable to connect the patch antenna to the free antenna connector on the radio.

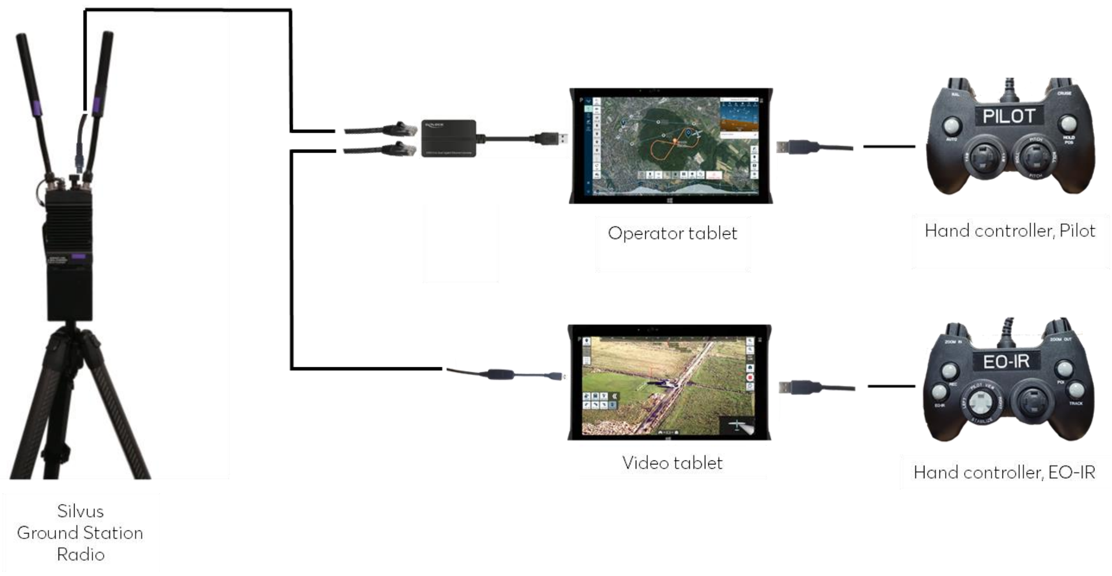
Connect USB-LAN adaptor to the operator tablet (USB port)

Connect ODU-LAN cable between the USB-LAN adaptor and the ODU connector marked PRI on the Silvus Ground Station Radio

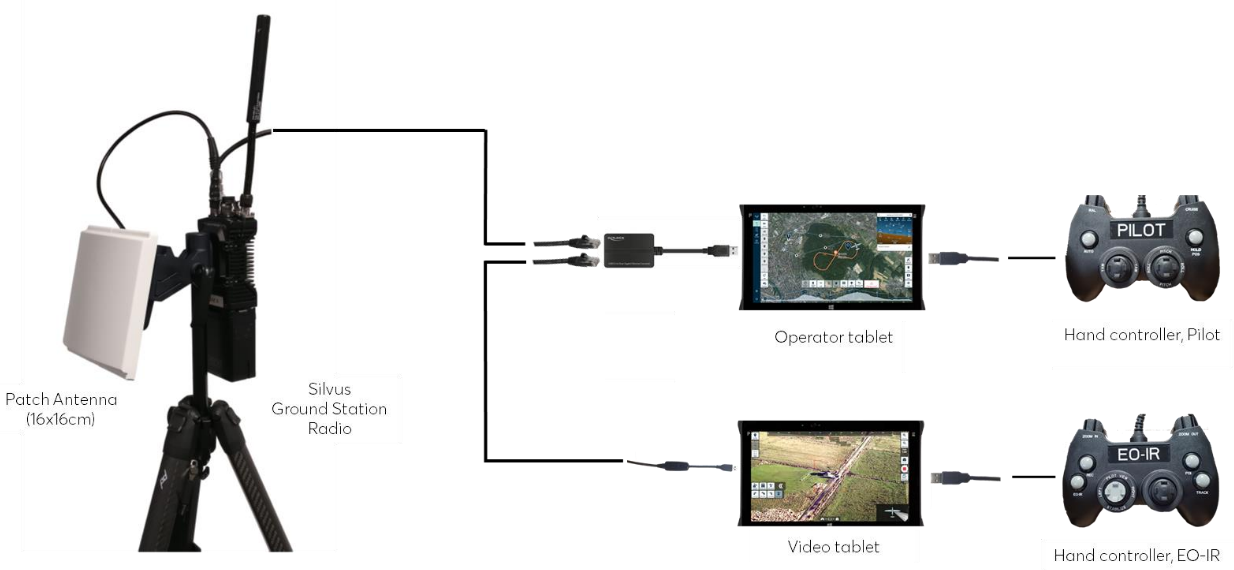
Connect USB-LAN cable (with the USB-LAN adaptor) between the Video tablet (USB port) and the free LAN port on the USB-LAN adaptor

Connect the Pilot controller to the operator tablet (USB port)

Connect the EO-IR controller to the video tablet (USB port)



Picture: System setup assembly with Silvus Ground Station Radio



Picture: System setup assembly with Silvus Ground Station Radio and optional 16x16 patch antenna

Heidrun EO/IR – Compact Ground Station Setup

Unfold the tripod and extend the legs (tripod must be levelled and stabile on the soil)

