

Multicopter communication protocol

This document describes communication protocol used to control UAV with Multicopter board hardware over any interface, including IP network.

Bartosz Nawrot

Protocol description

Binary structure of generic protocol message and used messages.

General message structure



- Preamble structure
 - 3 the same bytes and zero, example { $\$, \$, \$, 0$ }
- Preamble types:
 - Control, key value { $\$$ }
 - Signal, key value { $\%$ }
 - Autopilot, key value { \wedge }
- Payload size varies in case of preamble type
- CRC size is 16 bits and is computed only from payload data

Control message – {\$, \$, \$, 0}

- Payload size is 32 bytes
- Main controlling and telemetry message
- Is being send and receive by UAV frequently
- Payload contains serialized control object
- Data is direction dependent
 - When sending TO UAV - **ControlData**
 - When sending FROM UAV – **DebugData**

ControlData – user control

- Axis rotation over roll, pitch and yaw axis
- Throttle
- Mode for axis rotation interpretation (angular velocity, angle, etc.)
- Controller mode:
 - *MANUAL*
 - *HOLD: ALTITUDE*
 - *HOLD: POSITION*
 - *VIA_ROUTE*
 - *BACK_TO_BASE*
 - *AUTOLANDING*
 - *AUTOLANDING_AP*

ControlData – example

```
ControlData controlData;  
controlData.setEuler(Vect3Df(0.4f, -0.8f, 0.1f));  
controlData.setThrottle(0.43f);  
controlData.setControllerCommand(ControlData::AUTOLANDING_AP);  
controlData.setSolverMode(ControlData::ANGLE);
```

36, 36, 36, 0

205, 204, 204, 62,
205, 204, 76, 191,
205, 204, 204, 61,
246, 40, 220, 62,
176, 4, 2, 204,
0, 0, 0, 0,
0, 0, 0, 0,
0, 0, 0, 0

213, 146

DebugData - telemetry

- Euler angles (roll, pitch and yaw rotation)
- Geographic coordinates (latitude and longitude)
- Altitude - relative to base
- Velocity - relative to ground
- Controller state
- Battery charge voltage
- Flags (gps fix, autopilot, autoland, error handling, etc.)

DebugData – example

```
DebugData debugData;  
debugData.setEuler(Vect3Df(0.4f, -0.8f, 0.1f));  
debugData.setPosition(Vect2Df(50.0123f, 19.8231f));  
debugData.setAltitude(23.12f);  
debugData.setVelocity(2.23f);  
debugData.setControllerState(DebugData::VIA_ROUTE);  
debugData.setBatteryVoltage(13.43f);  
debugData.setGpsFlags(StateVector::FIX_3D);  
debugData.setSolverMode(ControlData::HEADLESS);
```

36, 36, 36, 0

205, 204, 204, 62,
205, 204, 76, 191,
205, 204, 204, 61,
152, 12, 72, 66,
181, 149, 158, 65,
195, 245, 184, 65,
82, 184, 14, 64,
64, 6, 195, 94

23, 161

Signal message – {%, %, %, 0}



- Command signal message
 - 4 bytes command
 - 4 bytes parameter (parameter can be any value, **for _VALUE command**)
- Data signal message
 - 4 bytes command
 - 2 bytes for max data packets, 2 bytes for actual data packet number
 - Data packet payload, max 50 bytes (max whole message size: 64 bytes)

Data sent over signal data message

- **Calibration settings**

- Contains sensors and input peripherals calibration parameters also contains hardware version
- Sent every board startup after ad hoc calibration

- **Control settings**

- Defines control parameters for drone (PID tuning, error handling options, etc.)
- Is stored in internal board memory and can be uploaded/downloaded by proper app. loop action

- **Route container**

- Contains route and route parameters for VIA_ROUTE control mode
- Size of route container is variable in case of number of waypoints

Calibration settings detailed description

- **gyroOffset** – 3 x float vector
 - unit: dps
- **accelCalib** – 3x3 float matrix
- **magnetSoft** – 3x3 float matrix
- **mangetHard** – 3 x float vector
- **altimSetting** – float scalar
 - unit: hPa
- **tempSetting** – float scalar
 - unit: K
- **radioLevels** – 16 x shot vector
- **pwmInputMap** – 8 x char vector
- **boardType** – enum:
 - TYPE_ULTIMATE_V4
 - TYPE_ULTIMATE_V5
 - TYPE_BASIC_V1
 - TYPE_BASIC_V2
 - TYPE_BASIC_V3
- **flags** – 32 x 1 bit (true/false)
 - 0: IS_GPS_CONNECTED
 - 1: IS_EXTERNAL_MAGNETOMETER_USED

