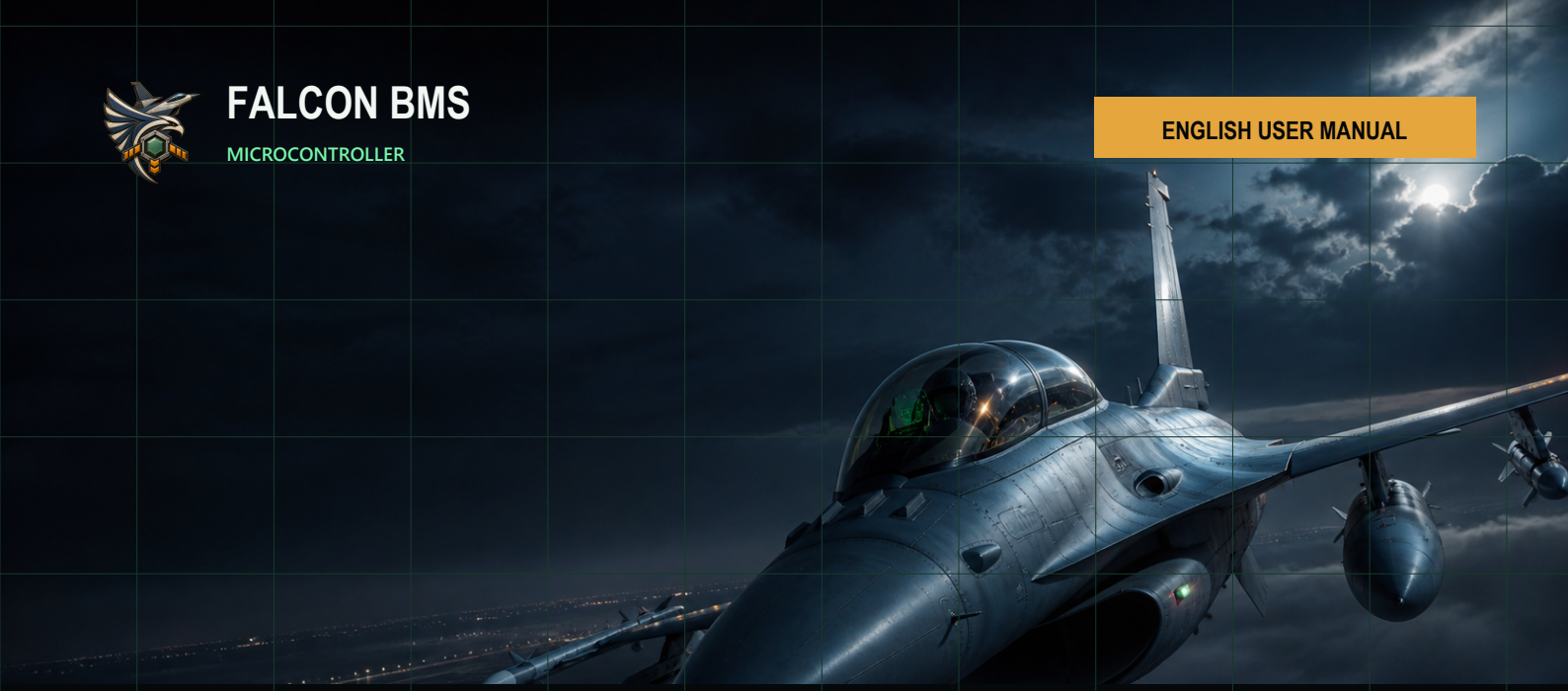
FALCON BMS

MICROCONTROLLER

ENGLISH USER MANUAL



HARDWARE READY / FALCON BMS 4.38

YOUR COCKPIT. YOUR HARDWARE.

Microcontroller outputs explained from the ground up in BMS Live Monitor

---

IDENTIFY / ROUTE / UNDERSTAND / OUTPUT SAFELY

USB, LAN and simulator paths for LEDs and cockpit data.

TARGET SYSTEM	Windows x64 / Falcon BMS 4.38
APPLICATION	BMS Live Monitor / Microcontroller
TRANSPORT	USB / LAN / local simulator
CATALOG	54 data fields / 120 lamp cells

VERSION 1.0 / DOCUMENT REVISION 02 SEP 2026

FLIGHTDATA 118 / FLIGHTDATA2 23 / READ-ONLY OUTPUT

Notes about this manual

SCOPE

This manual describes the MICROCONTROLLER tab in the local BMS Live Monitor source version 1.10.19 dated 2 September 2026. It applies only to Falcon BMS 4.38 with FlightData 118 and FlightData2 23.