Mount the aluminium extension pole to the tripod

Attach the Compact Ground Station on the mount on the aluminium pole

Attach the short-range antenna on top of the aluminium pole

Connect the antenna cable to the coax connector with a physical marking

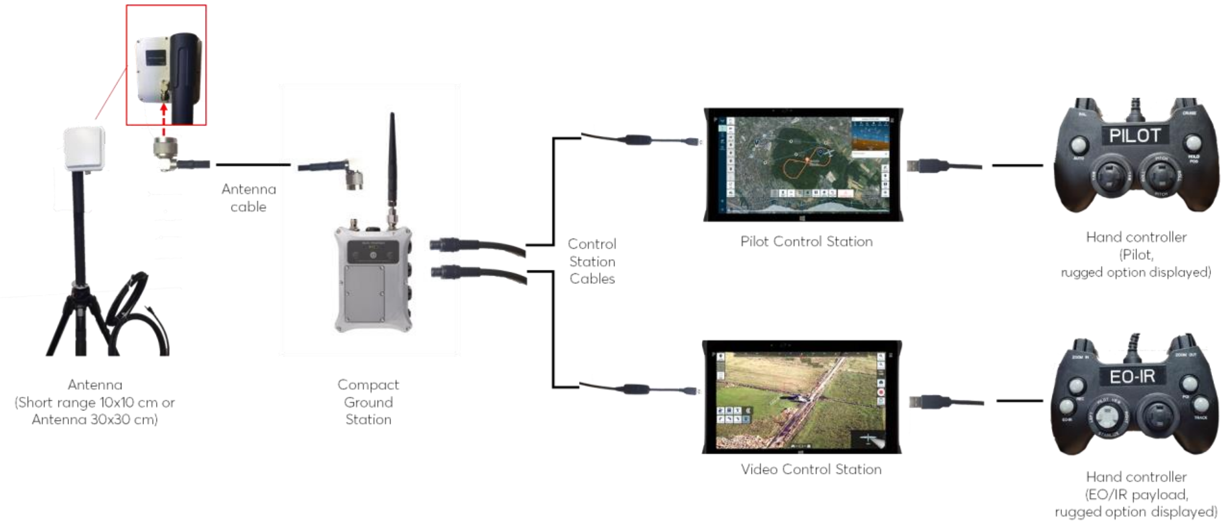
Mount the omni-directional antenna to the free coax connector

Connect USB-LAN cable (with the USB-LAN adaptor) between the Pilot tablet (USB port) and one of the connectors the Compact Ground Station

Connect USB-LAN cable (with the USB-LAN adaptor) between the Video tablet (USB port) and one of the connectors on the Compact Ground Station

Connect the Pilot controller to the operator tablet (USB port)

Connect the EO-IR controller to the video tablet (USB port)



Picture: Short Range antenna setup assembly

Heidrun EO/IR - Antenna Tracker Setup

Unfold the tripod and extend the legs. Tripod must be level and stable on the ground

Mount the antenna tracker house on top of the tripod and fasten the locking grip

Attach the antenna to the Compact Ground Station (slide it in place from the side and tighten the screw on the back of the mount)

Connect the antenna cable to the connector on the back of the antenna and the connector at the antenna mount on top of the Compact Ground Station

Connect USB-LAN cable (with the USB-LAN adaptor) between the operator tablet (USB port) and one of the connectors on the side of the Compact Ground Station

Connect USB-LAN cable (with the USB-LAN adaptor) between the Video tablet (USB port) and one of the connectors on the side of the Compact Ground Station

Connect the Pilot controller to the operator tablet (USB port)

Connect the EO-IR controller to the video tablet (USB port)

Picture: Antenna Tracker setup assembly

Heidrun Mapping UAS and Heidrun Radio Relay UAS with Compact Ground Station

Unfold the tripod and extend the legs (tripod must be levelled and stabile on the soil)

Mount the aluminium extension pole to the tripod

Attach the Compact Ground Station on the mount on the aluminium pole

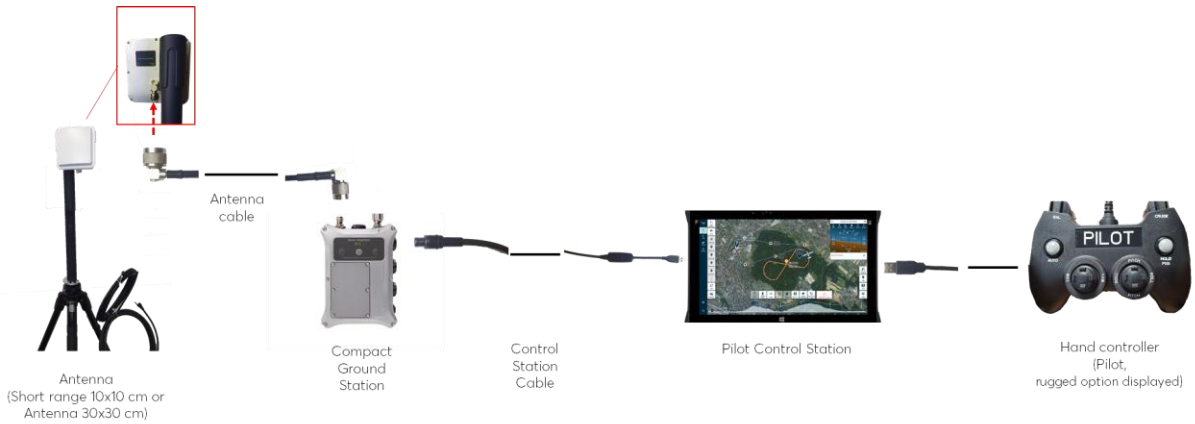
Attach the short-range antenna on top of the aluminium pole

Connect the antenna cable to one of the coax connectors on top of the Compact Ground Station

Mount the omni-directional antenna to the free coax connectors on top of the Compact Ground Station

