Robot XF(A5) V2.0.5 GCU Private Protocol User Guide

Contents

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Specifications

- **Document Version**: V2.0.5
- Protocol **Version:** V0.1

Product Information
The GCU (Generic Control Unit) operates on a private protocol and offers various features and improvements as per the revision history:

Features:

- UART baudrate changes into self-adaptive
- Add TCP Server mode in Network communication
- Add protocol version into data package
- Enhancements in data frames for both host computer and GCU
- Command & Feedback improvements
- Example data package renewal

Product Usage Instructions

Main Data Frame from Host Computer

- Add desired Euler angle and desired relative angle into roll/pitch/yaw control value (byte 5~10)
- Add control quantities effectiveness (bit B2) into statue (byte 11)

Main Data Frame from GCU

- Add FPV mode and Euler angle control mode into pod statue (byte 5)

- Delete exposure mode (bit B11) from camera statue (byte 6~7)

Sub Data Frame from Host Computer

- Delete distance from Home (byte 57~60)
- Add relative height (byte 57~60)

Revision History

Date	Document Version	Protocol Version
2023.06.19	V2.0	–

Date	Document Version	Protocol Version
2023.08.09 1. UART baudrate cha	V2.0.1 nges into self-adaptive. Ad	V0.0 d TCP Server mode in

1. UART baudrate changes into self-adaptive. Add TCP Server mode in Network communication. [P1]
2. Add protocol version into data package. Correct the mistake of header in package from GCU. [P2]
3. **Main data frame from host computer:**
    1. Add desired Euler angle and desired relative angle into roll/pitch/yaw control value (byte 5~10); [P3]
    2. Add control quantites effectiveness (bit B2) into statue (byte 11). [P3]
    3. Sub data frame from host computer:
    4. Delete distance from Home (byte 57~60); [P4]
    5. Add relative height (byte 57~60) . [P4]
4. Main data frame from GCU:
    1. Add FPV mode and Euler angle control mode into pod statue (byte 5); [P5]
    2. Delete exposure mode (bit B11) from camera statue (byte 6~7). [P5]
5. **Sub data frame from GCU:**
    1. Delete content of byte 59~61; [P6]
    2. Add current zoom rate of camera 1 (byte 59~60) and camera 2 (byte 61~62). [P6]
6. **Command & Feedback:**
    1. Add description of null command; [P7]
    2. Add command of FPV mode, Euler angle control mode, external tracking mode and OSD; [P7~P9]
    3. Detail description of gaze mode; [P8]
    4. Modify parameters of shutter, record, focus, palette and Night vision command. [P8~P9]
7. Renew example data package. [P11~P16]

Date	Document Version	Protocol Version
2023.10.12	V2.0.2	V0.1

1. Add explanation on byte order of the protocol. [P2]

2. **Main data frame from host computer:**
    1. Add coordinate system definition into description of absolute roll, pitch and yaw angle of carrier (byte 12~17). [P3]
3. **Main data frame from GCU:**
    1. Add lighting statue (bit B10) into camera statue (bit B10). [P5]
    2. Correct the mistake of coordinate axis direction (“upward as positive”→”downward as positive”) of vertical target-missing (byte 10~11). [P5]
    3. Add value range into description of X-ward/ Y-ward target-missing (byte 8~11). [P5]
    4. Add coordinate system definition and rotate order into description of X-axis/ Y-axis/ Z-axis absolute angular velocity of camera (byte 24~29). [P5]
4. **Command & Feedback:**
    1. Modify explanations on control values in descriptions of FPV mode, head lock mode and head follow mode. [P7]
    2. Correct the mistake of false feedback (“0x015 0x01〞→”0x15 0x01”) of gaze mode (geo-coordinates guide). [P8]
    3. Add coordinates of target frame’s top-left corner and lower-right corner into description of track mode. [P8]
    4. Add coordinates of screen’s top-left corner and lower-right corner in description of click to aim command. [P8]
    5. Add target-missing of screen’s center, top-left corner and lower-right corner in description of external track mode. [P9]
5. Add appendix 1: example of transformation of data frame from host computer. [P12]
6. Add appendix 2: definition of carrier’s coordinate system. [P13]
7. Add appendix 3: definition of camera’s coordinate system and rotate order. [P14]
8. Add appendix5: GPS time & UTC conversion function.[P21]

Date	Document Version	Protocol Version
2024.06.20	V2.0.5	V0.1

1. **Main Data Frame from Host Computer:**
    1. Add explaination about control value effectivity (bit B2) in description of statue (byte 11) . [P3]
2. **Main Data Frame from GCU:**
    1. Rename FPV to angle control 1 and add angle control 2 in pod operating mode (byte 5). [P5]
    2. Rename camera statue(byte 6~7) to pod statue. [P5]
3. **Sub Data Frame from GCU:**
    1. Add error code (byte 41~42). [P6]
    2. Add thermal camera statue (byte 63). [P6]
    3. Add camera statue (byte 64~65). [P7]
    4. Add time zone (byte 66). [P7]
4. **Command & Feedback:**
    1. Add commands of OSD coordinate, image auto reverse and time zone setting. [P8]
    2. Modify descriptions of angle control 1 (original FPV), head follow and Euler angle control. [P8]
    3. Add command of angle control 2. [P10]

    4. Modify the parameter range of palatte ([0,100]->[0,10]). [P11]
    5. Add commands of area temperature measurement, temperature alert, isotherm and spot temperature measurement. [P11~P12]
    6. Add function of switching to specified mode in pic-in-pic. [P12]
    7. Add commands of target detection and zoom camera digital zoom. [P13]
5. Add Appendix 2: Example of Transformation of Data Frame from GCU. [P16~P18]
6. Renew Appendix 5: Example Data Package. [P20~P28]
7. Add Appendix 7: Pod Code. [P30]

Port Configuration

UART Configuration

- UART level: TTL
- Data bits: 8
- Stop bits: 1
- Parity: None
- Communication mode: Full duplex
- Baudrate: 115200, 250000, 500000 and 1000000.
- Communication frequency: The recommended communication frequency range is 30~50Hz. The higher the frequency is, the better the effect of controlling is. There should not be too low frequency or data stop. There should not be BUS idle in one data package.