It deliberately starts at zero. Terms such as COM port, baud rate, protocol, data field, LED channel, raw value, delta and safe state are explained before you configure anything.

What this document covers

- The complete path from the Falcon cockpit to a microcontroller.
- Every visible field, tab, button and status message.
- Setup with the local simulator, a real USB device or a LAN controller.
- BASCOM LED 64, individual LED commands and NAME#WERT (name#value) with exact examples.
- All 54 raw/text signals and the complete catalog of 120 lamp cells.
- Automatic pit gating, flash logic, change-only transmission and safe state.

ARDUINO CODE BELONGS IN A SEPARATE DOCUMENT

This manual explains what the PC sends and what a microcontroller must understand in principle. Arduino sketches, parser code, libraries, pin assignments and concrete firmware intentionally belong in the separate Arduino manual.

Table of contents

1. What is the Microcontroller tab for?

The tab is the bridge between Falcon BMS flight data inside the PC and physical cockpit hardware. It selects data, assigns it to a device and turns it into simple commands. It is an output module: it reads Falcon, but it does not control Falcon.

Two different output worlds

Physical lamps	Falcon supplies lamp states. Live Monitor resolves flash, RWR, ECM and test logic and sends ON or OFF.
Raw and text data	Instrument values such as RPM, altitude and KIAS, plus DED/PFL, are transmitted as name#value messages.

A simple mental picture

```
Falcon BMS 4.38
        |  Shared Memory
        v
BMS Live Monitor
        |-- final lamp decision --> LED board
        `-- raw value/text packet -> display or motor control
```

NO INPUT PATH INTO FALCON

An LED route or raw data field does not press a switch in the simulator. The tab only transports cockpit states outward.

2. From a data field to real hardware

1. Falcon BMS writes its current flight state into shared memory on the PC.
2. BMS Live Monitor reads the fixed BMS 4.38 data contract.
3. For lamps, raw bits, flash bits, RWR state, ECM state and power are resolved into a final ON/OFF decision.
4. For instruments, the selected numeric or text value is formatted.
5. A route says which signal goes to which WHOAMI controller.
6. The router writes the matching wire command over USB, LAN or the local simulator.
7. The microcontroller receives the target and then drives an LED, display, servo or stepper motor.

Who is responsible for what?

Layer	Job	Not its job
Falcon BMS	Flight physics and cockpit logic	Knowing your pins
BMS Live Monitor	Read, resolve, route and send safely	Motor homing
Microcontroller firmware	Receive, validate, output and limit	Inventing Falcon lamp logic
Electronics	Drivers, power, protection and wiring	Deriving hardware from the PC protocol

IMPORTANT FOR LATER

The PC sends target states. Homing, end stops, motor/servo ramps, shortest-path motion across 0/360 degrees and a local timeout safe state belong in the microcontroller firmware.

3. Layout of the tab

The page contains a shared controller area, three assignment pages and a lower action bar.

Area	What you do there	Memory aid
1 / Identify controllers by WHOAMI	Set device, transport, protocol, speed and endpoint	Device first
2 / LED assignment	Assign one Falcon lamp to one output	Then lamps
3 / Raw data + DED/PFL	Assign numbers and text to a controller	Then instrument data
4 / Live decisions	See why a lamp is logically and physically on or off	Explanation, not setup
Bottom bar	Search, adopt result, start simulator, save and copy summary	Set up and verify

Header status

BMS 4.38 LIVE / IN PIT	Current data is available and hardware output is enabled automatically.
NOT IN PIT / SAFE	Falcon supplies data, but the 3D cockpit is not active. Outputs remain safe.
NO FRESH FLIGHT DATA / SAFE	Telemetry is stale. Old values are not reused as live values.

THE AUTOMATION IS INTENTIONAL

A controller is connected for payload output only while you are in the pit. Leaving the pit sends the safe state once and then closes the connection.