Connect USB-LAN cable (with the USB-LAN adaptor) between the operator tablet (USB port) and one of the connectors on the side of the Compact Ground Station

Connect the Pilot controller to the operator tablet (USB port)



Picture: Heidrun Mapping and Heidrun Radio Relay antenna setup assembly

Heidrun Mapping UAS and Heidrun Radio Relay UAS with Silvus Ground Station Radio

Unfold the tripod and extend the legs (tripod must be levelled and stabile on the soil)

Mount the Silvus Ground Station Radio on the extended tripod pole

OPTIONAL: Attach the patch antenna on top of the tripod pole

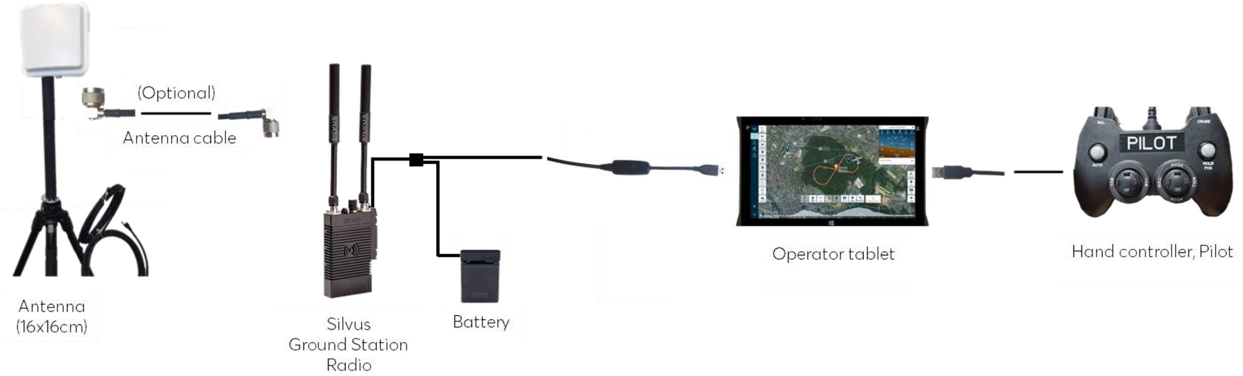
OPTIONAL: Detach one antenna from the Silvus Ground Station Radio and use the coax antenna cable to connect the patch antenna to the free antenna connector on the radio.

Connect USB-LAN adaptor to the operator tablet (USB port)

Connect ODU-LAN cable to the adaptor cable on the Silvus Ground Station Radio and the USB-LAN adaptor in the operator tablet

Connect the battery to the adaptor cable on the Silvus Ground Station Radio

Connect the Pilot controller to the operator tablet (USB port)



Picture: Heidrun Mapping and Heidrun Radio Relay antenna setup assembly with Silvus Ground Station Radio

Heidrun Mapping 433 MHz

Mount the antenna to the base plate

Connect the ground station with the cable to the base plate (place the base plate on an iron surface e.g. car roof top)

Connect USB cable between the Pilot tablet and the ground station

Connect the Pilot controller to the operator tablet (USB port)

Picture: Antenna setup and connected tablet for Cumulus UAS

Power on the Components

Power on the Silvus Ground Station Radio or Compact Ground Station (not applicable for 433MHz radio)

Power on Operator and Video tablets

Open SDM UI application (on Operator tablet)

Make sure you have selected the correct vehicle/aircraft type in SDM - for more information about the vehicle profile, see Sky-Watch Drone Manager Manual (document id 900005672).

Open HVC UI application (on Video tablet) (only applicable for Heidrun EO/IR UAS)

Connect UAV battery in UAV

SDM automatically connects to the vehicle/aircraft

Upload Flight Plan to UAV

Import a pre-defined flight plan in SDM or create a new flight plan in SDM. For more information how to import, create and adjust flight plans in SDM, see the Manual Sky-Watch Drone Manager Manual (document id 900005672).

Upload flight plan to UAV in SDM

Perform Pre-flight Check

Start the pre-flight check procedure using the "Pre-flight Check" button in SDM

Aircraft automatically enters pre-flight check mode

Arm the aircraft by pushing the arm button on the aircraft

The aircraft starts moving its control surfaces, verify that all surface moves smoothly in all directions. Confirm the step after a successful visual inspection of the control surfaces.[1]

OPTIONAL: Verify that the control surfaces are moving using the control pad

OPTIONAL: Verify payload functionality and/or calibrate payload:

EO/IR: Extend and calibrate camera in Video Viewer – in windy environment fix the UAV firmly with the hands for correct and precise calibration. The aircraft must be stable and completely horizontal throughout the calibration process.

Mapping: Take picture in SDM – ensure camera lens is faced towards the landscape before taken picture

Radio Relay: Extend antenna

Disarm the aircraft

OPTIONAL (Long Range Antenna Tracker only): Open Tracker Option and align the Antenna Tracker

Pre-flight check mode is finalized.

INFO: The servos in the vertical tail fin (Rudder) has a servo saver function to protect the servos during hard landings. Part of the servo saver is a safety lock function which are activated if the servo is pushed to its maximum position, and the servo will then 'jump' to a lock position and will not be able to move.

If the safety lock function is activated, the servo will not move during the pre-flight check and the control surface of the rudder or the elevator will not move as well.

You can push the servo out of the safety lock position by following these steps (during the pre-flight check):

Push the elevator arm slowly and firmly (apply the required strength required to move the servo arm) in the opposite direction (approx. 100 degrees) and the servo would then go out of the safety snap lock. You can feel when the servo is out of its safety snap position and should now be able to move freely again.
Please abort pre-flight check.
Dis-connect and re-connect UAV battery.
Perform automatic pre-flight check again and verify the servo and control surface/elevator is moving as expected.