Network Configuration

- UDP mode: The source port is 2337 and the default destination is the LAN broadcast address. The target port is 2338.
- TCP Server mode: The opposite end should be set to TCP Clint mode.

The remote IP address should be the same as GCU, and the remote port should be 2332.

Summary

- The communication uses Q&A mode. The host computer transmits data package firstly. After receiving the correct package, the GCU returns its package. A complete data package is made up of protocol header, package length, main data frame, sub data frame, command/feedback and CRC data.
- The length of the package is S bytes. The length of command / feedback part is variable.
- The command / feedback part includes order and parameter. Different order maps different parameter. Details as per chapter Data Frame in this document.
- The GCU will execute only once while continuously receiving commands with same order (even if the parameters are different). To trigger one same function, the data packages should be separated by a package with null command (Except External track command).

The structure of the data package is shown as below.

Section	Byte(s)	Description	Data Type	Details
From Host Computer				
Header	0	Main Data	U16	
	1	Sub Data	U8	
Length and Version	2–3	Length & Version Info		
Frame Data	4	Frame		
Frame Data	5–36	Main Data	32 bytes	
Frame Data	37–68	Sub Data	32 bytes	
From GCU				
Header	0	0x8A		
	1	0x5E		
Length and Version	2–3	Length & Version Info		
Frame Data	4	Frame		
Frame Data	5–36	Main Data	32 bytes	
Frame Data	37–68	Sub Data	32 bytes	
Command Data	69–S-3	Command (Variable Length)		
Feedback Data	69–S-3	Feedback (Variable Length)		
CRC High Byte	S-2	CRC High Byte	U16	
CRC Low Byte	S-1	CRC Low Byte	U16	

- The data checked by CRC is Byte 0~S-3.
- This protocol uses little-endian byte order (except CRC).

Data Frame

Main Data Frame from Host Computer

Byte(s)	Content	Description	Data Type	Details
5–6	Other modes, Zoom rate (deg/s)	When the control value is desired Euler a ngle.		Resolution: 0.01 deg; Range: 8000 to 18000
7–8	Pitch control value	When the control value is desired relative angle between pod and carrier.	S16	Resolution: 0.01 deg; Range: [-18000, 18000]
9–10	Yaw control value	Control value for yaw angle.	S16	Resolution: 0.01 deg; Range: [-18000, 18000]

Byte(s)	Content	Description	Data Type	Details
B7–B3	Reserved	Reserved bits.		These bits are 0
B2	Control value validity	0 – Control value invalid; 1 – Control value valid.	U8	
B1	Reserved	This bit is 0		
B0	Carrier's INS validity	0 – Carrier's INS invalid; 1 – Carrier's INS valid.	U8	
11	Status	Indicates if control value is valid.	U8	0 – Invalid, 1 – Valid
12–13	Absolute roll angle of carrier	Absolute roll angle of carrier in Euler angle.	S16	Resolution: 0.01 deg; Range: [-9000, 9000]
14–15	Absolute pitch angle of carrier	Absolute pitch angle of carrier in Euler angle.	S16	Resolution: 0.01 deg; Range: [-9000, 9000]
16–17	Absolute yaw angle of carrier	Absolute yaw angle of carrier in Euler angle.	U16	Resolution: 0.01 deg; Range: [0, 36000]
18–19	Northward acceleration of carrier	Northward acceleration of the carrier.	S16	Resolution: 0.01 m/s²; Northwards is positive
20–21	Eastward acceleration of carrier	Eastward acceleration of the carrier.	S16	Resolution: 0.01 m/s²; Eastwards is positive
22–23	Upward acceleration of carrier	Upward acceleration of the carrier.	S16	Resolution: 0.01 m/s²; Upwards is positive
24–25	Northward velocity of carrier	Northward velocity of the carrier.	S16	Resolution: 0.1 m/s; Northwards is positive
26–27	Eastward velocity of carrier	Eastward velocity of the carrier.	S16	Resolution: 0.1 m/s; Eastwards is positive
28–29	Upward velocity of carrier	Upward velocity of the carrier.	S16	Resolution: 0.1 m/s; Upwards is positive
30	Request code of sub-frame	Code for requested sub-frame from GCU.	U8	
31–36	Reserved	Reserved bytes.		

Byte(s)	Content	Description	Data Type	Details
37	Header of requested sub-data frame from GCU	GCU sub-frame request header (Ox00).	U8	

Byte 12~29 are very important. Incorrect data will cause error of pod altitude calculation

Sub Data Frame from Host Computer

Byte(s)	Content	Description	Data Type	Resolution
37	0x01	Header	U8	
38–41	Longitude of carrier	Longitude of the carrier	S32	Resolution: 1e-7 deg
42–45	Latitude of carrier	Latitude of the carrier	S32	Resolution: 1e-7 deg
46–49	Altitude of carrier	Altitude of the carrier	S32	Resolution: 1 mm
50	Available satellites	Number of available satellites	U8	
51–54	GNSS microsecond	GNSS microsecond	U32	
55–56	GNSS week	GNSS week	S16	
57–60	Relative height	Relative height	S32	Resolution: 1 mm
61–68	Reserved	Reserved bytes		Ox00

Byte 37~68 are all 0x00 if there is no sub frame data.