Calibration settings example

```
<?xml version="1.0" encoding="UTF-8"?>
<CalibrationSettings>
  <Setting name="gyroOffest">-122.149,82.8193,116.329,</Setting>
  <Setting name="accelCalib">0.995181,2.91904e-005,-0.0200353,2.91904e-
    005,0.995379,0.00290014,0.0200353,-0.00290014,0.995177,</Setting>
  <Setting name="magnetSoft">0.000265662,-4.86947e-005,6.08542e-005,-4.86947e-005,0.000265411,2.2428e-
    005,6.08542e-005,2.2428e-005,0.000336134,</Setting>
  <Setting name="magnetHard">-2074.93,-131.677,-4233.08,</Setting>
  <Setting name="altimSetting">996.404</Setting>
  <Setting name="tempSetting">303.765</Setting>
  <Setting name="radioLevels">172,1810,176,1812,172,1812,178,1800,173,1812,1813,172,173,1812,172,1812,</Setting>
  <Setting name="pwmInputMap">3,1,0,2,6,4,5,7,</Setting>
  <Setting name="boardType">ULTIMATE v5</Setting>
  <Setting name="flags">1,</Setting>
</CalibrationSettings>
```

37,37,37,0,185,134,1,0,4,0,0,0,74,76,244,194,123,163,165,66,115,168,232,66,47,196,126,63,232,221,244,55,18,33,164,188,232,221,244,55,40,209,126,63,70,16,62,59,18,33,164,60,70,16,62,187,235,195,126,63,141,72,201,27

37,37,37,0,185,134,1,0,4,0,1,0,139,57,137,61,76,184,179,61,127,56,137,61,76,184,221,38,139,57,195,35,188,55,179,61,127,56,195,35,188,55,36,59,176,57,225,174,1,197,80,173,3,195,164,72,132,197,219,25,121,68,89,249

37,37,37,0,185,134,1,0,4,0,2,0,236,225,151,67,0,0,44,67,0,64,226,68,0,0,48,67,0,128,226,68,0,0,44,67,0,128,226,68,0,0,50,67,0,0,225,68,0,0,45,67,0,128,226,68,0,160,226,68,0,0,199,70

37,37,37,0,185,134,1,0,4,0,3,0,44,67,0,0,45,67,0,128,226,68,0,0,44,67,0,128,226,68,3,3,1,0,2,6,4,5,5,0,0,0,1,0,0,0,141,64,102,175,204,204,204,204,204,204,204,204,226,68,0,0,208,205

Control settings detailed description

- **uavType** – enum:
 - TRICOPTER_REAR
 - TRICOPTER_FRONT
 - QUADROPTER_X
 - QUADROPTER_PLUS
 - HEXACOPTER_X
 - HEXACOPTER_PLUS
 - OCTOCOPTER_X
 - OCTOCOPTER_PLUS
- **initialSolverMode** – enum:
 - ControlData::SolverMode
- **manualThrottleMode** – enum:
 - STATIC
 - DYNAMIC
- **autoLandingDescendRate** – float scalar:
 - range: (0, -)
 - Unit: meters per second
- **maxAutoLandingTime** – float scalar:
 - Range: (0, -)
 - Unit: seconds
- **maxRollPitchControlValue** – float scalar:
 - Range: (0, 0.8727) (max 50 deg. of tilt)
 - Unit: radians
- **maxYawControlValue** – float scalar:
 - Range: (0, 3.4907) (max 200 deg per seconds of rotation)
 - Unit: radians
- **pidRollRate, pidPitchRate, pidYawRate** – 3 x float vector
 - Range: (0, -)
- **rollProp, pitchProp, yawProp** – float scalar
 - Range: (0, -)

Control settings detailed description

- **maxAutoAngle** – float scalar:
 - Range: (0, 0.5236) (max 30 deg. of tilt)
 - Unit: Radians
- **maxAutoVelocity** – float scalar:
 - Range: (0, 10)
 - Unit: metres per second
- **altPositionProp, altVelocityProp** – float scalar
 - Range: (0, -)
- **autoPositionProp, autoVelocityProp** – float scalar
 - Range: (0, -)
- **pidThrottleAccel, pidAutoAccel** – 3 x float vector
 - Range: (0, -)
- **stickPositionRateProp** – float scalar:
 - Range: (0, 10)
 - Units: metres per second
- **stickMovementType** – enum:
 - COPTER
 - GEOGRAPHIC
 - BASE_POINT
- **batteryType** – enum:
 - DISABLED
 - BATTERY_2S
 - BATTERY_3S
 - BATTERY_4S
 - BATTERY_5S
 - BATTERY_6S
- **errorHandlingAction** – enum:
 - AUTOLANDING
 - AUTOLANDING_AP
 - BACK_TO_BASE