If the servo arm is still not moving as expected, please re-place the specific mal-function servo with a new servo.

Perform instrument GCS check before launch

Just before taking the drone to the launch spot you do a final check of the following in the Vehicle status panel in the SDM application:

- Battery is fully charged
- GPS 3D fix is present
- Radio link is established
- UAV Mode is set to AUTO

4.3 Flying Sky-Watch UAVs

Take-off/Launch

Get into the position where the UAV should be launched. Always double check that the UAV:

is in good condition
is assembled correctly
holds a valid flight plan
is in AUTO mode
is launched in head wind
is launched in a direction free of obstacles.

Remove the "Remove before flight"-safety pin

Hold the aircraft by a firm grip with the preferred throwing hand around the landing bumper while holding the aircraft above shoulder

With the other hand the, push down the Arm button in the rear of the aircraft until the engine and propeller start to spin

Throw the aircraft in a straightforward line relative to the horizon up against the head wind

Aircraft will now perform the uploaded flight plan

Manoeuvring Flight

Sky-Watch UAVs can be flown in two ways:

Autonomous mode (Auto where the aircraft follows the uploaded flight plan)

Flying off-plan (Aircraft is airborne but not flying according to the uploaded plan)

Flying off-plan

Flying off-plan can be done in several ways either using the hand controller to manually navigate the aircraft or by using the in-built SDM features like "fly-to-here" to fly to any location and "Fly to POI" (see document id 900005672 Sky-Watch Drone Manager section 4.6.1 "Fly to any position (Fly-To-Here)" and 4.6.2 "Fly to POI" for detailed instructions).

Manual Navigation (Cruise mode)

The aircraft can be manually navigated when airborne using the Pilot hand controller. The Pilot hand controller must be connected to the tablet running SDM, and cruise mode is activated by pushing the CRUISE button on the hand controller. The aircraft will now be flying in cruise mode and the Pilot hand controller can be used for steering the aircraft.

INFO: Sky-Watch fixed wing UAVs keep a constant altitude (ATO) and course over ground flying in cruise mode. Use the hand controller to steer the aircraft and change the modes using the buttons on the hand controller. Always enable the 'Attitude Indicator' in SDM when flying in cruise mode.

INFO: When the Vehicle is in cruise mode, the vehicle's heading will be shown with a blue line and the vehicles next target is shown with a teal line

Altitude and course over ground can be corrected by the pilot via the Pilot hand controller.

Picture: Standard Pilot hand controller

Picture: Rugged Pilot hand controller

Button/Joystick control - Pilot hand controller	Function
YAW 'left'	Controls the rudder. Aircraft turns left
YAW 'right'	Controls the rudder. Aircraft turns right
Roll 'left'	Controls the wing. Aircraft roll/banks left
Roll 'right'	Controls the wing. Aircraft roll/banks right
Pitch 'up'	Controls the elevator. Aircraft moves to lower altitude

Pitch 'down'	Controls the elevator. Aircraft moves to higher altitude
Hold position	Puts the aircraft in a loiter circle at current altitude
Cruise	Cruise mode (manually navigation)
Auto	Autonomous mode (flying auto according to uploaded flight plan)
Return and Land	Execute the last part of the planed mission which contains the landing sequence. See 2.2.4.1.1 for more details

Flying in Cruise mode the pilot must pay special attention to AGL indicator in SDM UI application, and the surrounding environment the aircraft is flying in.

Approach

The Pilot should pay attention to changes in the surroundings of the environment where the landing zone has been configured. Is it still safe to perform the planned landing? Has the wind direction changed? If not safe to proceed or wind direction has changed, then place the aircraft in a hold loiter position by pushing the button 'Hold' in SDM, configure a new safe landing zone and/or change wind direction, and upload flight plan changes to aircraft and press button '**Return And Land**' to proceed with the landing.

Landing/Recovery

The aircraft system accomplishes landing by initiating what is called "deep stall". This puts the aircraft into an aerodynamically stable stall condition, where the aircraft will drop vertically to the ground.

The plane will have reached terminal velocity of 7-11 m/s after approximately 10 meters of vertical descent. As a result, the altitude where deep stall is activated, will have no practical effect on the vertical speed upon impact.

System Shutdown

When the aircraft has landed on the ground it can be picked up. Always move in from the behind (rotating propellers are dangerous and can be a hazard).

Install the safety pin (attached to the red ribbon "Remove before flight") as this disable the engine and push the disarm button on the aircraft.

Finally remove the hatch to the battery compartment and disconnect the UAV battery cable from the speed controller.

Post-flight Inspection

After each flight it is important to visually inspect all aircraft components to identify any damages which can have an impact on flight performance and safety and ensure these are fixed before planning next flight. Pay special attention to:

Cracks in wings

Cracks or hairline fractures in wing joiner tubes

Cracks in elevator

Broken elevator forks

Cracks in rudder

Cracks in fuselage

Broken landing bumper

5 Emergency Procedures

5.1 General Information

The default UAV reconfiguration modes are Return and Land (RAL) and EMERGENCY LAND (a forced deep stall). See paragraph 2.2.4.1.2 Protection of Critical Flight Functions.

The pilot always has the option to enter RAL or EMERGENCY LAND via the ground station user interface.

The warnings and alerts generated by the system will be presented visually in Sky-Watch Drone Manager accompanied by audio notifications.

5.2 Emergency Checklists

Engine Failure

The pilot's main priority is to recover the UAV safely without risk of causing damage to people, animals or property.

If the pilot assess that the UAV is at safe and sound location for landing, EMERGENCY LAND should be commanded by the pilot.