Main Data Frame from GCU

Byte(s)	Content	Description	Data Type	Resolution
5	Pod operating mode	Mode of operation for the pod	U8	Possible values: 0x10 to 0x1C (listed below)
6–7	Pod statue	Status of the pod	U16	B15–B13: Reserved. B12: Power-on status. B10: Lighting. B9: Night vision. B8: Ranging. B7: Coordinate validity. B0: Tracking status.
8–9	Horizontal target-missing	Horizontal target position relative to center of screen	S16	Range: [-1000, 1000]; Rightward positive
10–11	Vertical target-missing	Vertical target position relative to center of screen	S16	Range: [-1000, 1000]; Downward positive

Byte(s)	Content	Description	Data Type	Resolution
12–13	X-axis relative angle of camera	Relative X-axis angle of the camera	S16	Range: [-18000, 18000]; Resolution: 0.01 deg
14–15	Y-axis relative angle of camera	Relative Y-axis angle of the camera	S16	Range: [-9000, 9000]; Resolution: 0.01 deg
16–17	Z-axis relative angle of camera	Relative Z-axis angle of the camera	S16	Range: [-18000, 18000]; Resolution: 0.01 deg
18–19	Absolute roll angle of camera	Absolute roll angle of the camera (Euler angle)	S16	Range: [-9000, 9000]; Resolution: 0.01 deg
20–21	Absolute pitch angle of camera	Absolute pitch angle of the camera (Euler angle)	S16	Range: [-18000, 18000]; Resolution: 0.01 deg
22–23	Absolute yaw angle of camera	Absolute yaw angle of the camera (Euler angle)	U16	Range: [0, 36000]; Resolution: 0.01 deg
24–25	X-axis absolute angular velocity of camera	X-axis angular velocity of the camera	S16	Resolution: 0.01 deg/s
26–27	Y-axis absolute angular velocity of camera	Y-axis angular velocity of the camera	S16	Resolution: 0.01 deg/s
28–29	Z-axis absolute angular velocity of camera	Z-axis angular velocity of the camera	S16	Resolution: 0.01 deg/s

Byte(s)	Content	Description	Data Type	Resolution
30–36	Reserved	Reserved bytes		

Pod Operating Mode Possible Values:

- 0x10 – Angle control 1
- 0x11 – Head lock
- 0x12 – Head follow
- 0x13 – Orthoview
- 0x14 – Euler angle control mode
- 0x16 – Gaze
- 0x17 – Track
- 0x1C – Angle control 2

Sub Data Frame from GCU

Byte(s)	Content	Description	Data Type	Resolution
37	0x01	Header	U8	
38	Hardware version	Version of hardware	U8	
39	Firmware version	Version of firmware	U8	
40	Pod code	Code for the pod	U8	Details as per Appendix 7
41–42	Error code anomaly	Error codes for any anomalies	S32	
43–46	Distance from target	Measurement of distance from the target	S32	Resolution: 0.1 m (Invalid if -1m or 0m)
47–50	Longitude of target	Longitude of the target	S32	Resolution: 1e-7 deg
51–54	Latitude of target	Latitude of the target	S32	Resolution: 1e-7 deg
55–58	Altitude of target	Altitude of the target	S32	Resolution: 1 mm
59–60	Current zoom rate of camera	Current zoom rate of the camera (visible-light camera)	U16	Resolution: 0.1x
61–62	Current zoom rate of camera	Current zoom rate of the camera (thermal camera)	U16	Resolution: 0.1x
63	Thermal camera statue	Status of thermal camera	U8	B7: Temperature measurement, B6: Area temperature, etc.

Thermal Camera Status (Byte 63)

- **B7**: 0 – Temperature measurement unavailable; 1 – Temperature measurement available
- **B6**: 0 – Area temperature measurement off; 1 – Area temperature measurement on
- **B5**: 0 – Temperature alert off; 1 – Temperature alert on
- **B4**: 0 – Isotherm off; 1 – Isotherm on
- **B3**: 0 – Spot temperature measurement off; 1 – Spot temperature measurement on
- **B2**: Reserved
- **B1**: High temperature alert
- **B0**: Low-temperature alert

Byte(s)	Content	Description	Data Type	Resolution
64–65	Camera statue	Status of the camera	U16	B15: Target detection on/off; B14: Digital zoom on/off, etc.
66	Time zone	Time zone setting	U8	
67–68	Reserved	Reserved for future use	–	

Camera Statue (Byte 64-65)

- **B15**: 0 – Target detection off; 1 – Target detection on
- **B14**: 0 – Digital zoom off; 1 – Digital zoom on
- **B13**: 0 – OSD (On-Screen Display) off; 1 – OSD on
- **B12**: 0 – OSD displays carrier's coordinate; 1 – OSD displays target's coordinate
- **B11**: 0 – Image auto reverse on; 1 – Image auto reverse off
- **B10–B5**: Reserved
- **B4**: 0 – Not recording; 1 – Recording
- **B3**: Reserved
- **B2–B0**: uint_t – Pic-in-pic mode

Byte 37~68 are all 0x00 while an illegal sub frame header is requested.

Command & Feedback

Function	Code	Description	Success	Fail
Null	0x00	Separates commands with the same order	0x01 0x00	0x01 0x01
Calibration	0x01	Pod should remain static while calibrating, lasting a few seconds.	0x01 0x00	0x01 0x01
Order Parm	0x00			
Feedback	0x03	Feedback during operation	0x03 0x00	0x03 0x01
OSD	0x06	OSD displays coordinate system: 0x00 for Carrier's, 0x01 for Target's	0x06 0x00	0x06 0x01
Coordinate	0x07		0x07 0x00	0x07 0x01
Image auto reverse	0x08	Controls the image auto reverse. 0x00 for on, 0x01 for off	0x08 0x00	0x08 0x01
Time zone	0x10	Controls time zone setting	0x10 0x00	0x10 0x01
Angle control 1	0x10	Controls the angle of the pod (specific control values needed).	0x10 0x00	0x10 0x01
Head lock	0x11	Returns pod to neutral position without switching operation mode (lock mode).	0x11 0x00	0x11 0x01
Head follow	0x12	Returns pod to neutral yaw position while following target or heading.	0x12 0x00	0x12 0x01
Orthoview mode	0x13	Returns neutral yaw position without switching operation mode.	N/A	N/A
Track mode	0x14	Pod returns neutral position and exits tracking while tracking the target.	N/A	N/A
FPV Mode	0x15	No response from the pod in FPV mode.	N/A	N/A
Euler angle control	0x16	Pod locks Euler angles and does not respond to control.	N/A	N/A
Gaze Mode	0x17	Pod does not respond to control in Gaze mode.	N/A	N/A

Descriptions of Specific Modes:

- **Head Lock & Head Follow Mode**: The pod maintains its neutral position (yaw or pitch) without changing modes.
- **Orthoview Mode**: Only yaw angle is returned, and the pod doesn't switch modes.
- **Track Mode**: Neutral positions for both pitch and yaw are returned while exiting tracking mode.
- **FPV Mode, Euler Angle Control, and Gaze Mode**: The pod does not respond in these modes, as specified.

