

Multicopter communication protocol

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

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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

CalibrationSettings– 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>
```

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

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

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

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

ControlSettings– 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>
```

37,37,37,0,186,134,1,0,4,0,0,0,208,7,0,0,2,0,0,0,20,0,0,0,0,128,63,0,0,
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,
64,0,0,64,64,0,0,0,63,0,0,0,0,0,192,64,0,0,0,0,0,0,0,76,4,0,0,1,0,0,0,0
,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

RouteContainer– 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,

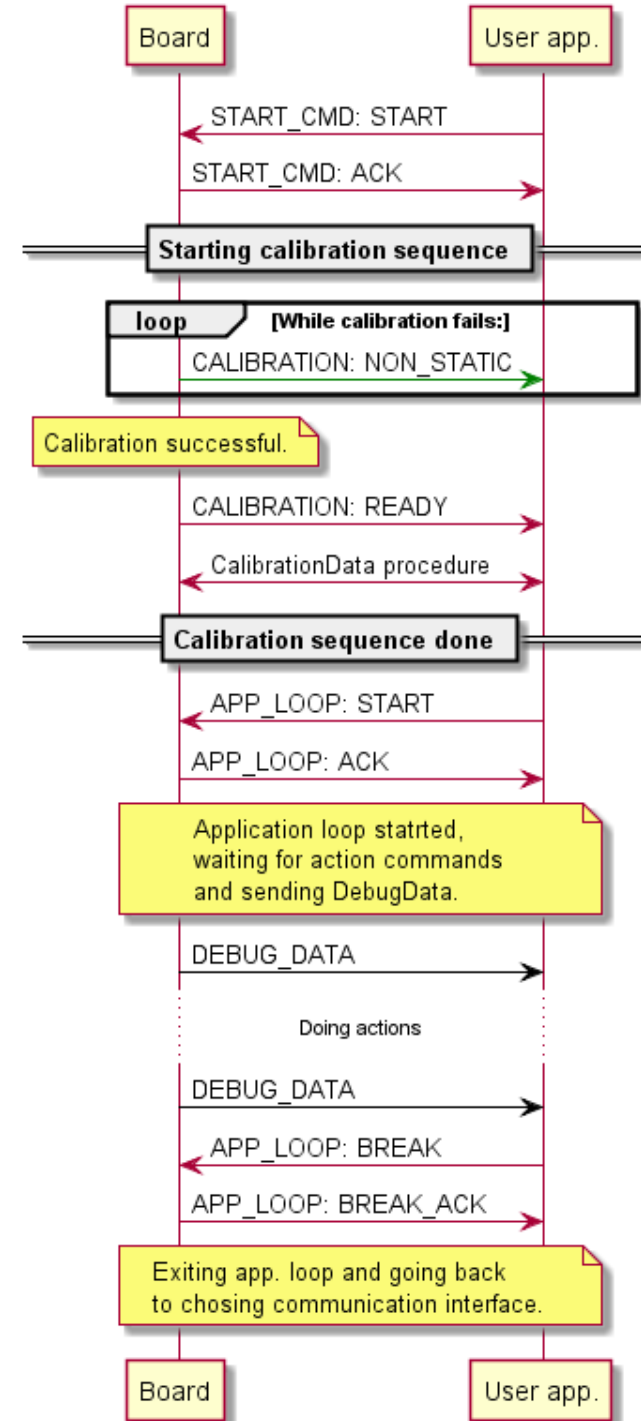
62, 143,



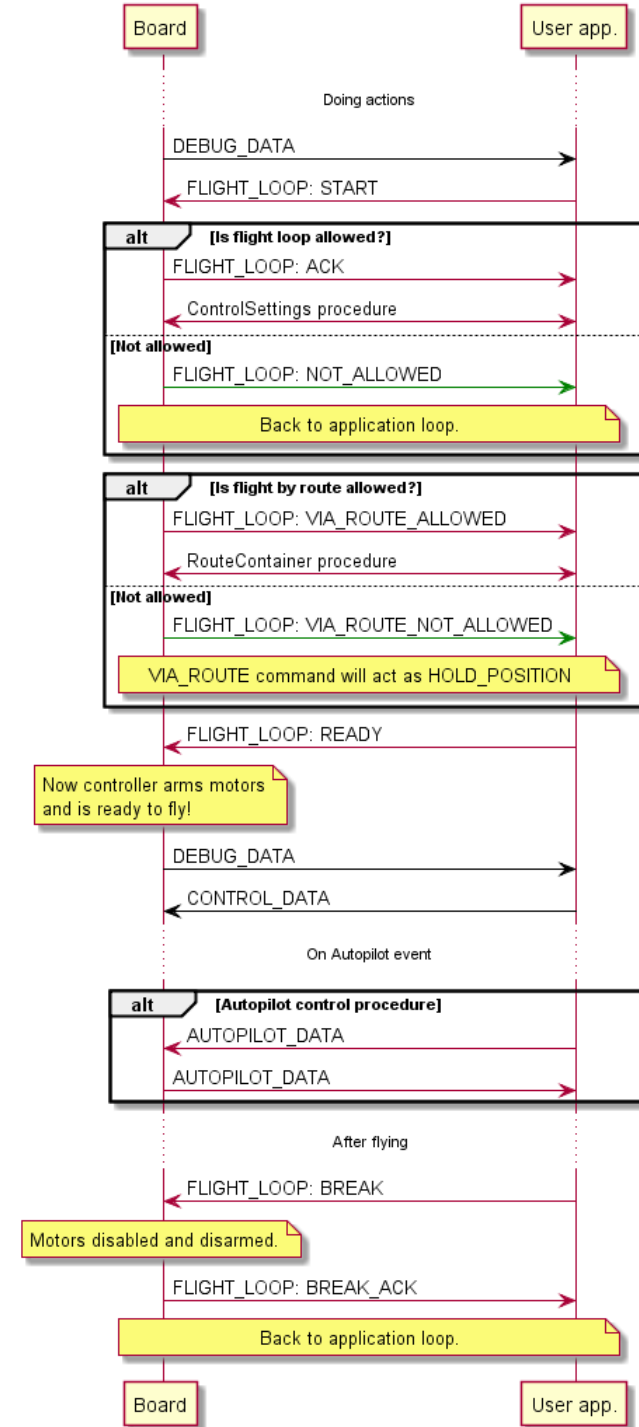
Use cases flow

Usage of described protocol for common actions with UAV usage.

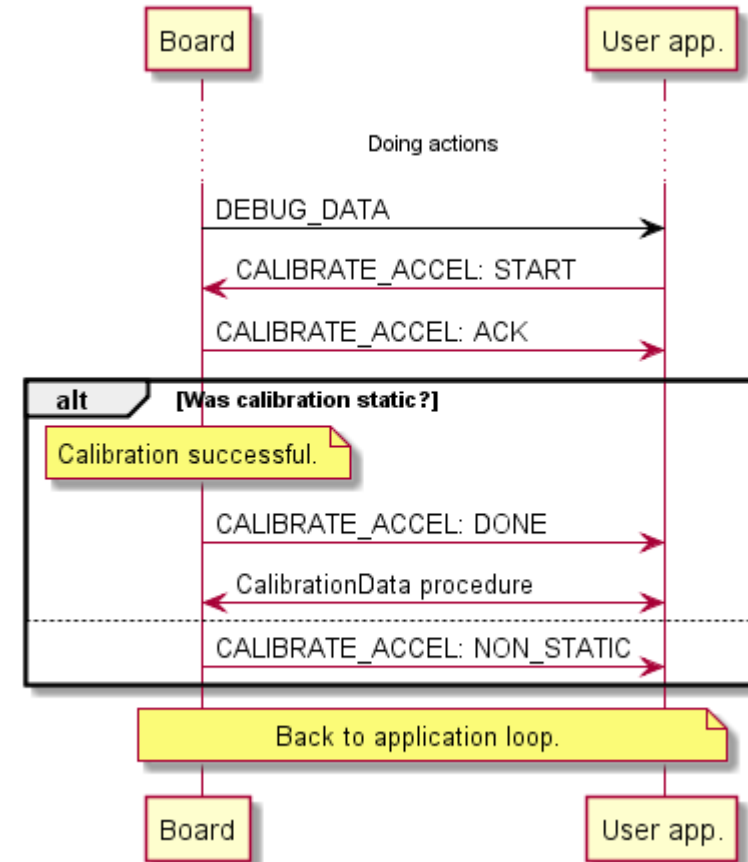
Startup calibration and *Application loop*