4. Basic terms without jargon

Term	Simple explanation	Example
Microcontroller	A tiny computer on a board that controls pins, LEDs, displays and motors	Arduino, ESP32 or a custom board
Firmware	The program running on the microcontroller	Reads a line until CR
Controller	One saved endpoint in the tab	LED001
WHOAMI	A name request used for safe identification	PC sends WHOAMI; device answers LED001
COM port	Windows name of a serial USB connection	COM5
Baud rate	Speed of the serial connection	115200 baud
Protocol	The common language of PC and device	LED#... or rpm#75.3
Route / assignment	A rule that tells one signal where to go	MASTER CAUTION -> LED001 -> output 27
CR	Carriage Return, character 13, ends every wire message	rpm#75.3\r
Safe state	A deliberately harmless state when live data is unavailable	LED off, raw value 0, blank DED

CR IS NOT A VISIBLE LETTER

The notation \r in examples represents one control character at the end of a message. A backslash and the letter r are not sent as two ordinary characters.

5. Prepare safely before hardware goes live

Electrical basics

- Use the correct series resistor for every LED.
- Never power motors, relays, solenoids, powerful lamps or large LED groups directly from a microcontroller pin.
- Use suitable driver stages, flyback paths, fuses and a correctly sized power supply.
- Connect grounds only according to a checked circuit. USB is not the power supply for the entire cockpit.
- For the first test, mechanically disconnect actuators or move them to a safe center position.

Safe software sequence

1. Use only the local simulator first.
2. Enable only one controller and one route.
3. Verify the safe value and the ON/OFF direction.
4. Then connect one harmless real LED.
5. Add motors and servos only after testing end limits, ramps and a local timeout.

DO NOT DISABLE DRIVERS OR THE GRAPHICS CARD

A microcontroller or COM-port problem is not solved by disabling the graphics card. Diagnose status, WHOAMI, port, baud rate, protocol and exactly one test route.

FIRMWARE NEEDS ITS OWN WATCHDOG

If the PC can no longer reach a disconnected controller, it cannot guarantee a final safe command. Firmware must therefore enter a safe state by itself after a receive timeout.

6. Every field in a controller row

Field	Meaning	Good first setting
ACTIVE	Only active controllers are connected and supplied in the pit	Enable after the row is complete
WHOAMI NAME	Permanent device identity; not merely the COM port	Unique, for example LED001
TYPE	MICROCONTROLLER, SIMULATOR, LAN or OTHER	Match the real transport
PROTOCOL	How lamps and values are written	BASCOM LED 64, NAME#WERT or GEMISCHT
BAUD	Serial speed for USB/COM	115200; must match firmware
LAST / PREFERRED PORT	Saved COM, LAN or simulator endpoint	COM5, LAN:192.168.1.40:43870 or SIM:LED001
PAUSE ms	Delay after each written command	0 for LED64 packet; otherwise start with 8
FOUND NOW	Endpoint found during the current search	Display only
STATUS	Connection, waiting state or specific error	Read before troubleshooting

Choose TYPE correctly

MICROCONTROLLER	Real serial USB device through a Windows COM port.
SIMULATOR	Local virtual endpoint without a COM driver.
LAN	Controller in the trusted local network; payload uses TCP.
OTHER	Another serial COM device that is not otherwise classified.

7. Recommended first test with the simulator

1. Click START SIMULATOR on the MICROCONTROLLER tab.
2. Select an existing virtual controller or create one with a unique WHOAMI name.
3. Choose USB for a local simulation channel or LAN for a local network test.
4. Select BASCOM LED 64, NAME#WERT or GEMISCHT to match the planned real device.
5. Click FIND WHOAMI NOW in Live Monitor.
6. Select the result and click ADOPT FOUND DEVICE.
7. Create and enable one LED or raw-data route.
8. Enter a Falcon mission and the pit; only then is payload output enabled.
9. Check the exact packets, 64 LED states or name#value rows in the simulator.

What the simulator proves

- WHOAMI identity and protocol match.
- The route reaches the intended controller.
- The PC sends the expected format and only required changes.
- The safe state appears when leaving the pit.

THE SIMULATOR DOES NOT TEST REAL ELECTRONICS

A correct packet does not prove pin assignment, voltage, driver circuitry, motor direction or mechanical end position. Those require the later firmware and hardware test.

8. Set up a real USB controller

Firmware requirement

```
PC -> WHOAMI\r
Device -> LED001\r
```

The WHOAMI name must be unique and stable. It must not be empty and should contain no |, # or line ending. The serial link uses ASCII, 8 data bits, no parity, one stop bit, no handshake, and DTR/RTS are disabled.