Control settings detailed description

- **escPwmFreq** – enum:
 - SLOW
 - MEDIUM
 - FAST
 - VERY_FAST
 - ONESHOT_125
- **gpsSensorPosition** – 3 x float vector:
 - Unit: metres
- **flags**:
 - ENABLE_FLIGHT_LOGGER
 - ALLOW_DYNAMIC_AUTOPILOT
 - GPS_SENSORS_POSITION_DEFINED

Control settings example

```
<?xml version="1.0" encoding="UTF-8"?>
<ControlSettings name="Quadrocopter">
  <Setting name="uavType">Quadrocopter "X"</Setting>
  <Setting name="initialSolverMode">Angle</Setting>
  <Setting name="manualThrottleMode">Dynamic</Setting>
  <Setting name="autoLandingDescendRate">1</Setting>
  <Setting name="maxAutoLandingTime">15</Setting>
  <Setting name="maxRollPitchControlValue">0.523599</Setting>
  <Setting name="maxYawControlValue">1.39626</Setting>
  <Setting name="pidRollRate">0.24,0.12,0.005,</Setting>
  <Setting name="pidPitchRate">0.24,0.12,0.005,</Setting>
  <Setting name="pidYawRate">1,0.5,0.005,</Setting>
  <Setting name="rollProp">4.5</Setting>
  <Setting name="pitchProp">4.5</Setting>
  <Setting name="yawProp">5</Setting>
  <Setting name="altPositionProp">0.5</Setting>
  <Setting name="altVelocityProp">2</Setting>
  <Setting name="pidThrottleAccel">0.009,0.018,0.0002,</Setting>
  <Setting name="throttleAltRateProp">1</Setting>
  <Setting name="maxAutoAngle">0.523599</Setting>
  <Setting name="maxAutoVelocity">6</Setting>
  <Setting name="autoPositionProp">0.7</Setting>
  <Setting name="autoVelocityProp">2</Setting>
  <Setting name="pidAutoAccel">3,0.5,0,</Setting>
  <Setting name="stickPositionRateProp">6</Setting>
  <Setting name="stickMovementMode">Copter</Setting>
  <Setting name="batteryType">Disabled</Setting>
  <Setting name="errorHandlingAction">Autoland</Setting>
  <Setting name="escPwmFreq">Medium</Setting>
  <Setting name="gpsSensorPosition">0,0,0,</Setting>
  <Setting name="flags">0,</Setting>
</ControlSettings>
```

37,37,37,0,186,134,1,0,4,0,0,0,208,7,0,0,2,0,0,0,20,0,0,0,0,0,128,63,0,0,
112,65,150,10,6,63,166,184,178,63,143,194,117,62,143,194,245,61,10,2
15,163,59,143,194,117,62,143,194,245,61,10,215,242,138

37,37,37,0,186,134,1,0,4,0,1,0,163,59,0,0,128,63,0,0,0,63,10,215,163,59
,0,0,144,64,0,0,144,64,0,0,160,64,0,0,0,63,0,0,0,64,188,116,19,60,188,1
16,147,60,23,183,81,57,0,0,128,63,233,240

37,37,37,0,186,134,1,0,4,0,2,0,150,10,6,63,0,0,192,64,51,51,51,63,0,0,0,
64,0,0,64,64,0,0,0,63,0,0,0,0,0,192,64,0,0,0,0,0,0,76,4,0,0,1,0,0,0,0
,0,198,220

37,37,37,0,186,134,1,0,4,0,3,0,0,0,0,0,0,0,0,0,0,0,0,0,120,69,148,255
,204,204,204,204,204,204,204,204,0,0,0,0,192,64,0,0,0,0,0,0,0,76,4,0,
0,1,0,0,0,0,0,97,32

Route container detailed description

- **routeSize** – unsigned scalar:
 - Number of waypoints
 - Range: (0, 16)
- **waypointTime** – float scalar:
 - Time for staying at waypoint
 - Range: (0, -)
 - Units: seconds
- **baseTime** – float scalar:
 - Time for staying above base before landing
 - Range: (0, -)
 - Units: seconds
- Waypoint:
 - **position** – 2x float vector
 - Latitude and longitude of Waypoint
 - Range:
 - Latitude: (-90, 90)
 - Longitude: (-180, 180)
 - Units: degrees
 - **absoluteAltitude** – float scalar
 - Absolute altitude for Waypoint
 - Range: (0, 2000)
 - Units: metres
 - **relativeAltitude** – float scalar
 - Waypoint altitude in relations to base
 - Range: (-, 1000)
 - Units: metres
 - **velocity** – float scalar
 - Velocity for reaching THIS Waypoint
 - Range: (0, 20)
 - Units: metres per second

Distance between Waypoints can not be greater than 1 km.