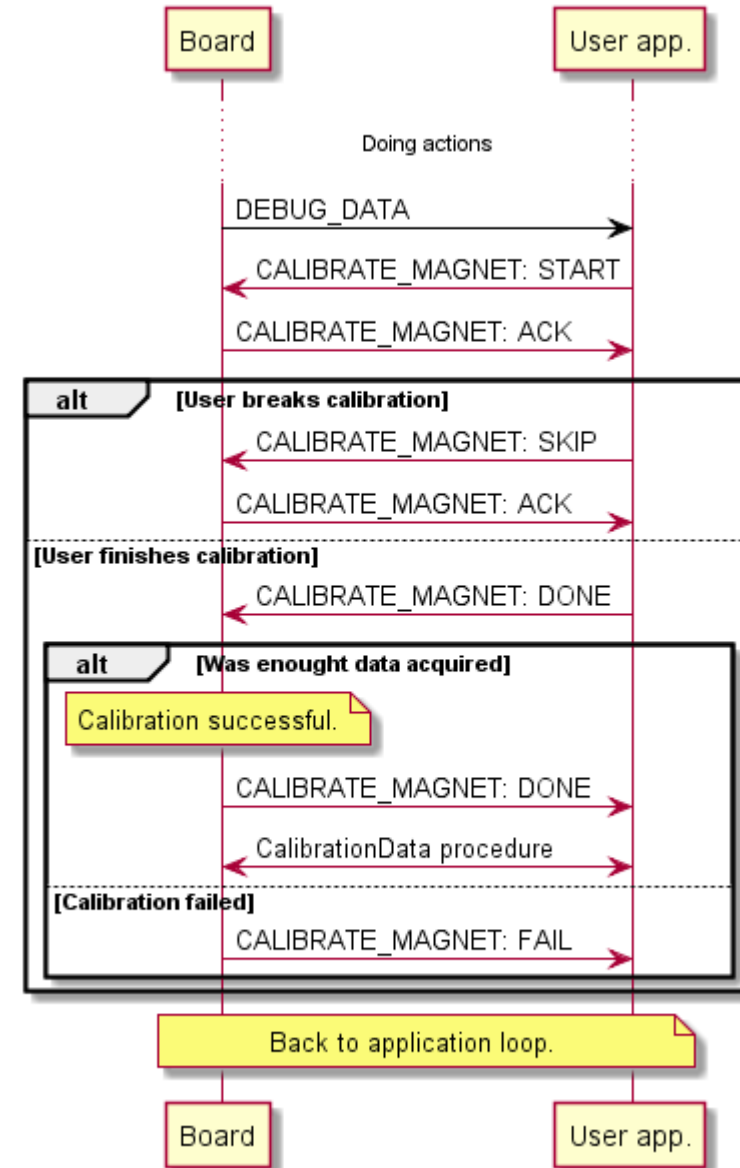
Action: *Flight loop*



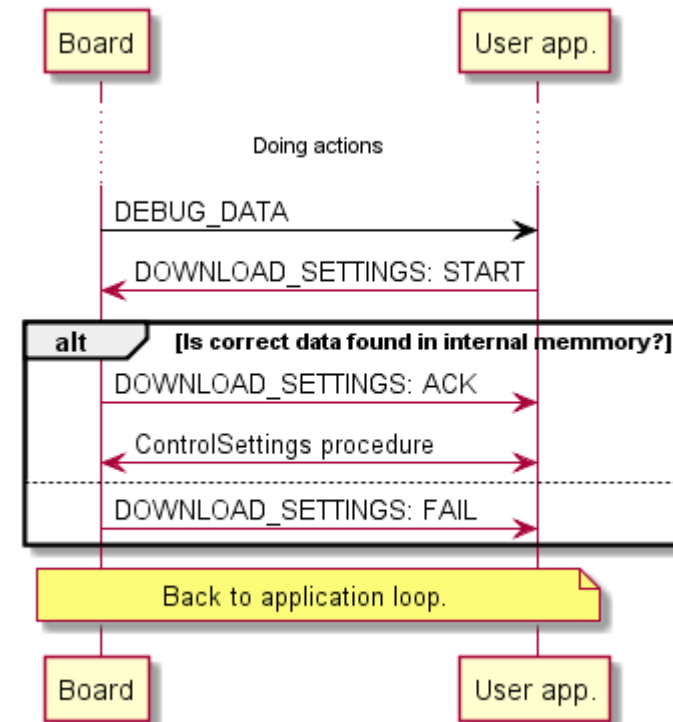
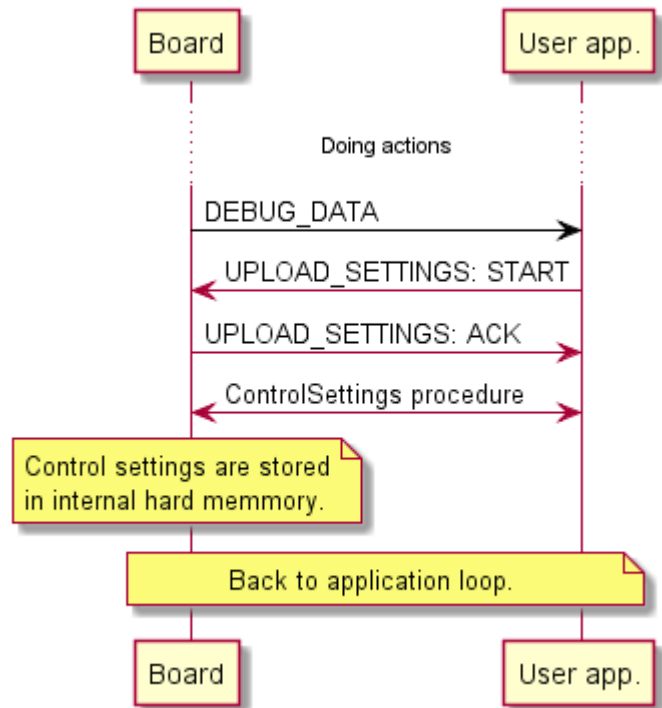
Action: *Calibrate accelerometer*