Function	Code	Description	Success	Fail
Orthoview	0x13	Desired Euler angles are provided, and the pod locks its current Euler angles when the control values are invalid.	0x13 0x00	0x13 0x01
Euler Angle Control	0x14	Desired Euler angles for controlling pitch and yaw.	0x14 0x00	0x14 0x01
Gaze (Geo-coordinates Guide)	0x15	The pod is directed to a specific point of interest using its geographical coordinates (longitude, latitude, altitude) provided in the control values.	0x15 0x00	0x15 0x01
Gaze (Geo-coordinates Lock)	0x16	The pod locks its position based on geographical coordinates (longitude, latitude, altitude) and maintains a fixed gaze. Requires valid carrier's INS data.	0x16 0x00	0x16 0x01
Track	0x17	Track mode is activated by providing tracking coordinates and setting the control values for tracking a target.	0x17 0x00	0x17 NN

Descriptions of Specific Functions:

1. **Orthoview**: Locks the pod's current Euler angles when control values are invalid.
2. **Euler Angle Control**: Control the pod's Euler angles (pitch, yaw) to desired positions.
3. **Gaze (Geo-coordinates Guide)**: Direct the pod towards a specific geographical point using its coordinates (longitude, latitude, altitude). Control values (PP, QQ, RR) are provided for accurate positioning.
4. **Gaze (Geo-coordinates Lock)**: Locks the pod's gaze on a geographical point and tracks its current position. Requires valid INS (Inertial Navigation System) data from the carrier.
5. **Track**: Starts or exits tracking a target by specifying coordinates (XO, YO, X1, Y1). The coordinates define the horizontal and vertical areas in the target frame, with the top-left corner as the origin.

Notes:

- For **Track**, "OX" and "YO" values are coordinates that represent the top-left and bottom-right corners of the target's frame on the screen. These are defined in U16 values, where 0 is the origin, and positive values move rightwards (X-axis) and downwards (Y-axis).
- **Gaze (Geo-coordinates)**: The pod needs valid carrier INS data to function properly in these modes.

The KK/NN(U8) is ordinal of operation triggered/failed cameras. B7~BO correspond camera 8~1. A certain bit being 1 means its corresponding camera being tagged. For example, 0x03 (00000011) means camera 1 and camera 2. Camera 1 is visible-light zoom camera by default and camera 2 is thermal camera by default.

Function	Code	Description	Success	Fail
Click to Aim	0x1A	The pod aims at a target based on provided horizontal (XO) and vertical (YO) coordinates. Coordinates are in U16, where (0,0) is the top-left of the screen and (10000,10000) is the bottom-right.	0x1A 0x00	0x1A NN
External Track	0x1B	The pod tracks the target based on horizontal and vertical missdistance values (PP, WW). These values indicate the target's location relative to the center of the screen.	0x1B 0x00	0x1B NN
Angle Control 2	0x1C	The pod adjusts its relative angles to the carrier, following the carrier while the control values are invalid.	0x1C 0x00	0x1C 0x01
Shutter (Record Start)	0x20	Starts recording.	0x20 0x00	0x20 0x01
Shutter (Stop Recording)	0x21	Stops recording.	0x21 0x00	0x21 0x01
Zoom In Continuously	0x22	Continuously zoom in.	0x22 0x00	0x22 NN
Zoom Out Continuously	0x23	Continuously zoom out.	0x23 0x00	0x23 NN
Zoom Stop	0x24	Stops the zoom function.	0x24 0x00	0x24 NN

Descriptions of Specific Functions:

1. **Click to Aim (0x1A)**: The pod aims at a specific target based on coordinates. These coordinates are provided as U16 values, where (0,0) is the top-left and (10000,10000) is the bottom-right corner of the screen.
2. **External Track (0x1B)**: The pod tracks the target based on the missdistance values (PP and WW), which indicate how far the target is from the center of the screen. The tracking mode starts with the command "Start tracking" (0x02) and can exit with "Exit tracking" (0x00).
3. **Angle Control 2 (0x1C)**: The pod adjusts its relative angles to the carrier, allowing it to follow the carrier's movement while the control values are invalid.
4. **Shutter (Record Start – 0x20)**: Starts recording the video feed.
5. **Shutter (Stop Recording – 0x21)**: Stops recording the video feed.

6. **Zoom In Continuously (0x22)**: The pod zooms in continuously.
7. **Zoom Out Continuously (0x23)**: The pod zooms out continuously.
8. **Zoom Stop (0x24)**: Stops the zoom function, ceasing any zoom in or out operations.

Notes:

- **External Track (0x1B)**: The PP and WW values represent the target's horizontal and vertical missdistance. The origin is at the screen's center, and the values indicate relative positioning.
- **Zoom Functions (0x22, 0x23, 0x24)**: These allow for continuous zooming in or out and stopping the zoom operation.

The KK/NN(U8) is ordinal of operation triggered/failed cameras. B7~B0 correspond camera 8~1. A certain bit being 1 means its corresponding camera being tagged. For example, 0x03 (00000011) means camera 1 and camera 2 is visible-light zoom camera by default and camera 2 is thermal camera by default.