Alternately, the pilot should switch to CRUISE CONTROL, glide towards a safer location and land using EMERGENCY LAND.

Loss of C2 Link ("Lost Link")

Because the pilot has no control the pilot's main priorities are:

- Maintain visual contact of the UAV.
- Maintain visual contact of the planned landing sight.
- Troubleshoot the C2 link to re-establish control of the UAV.

Loss of Navigation Systems (GNSS Lost)

Because the autopilot forces EMERGENCY LAND after 3[s] of no GNSS 3D fix, the pilot's priority is to

- Recover the UAV.
- If the impact has caused personal, animal or other third-party damage, consult operator's emergency procedures.

If GNSS Denied Navigation (GPS Denied RTL) is enabled the UAV will perform RTL based on compass, last known position, wind direction and estimated time to fly home (see 2.2.4.1.1 Flight Modes and 2.2.4.1.2.7 Loss of GNSS). The pilot's main priorities are:

- Maintain visual contact of the UAV, switch to CRUISE CONTROL, maneuver towards a safe location and land using EMERGENCY LAND.
- If visual contact to the UAV is lost, maintain visual contact with the airspace at the home position to regain visual contact with the UAV switch to CRUISE CONTROL, maneuver towards a safe location and initiate EMERGENCY LAND.
- Monitor the control station to identify if the UAV has regained GNSS and entered RAL.

Control Station Failures

Because the pilot now has no control, the pilot's main priorities are:

Maintain visual contact of the UAV

Maintain visual contact of the planned landing sight.

If possible, the pilot should re-establish control, alternately using a secondary ground station and or tablet.

Flyaway

Because the pilot has no control, the pilot's main priorities are:

- Initiate EMERGENCY LAND, if possible.
- Maintain visual contact of the UAV, if possible.
- Maintain visual contact of the planned landing sight.
- Troubleshoot the control station to re-establish control of the UAV.

Actuator Malfunction

If the pilot assess that the UAV is at safe and sound location for landing, EMERGENCY LAND should be commanded by the pilot. Otherwise a switch to RAL should be performed. If the UAV is uncapable to perform stable navigation, EMERGENCY LAND should be executed by the pilot.

Terrain Warning

Whenever a Terrain Warning or Alert is observed, the pilot's priorities are:

Using CRUISE MODE, immediately increase the UAV altitude and/or steer away from the path the UAV is currently following

Observe the Terrain Warning and ensure that the current steering actions are improving the conditions. Terrain Warnings include the current altitude (AGL) and the predicted time before critical altitude is reached

6 Handling, Servicing and Instructions for Maintenance and Continued Airworthiness

6.1 Introduction

This section contains factory-recommended procedures for proper ground handling and servicing of the aircraft. It also identifies certain inspection and maintenance requirements which must be followed if the aircraft is to retain that new-plane performance and dependability.

6.2 Ground Handling

As the aircraft doesn't weight much it is easy to lift and move the aircraft around. However, take caution and avoid excessive pressure at the aircraft fuselage, wing tips, elevator and rudder.

Due to the small weight of the aircraft, it is important in windy conditions to take caution when placing the aircraft on the ground for mission preparation. Always place the UAV in the foam cradle which keep the aircraft in a fixed position, and with the aircraft nose up against head wind. In very windy condition it can be necessary for one of the crew members to hold and fix the aircraft steady while placed in the cradle.

6.3 Disassembly, Storage, and Reassembly

The UAV is disassembled (detach wings, detach elevator, remove UAV battery) and all components are placed in the flight case the same places they were taken from for assembly.

All ground equipment is powered off and disconnected (remove cables), unmount compact ground station (if short range or long range antenna tracker set up has been used), unmount antennas and/or antenna trackers, fold tripod and place all components in the same places in the flight case where they were taken from for assembly.

If UAV system components have been in use in moisture environment, please allow equipment to dry up before flight case is closed and UAS is placed on storage.

See section 6.4.5 for handling and storage of UAV batteries.

6.4 Servicing, Charging and Replacing Aircraft Battery

Safety Guide

- Read and understand all instructions before handling and charging batteries.
- Failure to follow instructions listed may result in electric shock, fire, or injury.
- Use only chargers together with supplied batteries. Do not attempt to charge other types of batteries. And do not attempt to charge batteries in other chargers.
- Do not allow any foreign materials of conductive nature to make contact with any exposed electrical contacts on batteries or chargers.
- Power down device and disconnect batteries before charging.
- Chargers are intended for indoor use only. Do not immerse any part in water or any fluid.
- Do not disassemble batteries, chargers, or power supplies.
- Let batteries cool down before charging. Do not charge batteries at temperatures above 40 degrees Celsius.
- Do not charge very cold batteries. Do not charge batteries at temperatures below 0 degrees Celsius.
- Always use a fireproof and non-conductive container when you are charging, doing capacity check, or storing your batteries.
- Always remember that heat degrade Lithium batteries. The warmer the batteries get, the shorter their lifespan will be.
- In case of fire or extreme heat from batteries, place on a non-combustible surface and monitor the battery.

Before Charging

Check the battery and packaging, wires and connectors for defects, which may cause a short circuit and possible battery failure.

Always verify the charger is in good condition. A damaged charger can be dangerous when plugged into mains.

Charging

Never charge batteries:

When inside of the UAV
Temperature below freezing (0°C)
When batteries are hot (above 40° C)
Unattended

Always charge batteries in an open area away from flammable materials, liquids and surfaces.

A dual charger is included as part of the UAS for charging UAV batteries.