Step by step

1. Connect the controller by USB and note its current COM port in Windows Device Manager.
2. Choose ADD CONTROLLER. Activate the placeholder row, choose MICROCONTROLLER and set the correct baud rate.
3. Start FIND WHOAMI NOW. The search checks available COM ports at configured baud rates.
4. Verify the new device's WHOAMI name and COM port in the result list.
5. If the identity is new, use ADOPT FOUND DEVICE and then remove the placeholder row.
6. If the identity already exists, update LAST / PREFERRED PORT in that row. Do not create a duplicate.
7. Check protocol and PAUSE ms, save, enter the pit and test one route only.

> **A COM PORT CAN CHANGE**
>
> The WHOAMI name is the identity; the COM port is only the current path. After moving USB ports, search again and update the preferred port of the existing row.

9. Set up a LAN controller

LAN controllers are discovered by one UDP WHOAMI broadcast in the local IPv4 network. The default discovery port is 43862. A device answers with identity, protocol and its TCP data port.

```
PC broadcast -> WHOAMI\r  on UDP 43862
Device       -> GAUGE001|NAME#WERT|43870\r
Payload      -> TCP connection to IP-address:43870
```

1. Put the PC and controller in the same trusted local network.
2. Choose a unique WHOAMI name and a free TCP data port.
3. Run FIND WHOAMI NOW and check the LAN result.
4. Use ADOPT FOUND DEVICE; the endpoint is saved as LAN:IP:PORT.
5. Check LAN type, protocol and routes.
6. In the pit, Live Monitor connects directly to the saved TCP endpoint.

Security boundary

- This is a simple local cockpit data path without TLS or user authentication.
- Never expose UDP 43862 or the TCP data port to the internet or as an exposed host.
- If the IP address changes, run WHOAMI again and update the saved endpoint.

LAN STAYS INSIDE THE COCKPIT NETWORK

Router rules, public port forwarding and internet access are not required and must not be configured for this microcontroller path.

10. The three protocol selections

Protocol	LED behavior	Raw/text data
BASCOM LED 64	One complete LED# packet with 64 bits; ON/OFF command fields are locked	Selected name#value routes are sent as well
NAME#WERT	If LED routes exist: configured individual commands	Numbers, DED and PFL as name#value
GEMISCHT	Configured individual commands	Numbers, DED and PFL in the same stream

Which one fits?

- A classic 64-channel LED board: BASCOM LED 64.
- A pure gauge or display controller: NAME#WERT.
- One controller carrying lamps and instrument values: GEMISCHT.

BOTH ENDS MUST SPEAK THE SAME LANGUAGE

Changing the selection in Live Monitor does not change microcontroller firmware. The PC and device must expect the same protocol.

11. BASCOM LED 64 explained exactly

All active LED routes of one controller are combined into eight bytes. Eight bytes contain 64 bits and are represented by exactly 16 hexadecimal characters.

```
LED#8000000000000000\r   output 1 ON
LED#0000002000000000\r   only output 27 ON
LED#0000000000000001\r   output 64 ON
LED#0000000000000000\r   all 64 outputs OFF
```

Part	Meaning	Example
LED#	Fixed packet prefix	Always four visible characters
16 hex characters	Eight bytes / 64 LED bits	0000002000000000
Bit order	Output 1 is the most significant bit of byte 1	Output 64 is the least significant bit of byte 8
CR	Exactly one message terminator	Character 13

ONE CHANGE STILL SENDS A COMPLETE IMAGE

If one lamp changes, the router sends a new complete 64-bit state. Unassigned channels are OFF. If only channel 27 is on, the packet is always LED#0000002000000000 plus CR.

12. Individual LED commands explained

For NAME#WERT and GEMISCHT, each LED route contains one command for ON and one for OFF. New routes initially use the BASCOM single-output convention.

```
Output 5 ON   -> 51\r
Output 5 OFF  -> 52\r
Output 27 ON  -> 271\r
Output 27 OFF -> 272\r
```

Rule	Meaning
Final digit 1	ON in the default command
Final digit 2	OFF in the default command
1 to 64 characters	A custom firmware command may be entered without CR or LF
OFF before ON	When several lamps change in one cycle, OFF commands are sent first to avoid brief overlap

CUSTOM COMMANDS ARE ALLOWED

The command fields may contain another string defined by your firmware. Their exact parser belongs in the later firmware manual.