Function	Order Parm	Description	Success	Fail
Zoom to Specified Rate	0x25	Zoom at a specified rate, with values ranging from -32768 (maximum zoom) to 10000 (minimum zoom). Negative values represent zoom rates (e.g., -10 for 1x, -150 for 15x, -300 for 30x).	0x25 0x00	0x25 NN
Focus	0x26	Focus control functionality.	0x26 0x00	0x26 0x01
Palette Mode	0x2A	Adjust the desired palette mode, where 0x00 corresponds to the next palette option, 0x01 for a specific mode, etc.	0x2A 0x00	0x2A 0x02
Night Vision	0x2B	Control night vision mode. 0x00 for off, 0x01 for on, and 0x02 for auto.	0x2B 0x00	0x2B 0x01
Area Temperature Measurement	0x30	Control area temperature measurement. 0x00 for off, 0x01 for on.	0x30 0x00	0x30 NN
Temperature Alert	0x31	Set temperature alert thresholds. Includes high (HH) and low (LL) alert temperatures with a resolution of 0.1°C.	0x31 0x00	0x31 NN
Isotherm	0x32	Enable or disable isotherm mode. 0x00 for off, 0x01 for out-of-interval, and 0x02 for interval mode. High/low temperature thresholds (HH, LL) are set with a resolution of 0.1°C.	0x32 0x00	0x32 NN
Spot Temperature Measurement	0x33	Control spot temperature measurement. 0x00 for off, 0x01 for on. Coordinates (XO, YO) define the measurement point.	0x33 0x00	0x33 NN
OSD (On-Screen Display)	0x73	Control the on-screen display. 0x00 to display, 0x01 to hide.	0x73 0x00	0x73 0x01
Pic-in-Pic	0x74	Control picture-in-picture (PIP) mode. Values between 0x00 and 0x04 correspond to the available PIP modes.	0x74 0x00	0x74 0x01

Descriptions of Specific Functions:

1. **Zoom to Specified Rate (0x25)**: Controls the zoom level, with the rate provided in a specific format where negative values represent zoom rates (e.g., -10 for 1x zoom, -150 for 15x zoom, etc.), and positive values

define the zoom rate range.

2. **Focus (0x26)**: Adjusts the focus of the system.
3. **Palette Mode (0x2A)**: Changes the palette mode used by the system. The mode is selected by numeric options like 0x00 for the next palette option and 0x01 for the current mode.
4. **Night Vision (0x2B)**: Controls the night vision feature, enabling it in different modes (off, on, or auto).
5. **Area Temperature Measurement (0x30)**: Allows for temperature measurement across a specified area, controlled by coordinates (XO, YO, etc.).
6. **Temperature Alert (0x31)**: Sets the high and low temperature thresholds for alerts.
7. **Isotherm (0x32)**: Enables isotherm mode, which monitors areas within a specified temperature range, with interval modes and thresholds.
8. **Spot Temperature Measurement (0x33)**: Enables spot temperature measurement at a specific point on the screen.
9. **OSD (0x73)**: Controls the on-screen display visibility (show/hide).
10. **Pic-in-Pic (0x74)**: Controls the picture-in-picture functionality, offering various modes of display.

The KK/NN(U8) is ordinal of operation triggered/failed cameras. B7~B0 Camera 1 is visible-light zoom camera by default and camera 2 is thermal camera by default.

Here is a table summarizing the new functions and their details:

Function	Order Parm	Description	Success	Fail
Target Detection	0x75	Enable or disable target detection. 0x00 for off, 0x01 for on.	0x75 0x00	0x75 0x01
Zoom Camera	0x76	Control digital zoom. 0x00 for off, 0x01 for on.	0x76 0x00	0x76 0x01
Lighting Intensity	0x80	Adjust the lighting intensity. Values from 0 to 255, with 0 being no lighting and 255 being maximum intensity.	0x80 0x00	0x80 0x01
Ranging	0x81	Enable or disable ranging. 0x00 for off, 0x02 for on.	0x81 0x00	0x81 0x01

Descriptions of Specific Functions:

- **Target Detection (0x75)**: Controls whether target detection is active or inactive. This feature is used to detect specific objects or areas, depending on the system's capabilities.
  - `0x00` – Target detection is off.
  - `0x01` – Target detection is on.
- **Zoom Camera (0x76)**: Activates or deactivates digital zoom for camera functionality.
  - `0x00` – Digital zoom is off.
  - `0x01` – Digital zoom is on.
- **Lighting Intensity (0x80)**: Adjusts the intensity of the lighting. The intensity is set with an 8-bit value, ranging from `0` (no light) to `255` (maximum intensity).
  - Values: `0` – No lighting; `255` – Maximum lighting.
- **Ranging (0x81)**: Activates or deactivates ranging functionality. Ranging can be used to measure distances or

map areas.

- `0x00` – Ranging is off.
- `0x02` – Ranging is on.

Turing on light will turn on night vision at the same time. Turning off light will not turn off night vision.

CRC Function

uint16_t CalculateCrc16(uint8_t *ptr,uint8_t len) { uint16_t crc; uint8_t da; uint16_t crc_ta[16]={ 0x0000,0x1021,0x2042,0x3063,0x4084,0x50a5,0x60c6,0x70e7, 0x8108,0x9129,0xa14a,0xb16b,0xc18c,0xd1ad,0xe1ce,0xf1ef, }; crc=0; while(len–!=0) { da=crc>>12; crc<<=4; crc^=crc_ta[da^(*ptr>>4)]; da=crc>>12; crc<<=4; crc^=crc_ta[da^(*ptr&0x0F)]; ptr++; } return(crc);