The Sky-Watch dual charger can charge 2 pcs of UAV batteries independently. It takes approximately 2-3 hours to fully charge a depleted battery. The dual charger ONLY works with original Sky-Watch V2 batteries.

The charger has 2 LED indicators, one of each battery connection.

Solid RED: Battery is charging

Flashing Green: Charging almost done – balancing cells

Solid GREEN: Battery is fully charged

ATTENTION: Only Sky-Watch original UAV batteries with internal battery management system may be charged using Sky-Watch dual charger. Charging other batteries may result in fire hazards!

Discharging and Flight Operation

Check the battery and packaging, wires and connectors for defects, which may cause a short circuit and possible battery failure.

Check the battery capacity and battery internal resistance regularly. Sky-Watch recommends every 6 months or for every 20 discharges cycles, whatever comes first. Dispose batteries below a minimum capacity level of 75% (7500mAh/110Wh) and batteries with internal resistance higher than 100mΩ. Do not measure the internal resistance at fully charged or fully discharged state, but discharge batteries at least 10% before measurement.

The maximum flight time will decrease as the battery wears out.

Instruments for battery check is not yet a part of the standard tool package.

Never allow the temperature of batteries to exceed 60°C. The protective thermal fuse will disconnect the battery above 60°C – and will reset once temperature is normalized.

Recommended UAV battery operation temperature is 15°C - 25°C when UAV battery is mounted and connected to UAV just before launch.

INFO: Never launch the aircraft with a UAV battery with a temperature below 10°C.

ATTENTION: Sky-Watch recommends that UAV batteries are replaced and not to be used for UAV flight missions when the UAV battery can't provide minimum 110Wh or after 250 charge cycles – whatever comes first.

Storage

The battery storage specification is between -20°C - 45°C.

Long term storage (90+ days) should not be done above 25°C. Store batteries as cold as possible, especially for long term storage. Charge the batteries to around 14.6V for long term storage.

Storing batteries fully charged at high temperatures causes irreversible damage to the capacity of the battery. Figure 1 shows storage as a function of state-of-charge and temperature.

Temperature	Lead acid at full charge	Nickel-based at any charge	Lithium-ion (Li-cobalt)	
			40% charge	100% charge
0°C	97%	99%	98%	94%
25°C	90%	97%	96%	80%
40°C	62%	95%	85%	65%
60°C	38% (after 6 months)	70%	75%	60% (after 3 months)

Figure 1 Estimated recoverable capacity when storing a battery for one year. Elevated temperature hastens permanent capacity loss. Depending on battery type, lithium-ion is also sensitive to charge levels.
Source: BatteryUniversity.com

Travel and Transportation

Use a suitable battery-bag, like the one supplied with the UAV system.

When travelling on an airplane always pack your batteries in your carry-on bag and never in your checked baggage.

Transportation can affect the compass of the UAV and it is required to conduct a new compass calibration if the UAV has traveled more than 1000km since last take-off.

6.5 Cleaning and Care

Dust

Aircraft component	Instruction
Fuselage surface, wings and elevator	Remove dust from hinge line, wing connectors and servos with a soft brush. Remove dust, grass etc. from motor with soft brush first and finally with air (camera lens air blower or canned air duster). Mud on surfaces can be wiped off with a semi-wet cloth.
Landing bumper	Remove any objects stock in the bumper pad.
Inside fuselage	Clean the battery compartment for dust with a piece of cloth or air (camera lens air blower or canned air duster). Clean camera and lens (still camera and EO/IR camera) with soft brush or air (camera lens air blower or canned air duster).
EO/IR retract mechanism	Clean EO/IR camera retract mechanism with soft brush or air (camera lens air blower or canned air duster).

IF the UAV has been directly exposed to highly dusty environment (e.g., sand/dust storm), dust must be removed from the inside according to the following procedure, before battery power is connected to the UAV

Tilt the UAV fuselage backwards at a 45° angle so that the UAV tail is pointing downwards and hold until drained.

Hold the UAV fuselage vertically, with the UAV tail pointing down. Knock slightly on the fuselage with the hand and observe if dust is falling out of tail opening. If dust is falling out, continue knocking on the fuselage until no more dust is falling out.

Hold the UAV fuselage vertically, with the UAV tip pointing down. Knock slightly on the fuselage with the hand and observe if dust is falling out of tip opening. If dust is falling out, continue knocking on the fuselage until no more dust is falling out.

If there are dust on the camera lenses, brush it off with a soft brush.

If there are dust in connectors and SD card holder, it is recommended to remove it with a vacuum cleaner or alternative with air (camera lens air blower or canned air duster).

Water

If the aircraft has been directly exposed to rain, water can have reached the inside of the fuselage. As a pre-caution to remove any potential water it must be drained through the drain holes in the bottom of the fuselage before flight or storage. Please use this procedure:

Tilt the UAV fuselage backwards at a 45° angle so that the UAV tail is pointing downwards and hold until drained.

Tilt the UAV fuselage forwards and slightly to the side and hold until drained

For long time storage ensure that the inside and outside of the fuselage is dry before storing inside flight case.

6.6 Authorized Field-level or Preventative Maintenance

For all Sky-Watch Fixed Wing UAV systems, a set of preventative maintenance and service tasks are described and documented in "Fixed Wing UAV Maintenance and Service Schedule" (document id 900005709).

A task can either be an inspection carried out before launching and flying the aircraft or after a completed mission, or a task to replace a specific aircraft component at a given interval (operational hours or landings). It is the responsibility of the end user to maintain a service log for each aircraft where all maintenance and service tasks are documented. In relation to this a logbook (physical or electronical) for all flight operations for every aircraft must be maintained to document number of flights, landings and total operational hours.