13. Every field in an LED assignment

Field	Meaning	Rule
ACTIVE	This individual route is enabled	Enable after controller and channel are correct
LAMP	Named physical lamp from the verified catalog	Do not replace it with a similar signal
CONTROLLER	Target WHOAMI identity	One route targets exactly one controller
CHANNEL	Physical or logical LED channel	1 to 64; use each channel once per controller
ON COMMAND	Command for the ON phase	Locked for BASCOM LED 64
OFF COMMAND	Command for the OFF phase	Locked for BASCOM LED 64
LIVE	Logical and current physical output state	Flashing may currently show OFF

Clean assignment rules

- Use each controller channel only once.
- A lamp may be routed to multiple controllers only as separate routes.
- Leave unused routes unassigned and inactive.
- After every change, test in the simulator or with one harmless LED.

14. Complete LED example: MASTER CAUTION

Goal: the physical MASTER CAUTION LED is connected to output 27 of controller LED001 and follows the real Falcon state.

Setting	Value	Why
Controller	LED001 / BASCOM LED 64	The target 64-channel board
Lamp	GLARESHIELD / MASTER CAUTION	Verified physical lamp cell
Official source	LightBits.MasterCaution	The real Falcon lamp bit
Channel	27	Chosen hardware output
Live packet	LED#0000002000000000 + CR	Channel 27 ON, all others OFF in this example
Safe packet	LED#0000000000000000 + CR	All outputs OFF

1. Create and activate the controller row.
2. Create and activate the LED route.
3. Enter the pit and trigger/clear the official MASTER CAUTION state.
4. Verify channel 27 and the complete packet in the simulator.
5. Leave the pit and verify the all-zero safe packet.

USE THE SELECTABLE PHYSICAL LAMP

MASTER CAUTION follows LightBits.MasterCaution. Internal delays or collection masks are not replacement outputs.

15. Every field under Raw data + DED/PFL

Field	Meaning	Example
ACTIVE	This data route is used	Checked
DATA FIELD	One of 54 verified numeric/text signals	ENGINE / RPM
CONTROLLER	Receiver of this route	GAUGE001
CHANNEL	Optional integer channel	0 or twice a gauge number
WIRE NAME	Name to the left of #	rpm
DECIMALS	Text formatting from 0 to 6 places	1 produces 75.3
SEND ONLY CHANGE >=	Minimum raw change from the last transmitted value	0.5
SAFE VALUE	Value sent when pit/telemetry is lost	0 or a safe neutral position
LIVE VALUE	Currently formatted value while in the pit	75.3

A complete RPM wire set

```
Selection:          ENGINE / RPM
Wire name:          rpm
Decimals:           1
Send change >=:     0.5
Live output:        rpm#75.3\r
Safe output:        rpm#0\r
```

16. Decimals, delta and safe value

Decimals

This field only changes how the number looks as text. A source value of 75.345 becomes 75.3 with one decimal and 75.345 with three. The wire always uses a decimal point.

Delta / minimum change

Delta is compared with the real raw value, not merely the rounded display text. A small delta reacts more finely but creates more messages. A large delta saves traffic but makes gauges update in larger steps.

Example	Decision
Last sent raw value 75.00 / new raw value 75.32 / delta 0.50	Do not send
Last sent raw value 75.00 / new raw value 75.51 / delta 0.50	Send
NaN or infinity	Formatted as 0

Safe value

- A normal route with a safe value sends name#safe plus CR when the gate closes.
- A blank safe value means no separate safe value is sent for that numeric route.
- Firmware must still enforce mechanical limits and a local receive-timeout state.

17. DED and PFL as complete text packets

DED and PFL are not arbitrary single lines. Each message contains exactly five lines of 25 characters, joined by four vertical bars.

```
ded#LINE 1 WITH 25 CHARACTERS|LINE 2 WITH 25 CHARACTERS|
    LINE 3 WITH 25 CHARACTERS|LINE 4 WITH 25 CHARACTERS|
    LINE 5 WITH 25 CHARACTERS\r
```

- Short lines are padded on the right; long lines are cut after 25 characters.
- A vertical bar inside Falcon text becomes / because | is the line separator.
- Falcon control characters 1 and 2 are shown as + and *; other control characters become -.
- Non-ASCII characters are transmitted as ?.
- A new packet is sent only when the full five-line packet changes.