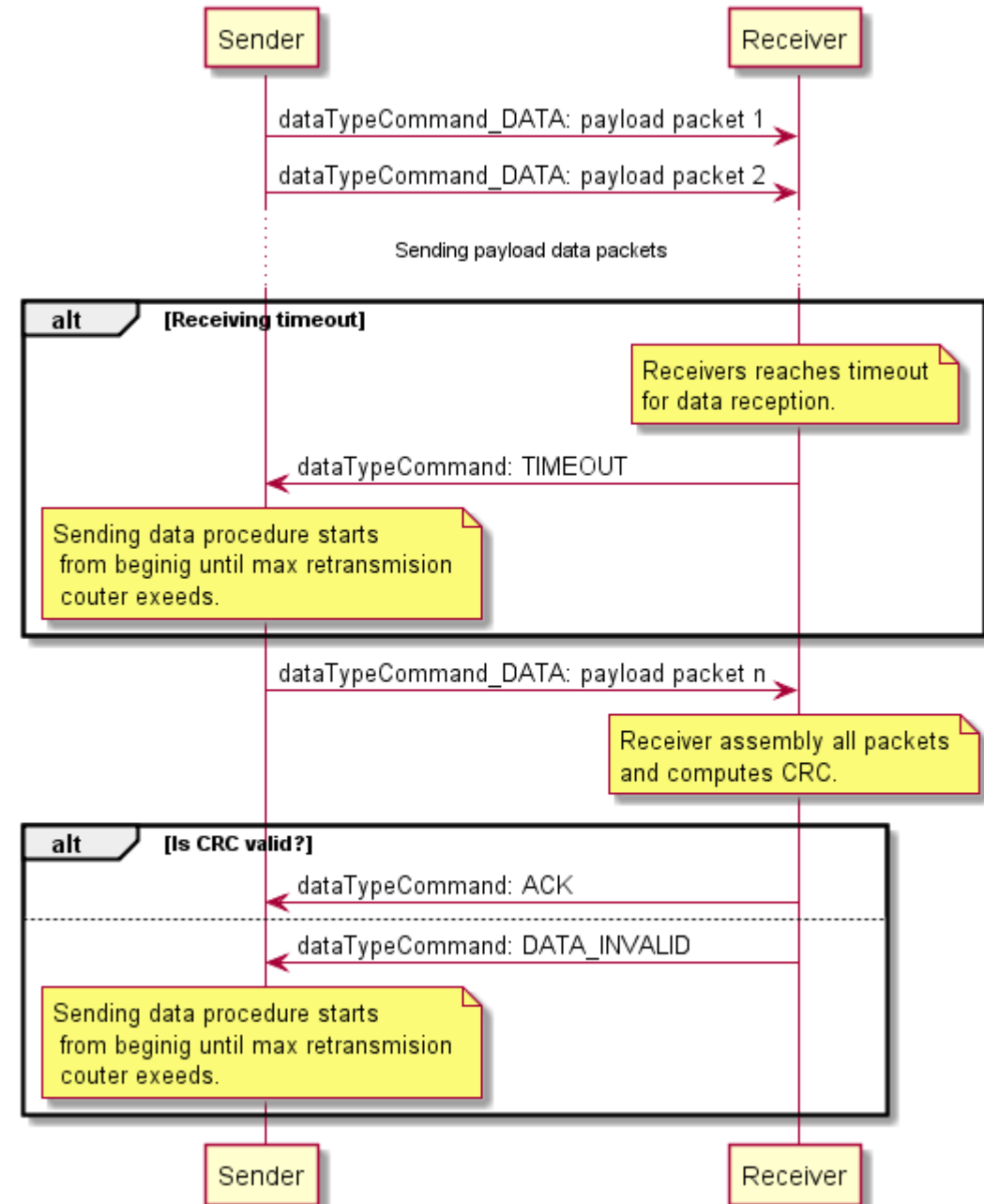
Action: *Calibrate magnetometer*



Action: *Upload* and *download* control settings



Signal data sending/receiving procedure



DFU mode by start
command

The end

Questions 😊