Appendix 1 Example of Transformation of Data Frame from Host Computer

Byte	**0**	**1**	**2-3**	**4**	**5-6**	**7-8**	**9-10**	**11**	**12-13**	**14-15**	**16-17**	**18-19**	**20-21**	**22-23**	**24-25**	**26-27**	**28-29**	**30**	**31-36**	**37**	**38-41**	**42-45**	**46-49**	**Content**
Original Data	OXA8	Header	0xE5	Package Length	72	Protocol Version	0x01	Roll Control Value	100	Pitch Control Value	-100	Yaw Control Value	0x05	Control Value Valid	State	Carrier's INS Valid	Absolute Roll Angle	-11.32130°	Absolute Pitch Angle	1.01°	Absolute Yaw Angle	240°	Acceleration of Carrier	1.123m/s²

Byte	Content	Original Data	Accuracy or Binary Conversion (Little-endian)	Hexadecimal (Little-endian)	Hexadecimal (Big-endian)
50	Available Satellites	19	19	13	19
51-54	GNSS Microsecond	352718000	352718000	00 06 15 B0	00 06 15 B0
55-56	GNSS Week	2278	2278	E6 08	E6 08
57-60	Relative Height	12.12m	12120	58 2F 00 00	58 2F 00 00
61-68	Reserved	00 00 00 00 00 00	00 00 00 00 00 00	00 00 00 00 00 00	00 00 00 00 00 00
69	Null Command	0x00	00	00	00
70-71	CRC	N/A	N/A	E9 D4	E9 D4

The complete data package from the host computer: A8 E5 48 00 01 00 00 64 00 9C FF 05 94 FB 65 00 C0 5D 70 00 90 FF 70 00 40 80 C0 F7 40 80 01 00 00 00 00 00 00 01 24 F2 DF 65 16 EE AA 16 A3 A0 00 00 13 B0 0C 06 15 E6 08 58 2F 00 00 00 00 00 00 00 00 00 00 E9 D4

Appendix 2 Example of Transformation of Data Frame from GCU

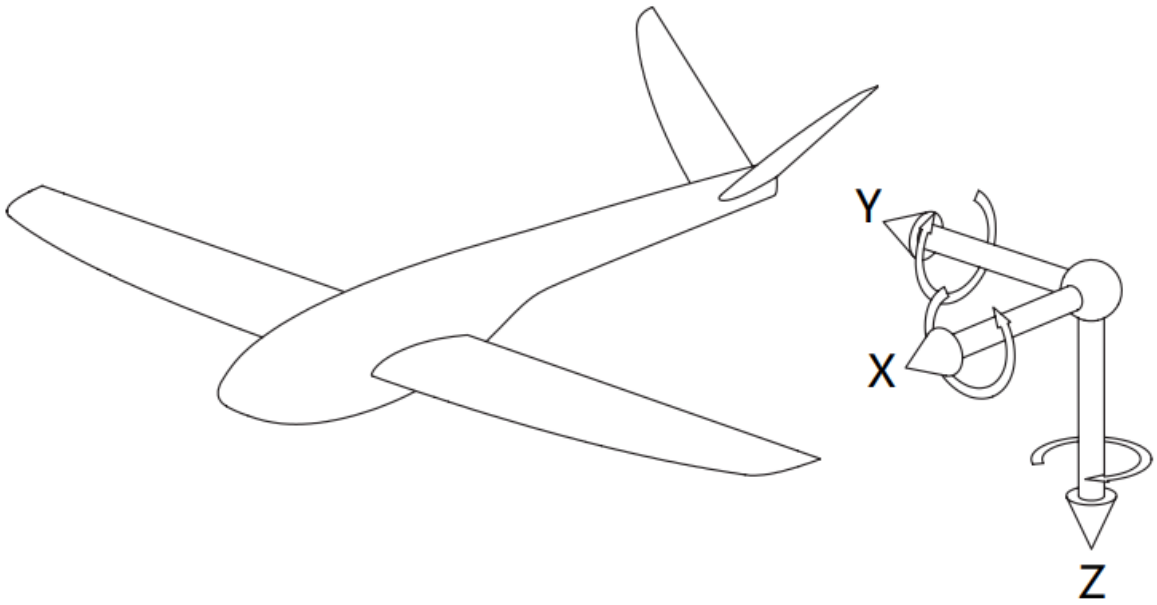
The complete data package from GCU: 8A 5E 49 00 02 12 01 80 0C FE F4 01 DD FC 20 00 4A 18 FF FF A5 03 47 18 FF FF 01 00 FE FF 00 00 00 00 00 00 00 01 1F 32 29 00 00 06 17 00 00 24 F2 DF 65 16 EE AA 16 A3 A0 00 00 2B 01 14 00 00 00 00 08 00 00 20 00 EC 85

Byte	Content	Original Data (Hexadecimal)	Parsed Data
1	Header	A8	A8
2~3	Package Length	5E 49	73
4	Protocol Version	00	0.2
5	Pod Operation mode	02	Head follow
6~7	Pod Statue	01 80	0000 0001 1000 0000
8-9	Horizontal target-missing	OC FE	Ranging on.
10~11	Vertical target-missing	F4 01	Range and target coordinate valid
12~13	X-axis relative angle of camera	DD FC	-500
14~15	Y-axis relative angle of camera	20 00	500
16~17	Z-axis relative angle of camera	4A 18	-8.03°

Byte	Content	Original Data (Hexadecimal)	Parsed Data
18~19	Absolute roll angle of camera	FF FF	0.32°
20~21	Absolute pitch angle of camera	A5 03	62.18°
22~23	Absolute yaw angle of camera	47 18	-0.01°
24~25	X-axis absolute angular velocity of camera	FF FF	19.33°
26~27	Y-axis absolute angular velocity of camera	01 00	62.15°
28~29	Z-axis absolute angular velocity of camera	FE FF	-0.1 deg/s
30~36	Reserved	00 00 00 00 00 00	0.1 deg/s
37	Sub header	00	-0.2 deg/s
38	Hardware version	00	5.0
39	Firmware version	00	D-90AI
40	Pod code	00	589.4m
41~42	Error code	00 00	170.917533212
43~46	Distance from target	01 2B 01	38.030082231
47~50	Longitude of target	00 00 00 00	41.1231m
51~55	Latitude of target	00 00 00 00	29.9x
55~58	Altitude of target	06 17 00 00	
59~60	Current zoom rate of camera	24 F2 DF 65	
61~62	Reserved	16 EE AA 16	