For each maintenance and service task an Echelon level is clearly stated describing the authorization level required to carry out the task.

Echelon level	Description
E1	Operation can be performed by end user in field
E2	Operation can be performed by end user at own depot
E3	Operation must be performed by SKY-WATCH Certified Maintenance & Service Technicians at service centre/workshop
E4	Operations can only be performed by Sky-Watch

7 Supplements

This section contains the appropriate supplements necessary to safely and efficiently operate the UAV when equipped with various optional components and payloads/sensors which can vary depending on the specific UAS configuration delivered to the customer.

7.1 Operation of Payloads, Optional Equipment, and Accessories

Payloads/Sensors

Dual EO/IR Camera

DUAL LENS GIMBAL	
Payload platform	Button extractable gimbal mount
Gimbal	Separately controllable 2-axis stabilized gimbal
Visible camera (EO)	Visible 400-700 nm Resolution: 1280x720 (720p) Zoom: x6.6 + x2 digital (x 13.2 total continuous zoom) HFOV: 38.8° WFOV – 5.9° - 2.9° DFOV
Thermal camera (IR)	LWIR uncooled (8-12µm) Resolution: 640 x 480 Zoom: x4 digital HFOV: 32° WFOV - 8° DFOV
Extracted range of rotation	+/- 180° azimuth (0 = UAV body heading)
Retracted range of rotation	Fixed 0° azimuth (0 = UAV body heading) -45° to -70° pith (0 = UAV water line, + is up)

ATTENTION: As temperature influences the thermal picture of the IR camera it is important to calibrate the IR camera to the temperature of the operating environment. The temperature will drop the higher altitudes you fly your aircraft in. Hence, it can be necessary to re-calibrate the IR camera when in air. You can visually see when a re-calibration is required as the edges of the picture of the video stream gets blurred.

The re-calibration is done in the Heidrun Video Controller UI application (aka HVC).

Still Camera (mapping camera)

ADTi 24MP camera

STILL CAMERA	
Payload platform	Bottom mounted downfacing camera
Lens options	E-mount lenses 25mm and 35mm
Sensor	APS-C type (23.5 x 15.6 mm) Exmor® CMOS sensor Number of effective pixels: 24.3 MP Image sensor: 3:2
Recording format (still images)	JPEG (DCF Ver. 2.0, Exif Ver.2.3, MPF Baseline compliant), RAW (Sony ARW 2.3 format).
Image size	Image size 3:2 L: 6000 x 4000 (24 M) M: 4240 x 2832 (12 M) S: 3008 x 2000 (6.0 M) Image size 16:9 L: 6000 x 3376 (20M) M: 4240 x 2400 (10M) S: 3008 x 1688 (5.1M)
Image quality modes	JPEG Fine, JPEG Standard, RAW, RAW+JPEG
Power	Powered directly from UAV
Environmental	Operating temperature: -20° C to +55°C

Sony R10C

STILL CAMERA	
Payload platform	Bottom mounted downfacing camera
Lens options	E-mount lenses 16mm and 20mm
Sensor	APS-C type (23.2 x 15.4 mm) Exmor® APS HD CMOS sensor Number of effective pixels: 20.4 MP
Power	Lithium-ion battery Nominal voltage 7.2V DC
Environmental	Operating temperature: 0° C to +40°C

ATTENTION: When Mapping UAV is equipped with SONY R10C still camera please be aware of the camera is powered by its own camera battery, and always remember to fully charge the camera battery so the camera will function during the entire mapping mission.

Ground Antennas

Ground Antenna (Mapping 433MHz)

For highest possible radio quality between the aircraft and the ground station the antenna base plate should be placed on a metal surface of at least 1x1m – e.g. the car roof.

Omni-directional Antenna (EO/IR, Mapping, Relay)

In general place the Compact Ground Station or the Silvus Ground Station Radio as high as possible for best possible signal strength between aircraft and ground station. Unfold the tripod to its maximum length or otherwise place the ground station high.

Patch Antennas (EO/IR)

In general place antenna as high as possible for best possible signal strength between aircraft and ground station. Unfold the tripod to its maximum length.

Silvus Radio Systems

The Silvus radios comes pre-configured from Sky-Watch and will be managed by SDM during normal operation. Further information about the Silvus radios can be found in the User Manual for the Silvus radios, which can be accessed via the web interface on the radios.

ATTENTION: Changing any settings other than the ones listed here can cause degradation of the radio link or completely break the radio link to the UAV.

ATTENTION: Changing setting that are critical for the radio setup can cause permanent loss of communication between the ground radio and the UAV. The system needs to be serviced at Sky-Watch if the link is permanently lost.

Silvus Web Interface

The Silvus web interface can be accessed through a standard web browser. Connect the radio and go to http://192.168.1.202/.

The user manual for the radios can be accessed via the book-icon (shown after the page title).

Radio Link Encryption Keys

The radio link for the Silvus systems is encrypted with AES-GCM 256 ECDH-KAS. The system comes with default encryption keys generated specifically to the individual UAV.

The four encryption keys for the AES-GCM 256 ECDH-KAS encryption can be changed through the Silvus Web interface. Refer to the Silvus User manual for information on how the change the encryption keys.

Silvus Batteries and Charging

A charger is included for the Silvus ground station radio. The charger solution provided depends on the selected radio configuration.

The Silvus SC4200 Radio solution comes with a Twist-On MBITR Battery and compatible charger; the Bren-Tronic BTC-70716-1 Desktop Charger for Silvus radio Battery.

For technical details please refer to the BTC-70716-1 Technical Datasheet and Reference guide. In general, always handle batteries as described in Safety Guide for batteries.