Route container example

```
<?xml version="1.0" encoding="UTF-8"?>
<RouteContainer name="Fast test route">
  <Setting name="routeSize">5</Setting>
  <Setting name="waypointTime">12.3</Setting>
  <Setting name="baseTime">18.85</Setting>
  - <Waypoint>
    <Setting name="position">50.001379,20.001657,</Setting>
    <Setting name="absoluteAltitude">5</Setting>
    <Setting name="relativeAltitude">-20</Setting>
    <Setting name="velocity">5</Setting>
  </Waypoint>
  - <Waypoint>
    <Setting name="position">49.998545,20.000032,</Setting>
    <Setting name="absoluteAltitude">15</Setting>
    <Setting name="relativeAltitude">-20</Setting>
    <Setting name="velocity">9</Setting>
  </Waypoint>
  - <Waypoint>
    <Setting name="position">50.000587,19.999393,</Setting>
    <Setting name="absoluteAltitude">-5</Setting>
    <Setting name="relativeAltitude">-20</Setting>
    <Setting name="velocity">3</Setting>
  </Waypoint>
  - <Waypoint>
    <Setting name="position">50.000501,19.998894,</Setting>
    <Setting name="absoluteAltitude">-5</Setting>
    <Setting name="relativeAltitude">-20</Setting>
    <Setting name="velocity">4</Setting>
  </Waypoint>
  - <Waypoint>
    <Setting name="position">50.000811,20.0006,</Setting>
    <Setting name="absoluteAltitude">-10</Setting>
    <Setting name="relativeAltitude">-20</Setting>
    <Setting name="velocity">5</Setting>
  </Waypoint>
</RouteContainer>
```

37,37,37,0,187,134,1,0,5,0,0,0,105,207,207,196,5,0,0,0,205,204,68,65,2
05,204,150,65,12,2,27,0,205,205,205,205,228,253,30,49,45,0,73,64,4,25
0,124,145,108,0,52,64,0,0,160,193,0,0,160,64,0,0,238,161

37,37,37,0,187,134,1,0,5,0,1,0,160,64,205,205,205,205,12,2,27,0,205,20
5,205,205,135,21,95,79,208,255,72,64,51,7,39,27,2,0,52,64,0,0,160,193,
0,0,112,65,0,0,16,65,205,205,205,205,12,2,27,0,20,104

37,37,37,0,187,134,1,0,5,0,2,0,205,205,205,205,130,190,93,57,19,0,73,6
4,142,143,196,62,216,255,51,64,0,0,160,193,0,0,160,192,0,0,64,64,205,
205,205,205,12,2,27,0,205,205,205,205,33,107,21,103,16,0,155,45

37,37,37,0,187,134,1,0,5,0,3,0,73,64,205,230,231,136,183,255,51,64,0,0
,160,193,0,0,160,192,0,0,128,64,205,205,205,205,12,2,27,0,205,205,205
,205,51,247,44,148,26,0,73,64,30,231,38,81,39,0,52,64,110,66

37,37,37,0,187,134,1,0,5,0,4,0,0,0,160,193,0,0,32,193,0,0,160,64,205,20
5,205,205,160,192,0,0,128,64,205,205,205,205,12,2,27,0,205,205,205,2
05,51,247,44,148,26,0,73,64,30,231,38,81,39,0,52,64,122,227

Autopilot message – {^, ^, ^, 0}

- Payload size is 26 bytes
- Used to control UAV in HOLD:POSITION command
- Allows to move drone to position by defining it in absolute global coordinates
- Is send on change target event (or retransmitted in specific period of time)
- Autopilot transaction is always initiated by user and as acknowledge message is sent back from UAV
- Contains serialized *AutopilotData*

AutopilotData – autonomus control

- Target geographic location
- Target relative altititude
- Autopilot mode flags:
 - *To be defined after real life tests with issues like:*
 - *Stick control vs dynamic target*
 - *Altitude throttle control*
 - *Yaw control*
 - *„Autoland when at target”*

AutopilotData – example

```
AutopilotData autopilotData;  
autopilotData.setTargetPosition(Vect2Dd(50.00236, 20.00089));  
autopilotData.setTargetAltitude(14.232f);
```