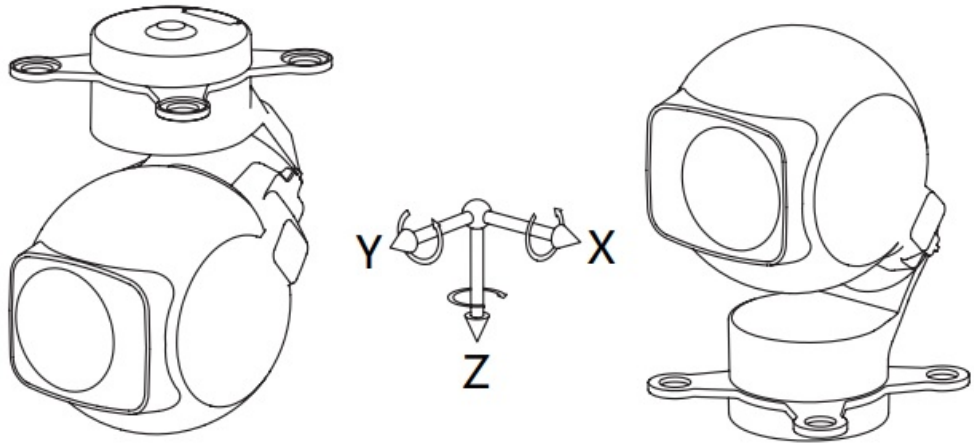
Byte	Content	Original Data (Hexadecimal)	Parsed Data
61~62	Current zoom rate of camera 2	14 00	2x
63	Thermal camera statue	00	UTC+8
64~65	Camera statue	00 00	Shutter success
66	Time zone	08	
67~68	Reserved	00 00	
69~70	Feedback	20 00	
71~72	CRC	EC 85	

Appendix 3 Definition of Carrier's Coordinate System



Appendix 4 Definition of Camera's Coordinate System and Rotate Order

1. Coordinate system definition



Downword Power-on Upword Power-off

The control port of the pod should point to negative X-ward of the carrier. The damping platform should be

parallel to the XOY plane of the carrier. The pod should be mount as close as possible to the C.G. of the carrier.

2. **Rotate order:** Z → Y → X.
3. **Angles transformation**
   - **Define:**
     - CamPhi: Absolute roll angle of camera (Main data frame from GCU, byte 18~19)
     - CamThe: Absolute pitch angle of camera (Main data frame from GCU, byte 20~21)
     - CamPsi: Absolute yaw angle of camera (Main data frame from GCU, byte 22~23)
     - AngleX: X-axis absolute angle of camera
     - AngleY: Y-axis absolute angle of camera
     - AngleZ: Z-axis absolute angle of camera
   - **The parameters above are transformed as below**
     - AngleZ += 90;
     - WARP (AngleZ , 360);
     - CamPhi = +AngleY;
     - CamThe = -AngleX;
     - CamPsi = +AngleZ;

Appendix 5 Example Data Package

- **Null command**
  A8 E5 48 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 FD 13
- **Pitch control (keep current control mode, control value 100)**
  A8 E5 48 00 02 00 00 64 00 00 00 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 E7 9F
- **Pitch control (keep current control mode, control value -100)**
  A8 E5 48 00 02 00 00 9C FF 00 00 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 0F 0E
- **Yaw control (keep current control mode, control value 1000)**
  A8 E5 48 00 02 00 00 00 00 E8 03 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 DC 69
- **Neutral**
  A8 E5 48 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 03 CD 70
- **OSD displays carrier's coordinate**
  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 06 00 E7 0D
- **OSD displays target's coordinate**
  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 06 01 F7 2C
- **Image auto reverse on**

A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 07 00 D4 3C

- **Image auto reverse off**

  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 07 01 C4 1D

- **Time zone setting (UTC-2)**

  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 08 FE CA D3

- **Angle control 1 (control values invalid)**

  A8 E5 48 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 10 01 86

- **Angle control 1 (Euler angle: roll 0° , pitch 45° , yaw 60°)**

  A8 E5 48 00 02 00 00 94 11 70 17 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 10 4A 53

- **Angle control 1 (Euler angle: roll 20° , pitch 0° , yaw 0°)**

  A8 E5 48 00 02 D0 07 00 00 00 00 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 10 05 F7

- **Head lock (control values invalid)**

  A8 E5 48 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

- **Head lock (relative angular velocity +10° /s)**

  A8 E5 48 00 02 00 00 00 00 E8 03 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 11 DE 79

- **Head follow (control values invalid)**

  A8 E5 48 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 12 CF 60

- **Orthoview (control values invalid)**

  A8 E5 48 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 13 DF 41

- **Euler angle control (control values invalid)**

  A8 E5 48 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 14 41 02

- **Euler angle control (Euler angle: roll 0° , pitch -45° , yaw 0°)**

  A8 E5 48 00 02 00 00 6C EE 00 00 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 14 A5 6A

- **Start tracking (X0=100, Y0=100, X1=105, Y1=105)**

  A8 E5 52 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 17 01 01 64 00 64 00 69 00 69 00 20 55

- **Exit tracking**

A8 E5 52 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 17 01 00 64 00 64 00 69 00 69 00 CB 76

- **Click to aim (X=100, Y=100)**

  A8 E5 4D 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 1A 01 64 00 64 00 48 AF
- **Click to aim (X=5000, Y=5000)**

  A8 E5 4D 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 1A 01 88 13 88 13 EE C9
- **Click to aim (X=10000, Y=10000)**

  A8 E5 4D 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 1A 01 10 27 10 27 53 65
- **Click to aim (X=10000, Y=5000)**