MBITR Battery Charging Procedure

There are two options for powering the BTC-70716-1 charger.

Mains supply (100 to 240VAC, 50/60 Hz) via the BTC-70716-1 Power supply.

Using the XT60 to 5.5mm DC jack Cable and connecting to a UAV battery (10Ah, 16.8V).

Plug in the appropriate power cord into the BTC-70716-1 charger

Connect the power cord to the selected power source mains or 16.8V UAV battery. The LED on the power supply will illuminate, and the LED's on the charger will cycle through and then indicate the standby state.

Make sure that the connector and contact pads on the battery are clean and free of foreign matter, then push battery all the way into bay.

The charge cycle for the battery will now start.

The charger is equipped with three LED's that will light according to the state of the charge cycle:

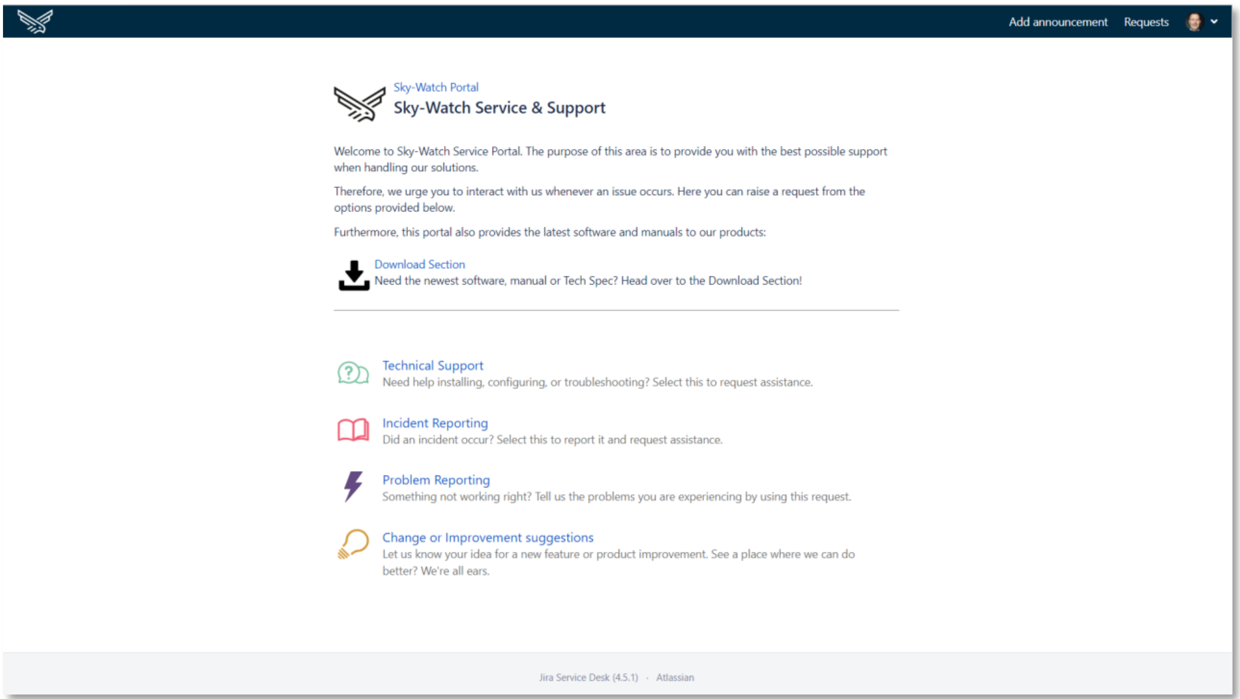
Indicator Light	State of Charging
Yellow (Slow Blinking)	Standby. (No Battery)
Yellow (Fast Blinking)	Precharge
Yellow	Bulk charging
Green (Slow Blinking)	Top Charging (>90%)
Green	Charge Complete
Red	Charge/Battery Error

At least once per year the MBITR battery should be fully cycled (fully charged -> fully discharged -> fully charged).

7.2Information for the Owner

Improvements or Corrections

As part of the continuous support and service Sky-Watch offers all its customers a support and service agreement which include software releases for all product components. All software releases are made available for download and installation from the Sky-Watch Customer Support Portal (support.sky-watch.com - requires username and login to access).



Picture: Screen shot of Sky-Watch Customer Support Portal

Software releases are either categorized as bugfix/patch releases (only bug fixes) or minor releases (includes bugfixes, feature enhancements and new features) which are guaranteed to be backward compatible or major releases (can be changes in API, external interfaces, introduction of new concepts, new features).

New software releases are installed via Sky-Watch Drone Manager.

Customers are notified about new software releases via newsletters, update notifications in SDM and/or service bulletins, and release notes are available at the Sky-Watch Customer Support Portal.

Hardware and mechanical updates which are of general interest (not mandatory) or critical (mandatory) are all communicated via newsletters and/or service bulletins directly to customers.

Owner Change of Address and Contact Notice

Any changes to owner's/end user's address and contact information is the responsibility of the owner and must be communicated to Sky-Watch (which include Sky-Watch resellers/distributors) without any delays. This enables Sky-Watch to be able to communicate any information and service bulletins about the UAS as a whole or individual system components without any delays.

7.3 Incident and Problem Reporting

Should the customer experience any technical problems or aircraft incidents these are all required to be registered and communicated to Sky-Watch, and must be done via the Sky-Watch Customer Support Portal at http://support.sky-watch.com

All customers will be created with a personal user account to access the Customer Support Portal. Any problems logging into the customer support portal can be raised to the Sky-Watch Support Team by sending an e-mail to support@sky-watch.com