94,94,94,0

199,104,29,85,
77,0,73,64,
184,228,184,83,
58,0,52,64,
70,182,99,65,
0,0,0,0,

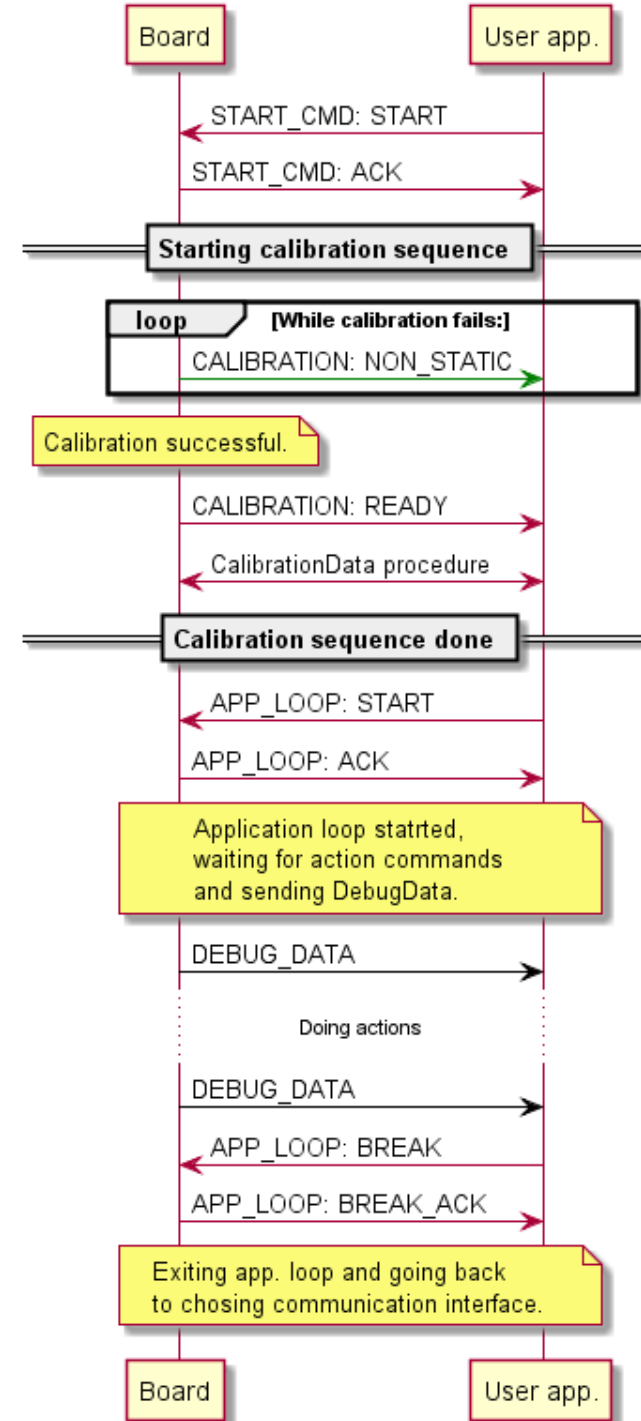
62,143,



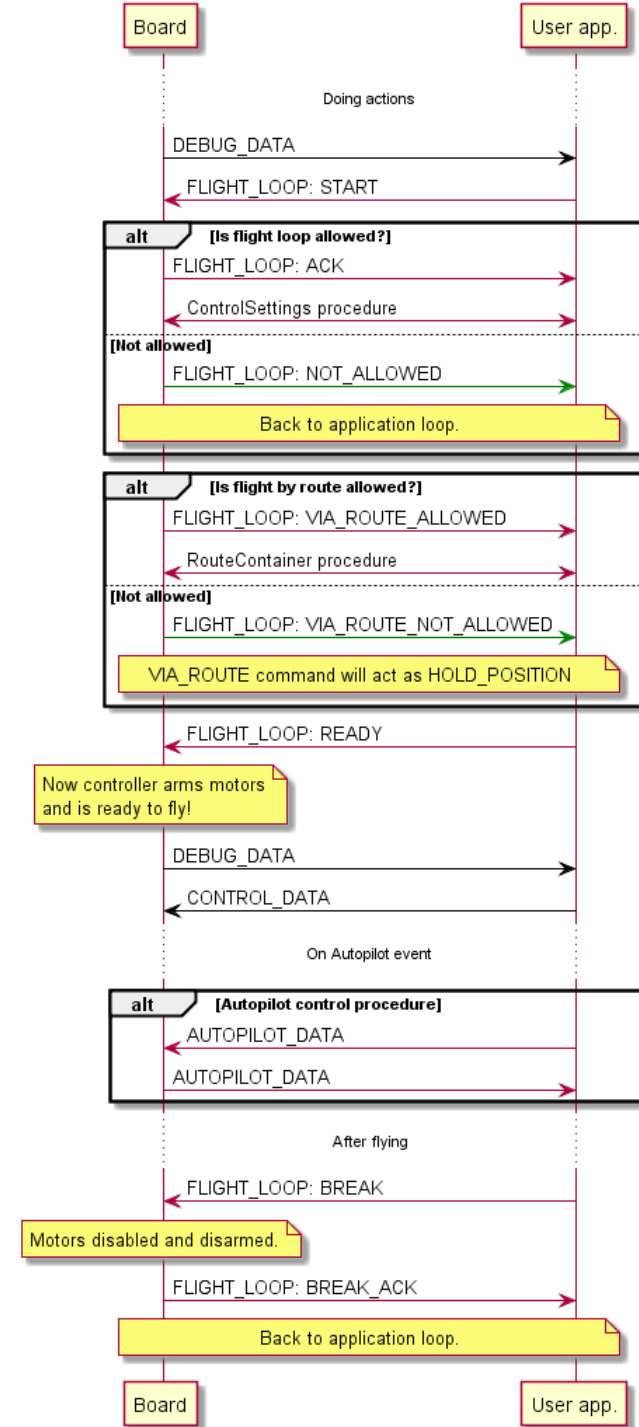