  A8 E5 4D 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 1A 01 10 27 88 13 B4 F0
- **External track (X=100, Y=20)**

  A8 E5 4E 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 1B 01 9C FF 14 00 02 53 0A
- **Angle control 2 (control values invalid)**

  A8 E5 48 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 1C 2E AE
- **Shutter**

  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 20 01 5B 6C
- **Start/stop recording**

  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 21 01 68 5D
- **Camera 1 continuously zooms in**

  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 22 01 3D 0E
- **Camera 1 continuously zooms out**

  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 23 01 0E 3F
- **Camera 1 stop zooming**

A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 24 01 97 A8

- **Camera 1 zooms to specified rate (5000, corresponds to half of max rate)**
  A8 E5 4B 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 25 01 88 13 73 0C
- **All cameras zoom to specified rate (1.0x)**
  A8 E5 4B 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 25 FF F6 FF F6 21
- **All cameras zoom to specified rate (5.5x)**
  A8 E5 4B 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 25 FF C9 FF E3 8A
- **Camera 1 zooms to specified rate (60.3x)**
  A8 E5 4B 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 25 01 A5 FD 75 DC
- **Focus**
  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 26 01 F1 CA
- **Next palette option**
  A8 E5 4A 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 2A 02 00 8B E6
- **Palette mode 3**
  A8 E5 4A 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 2A 02 03 BB 85
- **Night vision on**
  A8 E5 4A 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 2B 01 01 F9 A4
- **Night vision off**
  A8 E5 4A 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 2B 01 00 E9 85
- **Area temperature measurement on (X0=4000, Y0=4000, X1=6000, Y1=6000)**
  A8 E5 52 00 02 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 30 02 01 A0 0F A0 0F 70 17 70 17 BE 6D
- **Area temperature measurement off**

A8 E5 52 00 02 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 30 02 00 00 00 00 00 00 00 00 00 33 96

- **Temperature alert on (high alert temperature 30.2 ° C, low alert temperature 20.0° C)**
  A8 E5 4E 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 31 02 01 2E 01 C8 00 E8 93
- **Temperature alert off**
  A8 E5 4E 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 31 02 00 2E 01 C8 00 42 C2
- **Isotherm on (interval mode, 15.0° C~25.2° C)**
  A8 E5 4E 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 32 02 01 FC 00 96 00 6F FA
- **Isotherm off**
  A8 E5 4E 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 32 02 00 FC 00 96 00 C5 AB
- **Spot temperature measurement on (X=4000, Y=5000)**
  A8 E5 4E 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 33 02 01 A0 0F 88 13 C3 8D
- **Spot temperature measurement off**
  A8 E5 4E 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 33 02 00 00 00 88 13 AF 9B
- **OSD on**
  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 73 01 B8 60
- **OSD off**
  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 73 00 A8 41
- **Next pic-in-pic option**
  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 74 00 89 36
- **Pic-in-pic mode 3**
  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 74 03 B9 55

- **Target detection on**
  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 75 01 AA 26
- **Target detection off**
  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 75 00 BA 07
- **Zoom camera digital zoom on**
  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 76 01 FF 75
- **Zoom camera digital zoom off**
  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 76
- 00 EF 54
- **Lighting on (255)**
  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 80 FF 48 C3
- **Lighting off**
  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 80 00 56 33
- **Continuously ranging on**
  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 81 02 45 40
- **Continuously ranging off**
  A8 E5 49 00 02 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 81 00 65 02

Appendix 6 GPS time & UTC conversion function (without leap second processing)

```
static const uint16_t gpst0[] = {1980, 1, 6, 0, 0, 0}; uint64_t epoch2time(const uint16_t *ep) { const uint16_t _day[] = {1, 32, 60, 91, 121, 152, 182, 213, 244, 274, 305, 335}; uint64_t seconds = 0; uint16_t days, year = ep[0], mon = ep[1], day = ep[2]; if (year < 1970 || 2099 < year || mon < 1 || 12 < mon) return seconds; /* leap year if year%4==0 in 1901-2099 */ days=(year-1970)*365+(year-1969)/4+_day[mon-1]+day-2+(year%4==0 && mon>=3?1:0); seconds = floor(ep[5]);seconds = (uint64_t)days * 86400 + ep[3] * 3600 + ep[4] * 60 + seconds; return seconds; } uint64_t gpst2time(int16_t week, uint32_t sec){ uint64_t t = epoch2time(gpst0); if (sec < -1E9 || 1E9 < sec) sec = 0.0; t += 86400 * 7 * week + sec; return t; } uint8_t time2gps(uint64_t time, int16_t *week, uint32_t *msec){ uint64_t t = epoch2time(gpst0); t = time – t; * week = t / 604800; // 604800=7*86400 * msec = (t % 604800) * 1000; return 1; }
```

Appendix 7 Pod Code

Code	Model
0	Z-6A
2	Z-6C
3	M-2400G2
21	Z-8TA
22	Z-8TB
24	Z-8RA
25	Z-8RB
26	Z-8RC
27	Z-8LA
30	Z-9A
31	Z-9B
40	D-80AI
41	D-90AI
44	D-80Pro
45	D-90Pro
49	Z-1PRO
50	Z-1MINI
51	Z-2PRO
52	Z-2MINI
53	D-125AI
54	D-150AI
55	D-90DE
56	D-115AI

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FAQ

Q: What is the purpose of the private protocol used by the GCU?
A: The private protocol ensures secure and efficient communication between the GCU and connected devices.

Q: How can I update the protocol version of the GCU?
A: To update the protocol version, refer to the product manual for specific instructions provided by the manufacturer.

Documents / Resources

	**Robot XF(A5) V2.0.5 GCU Private Protocol** [pdf] User Guide XF A5 V2.0.5, XF A5 V2.0.1, XF A5 V2.0.2, XF A5 V2.0.5 GCU Private Protocol, XF A5 V2.0.5, GCU Private Protocol, Private Protocol, Protocol

References

- **User Manual**