Use cases flow

Usage of described protocol for common actions with UAV usage.

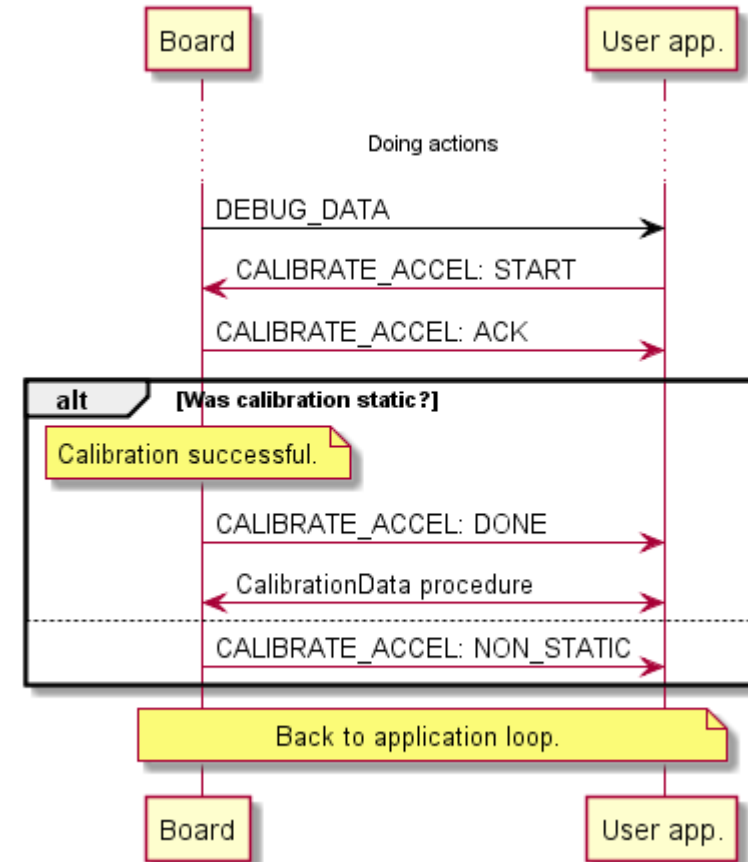
Startup calibration and *Application loop*



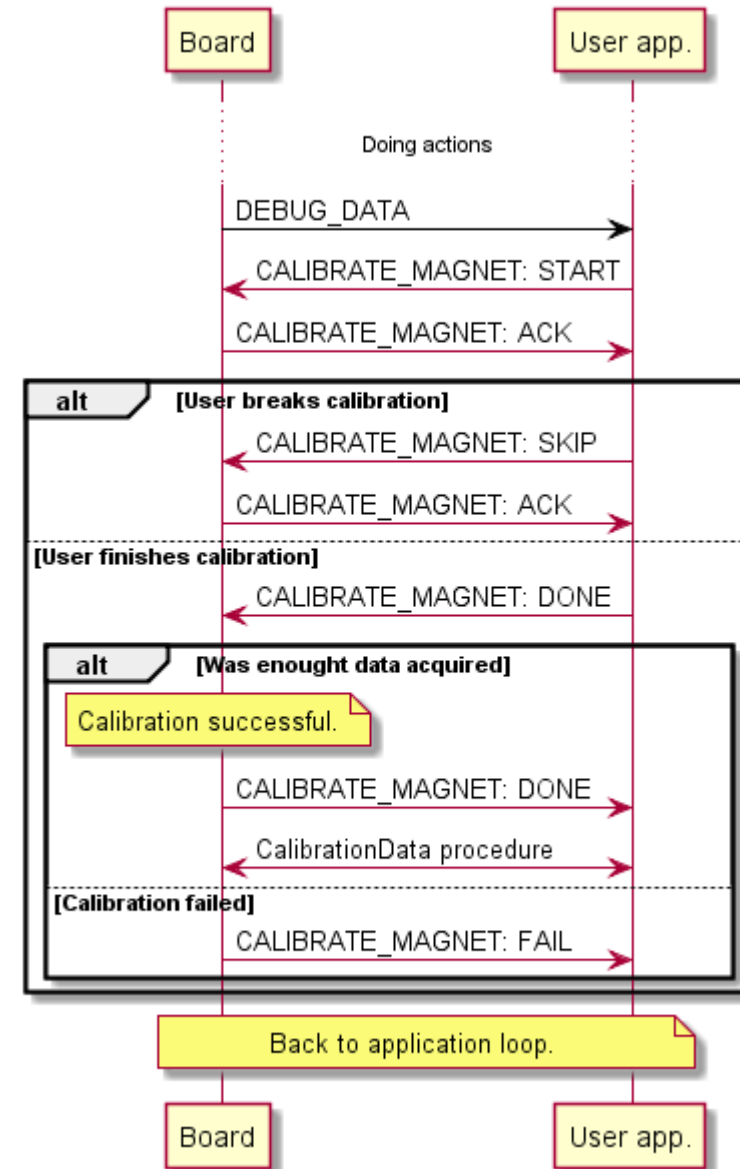
Action: *Flight loop*



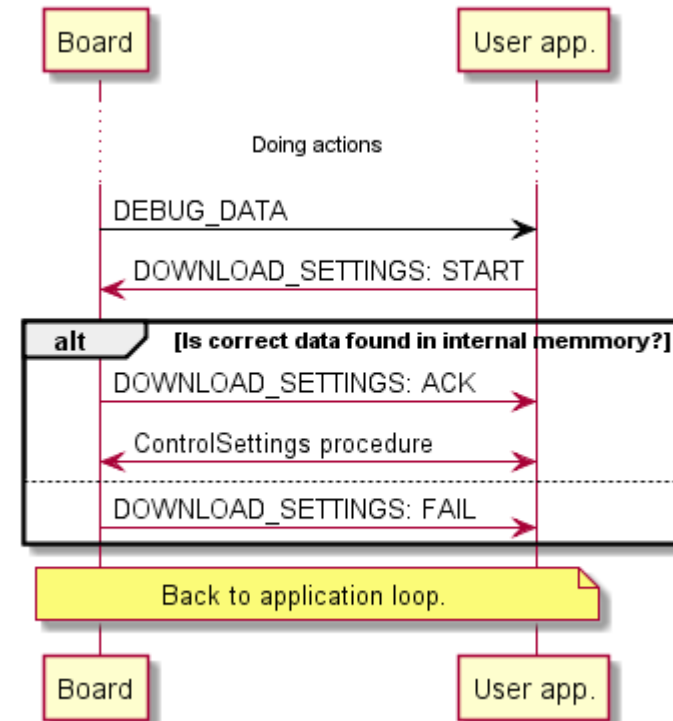
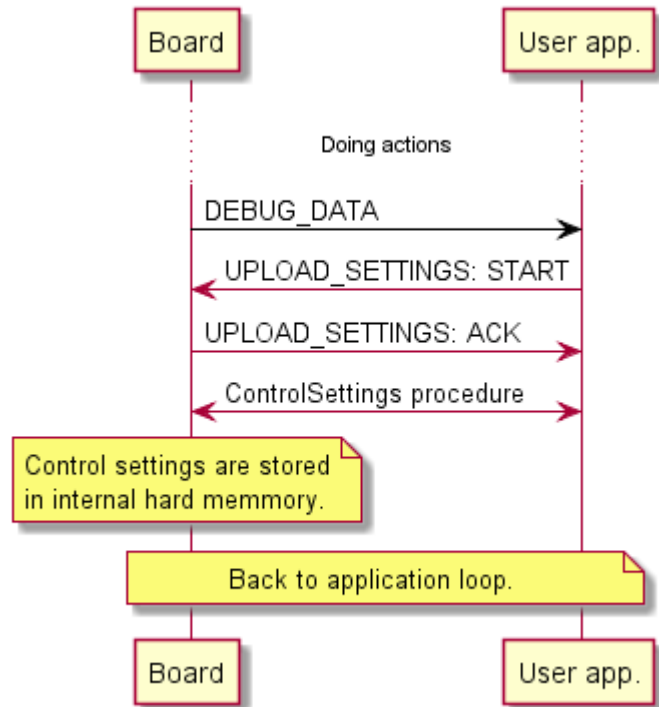
Action: *Calibrate accelerometer*



Action: *Calibrate magnetometer*

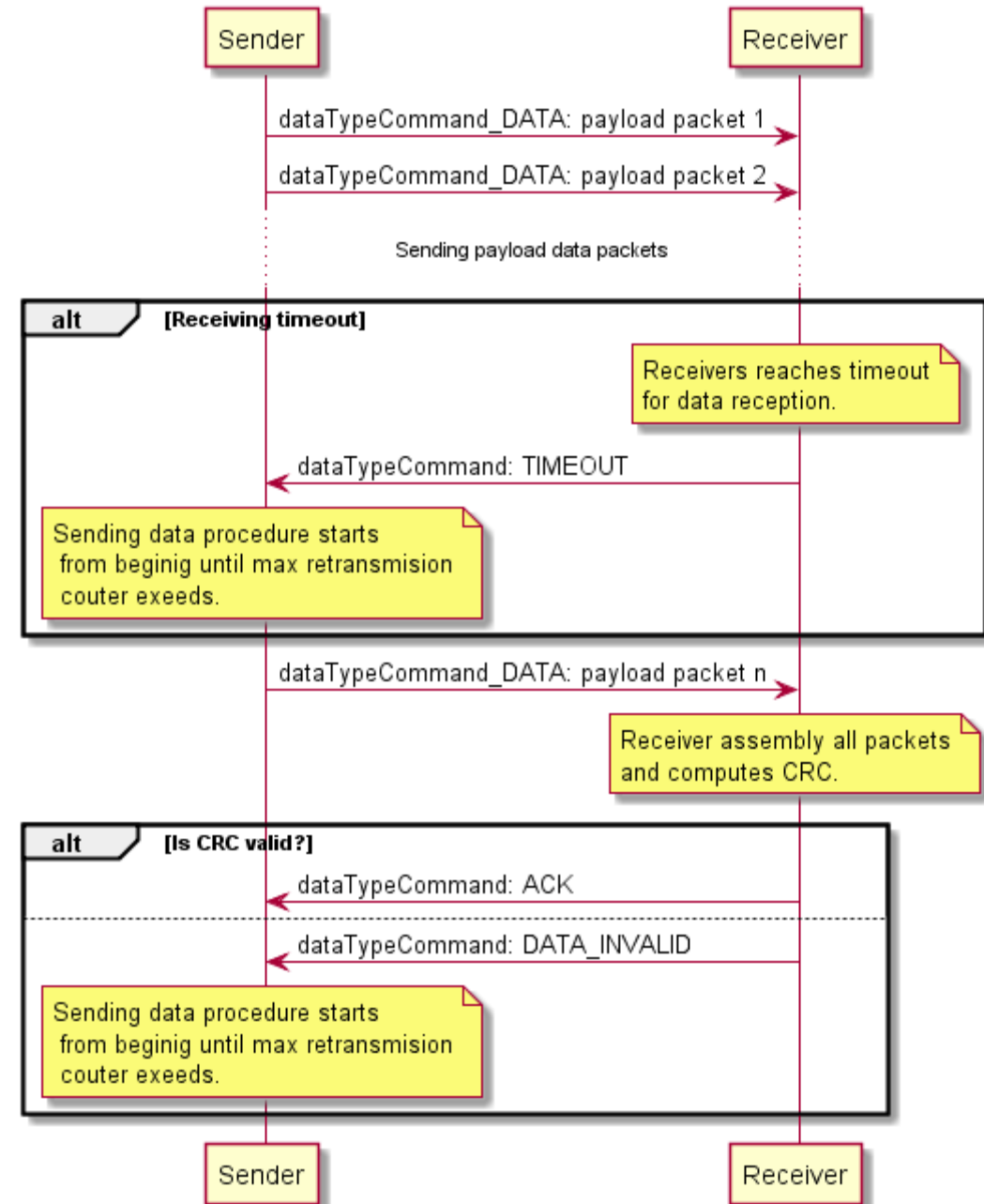


Action: *Upload* and *download* control settings



Action: **Sensors logger**

Signal data sending/receiving procedure



DFU mode by start
command

The end

Questions 😊