Power and safe state

DED	Requires Emergency Power; otherwise one complete blank 5 x 25 packet is sent.
PFL	Requires Essential Power; otherwise one complete blank 5 x 25 packet is sent.

THE SAFE-VALUE CELL IS NOT THE DISPLAY CONTENT

For DED and PFL, Live Monitor always enforces the complete blank 5 x 25 packet. A short placeholder such as |||| is not an equivalent packet.

18. Live decisions and flash phases

Column	Meaning	Example
LAMP	Physical lamp cell	CAUTION PANEL / PROBE HEAT
BMS STATUS	Logical active/inactive state	ACTIVE
OUTPUT	ON or OFF in this exact flash phase	OFF
MODE	OFF, steady or flash frequency	FLASHING 4 Hz
SOURCE	Shared-memory field and mask	LightBits2 0x01000000
REASON	Complete decision including raw and flash information	Official state active; current flash phase OFF

Logically ON can physically be OFF right now

A flashing lamp remains ACTIVE in BMS STATUS. OUTPUT alternates between ON and OFF with the current phase. This is the difference between the lamp should flash and the LED is lit at this exact moment.

Flash modes

SLOW	1 Hz; for example OUTER MARKER or slow JFS.
2 Hz	Standard flashing; for example EPU RUN, ELEC SYS or ECM warm-up.
2.5 Hz	Special RWR SYSTEM phase.
4 Hz	Fast; for example PROBE HEAT, LAUNCH or MIDDLE MARKER.

19. Special lamp logic already handled by the PC

Area	What Live Monitor resolves	Firmware consequence
Flash bits	Flashing gates an already active lamp by phase	Output only the received ON/OFF state
RWR	Power, lamp test, static legends, SYSTEM flashing and dynamic cells	Do not recreate RWR logic
ECM	Five programs with S, A, T and F; OFF before ON	20 separate lamp cells
MRK BCN	OUTER slow, MIDDLE fast with priority	Only one physical MRK BCN lamp
JFS	FAST has priority over SLOW	Output the final flash phase
ATF NOT ENGAGED	Final Falcon caution state	Do not recreate trigger rules

Two common mix-ups

- LightBits3.NoseGearDown is the green nose-gear down-and-locked indication. LightBits2.GEARHANDLE is the warning in the gear handle and is not a substitute.
- There is one physical MRK BCN lamp. Old outer-marker and middle-marker routes are normalized to marker-beacon.

DO NOT INVENT COCKPIT LOGIC TWICE

If a physical Falcon lamp can be selected, firmware should follow the final ON/OFF command. Custom RPM, altitude or speed thresholds would be a different feature, not this lamp route.

20. Automation, pit gate and safe state

When hardware becomes live

Fresh telemetry	The newest Falcon record is no more than about 750 ms old.
In the pit	The 3D cockpit is active.
No flight end	Falcon reports neither End Flight nor Exit Game.
Controller active	Identity and a saved endpoint exist.

What happens when the gate closes

1. Every BASCOM LED 64 board receives LED#0000000000000000 plus CR.
2. Every active individual LED route receives its OFF command.
3. Every normal data route with a safe value receives name#safe plus CR.
4. DED and PFL each receive one complete blank 5 x 25 packet.
5. The safe state is applied once per existing connection.
6. Connections are then closed. Re-entering the pit triggers a new full synchronization.

> **SAFE DOES NOT MEAN A FROZEN OLD VALUE**
>
> Outside the pit, the raw LIVE field is blank. The router intentionally changes to the configured safe output instead of holding the last indication forever.

21. Divide work across several controllers

WHOAMI	Protocol	Job	Example routes
LED001	BASCOM LED 64	Left warning and indexer lamps	MASTER CAUTION, AOA, AR/NWS
LED002	BASCOM LED 64	Caution panel and electrical lamps	EQUIP HOT, ELEC SYS, GEN
GAUGE001	NAME#WERT	Primary analog instruments	kias, mach, altitude, vvi
RADIO001	NAME#WERT	UHF, TACAN and CMDS displays	uhf-channel, tacan-ufc-channel, cmds-chaff
PANEL001	GEMISCHT	Small mixed assembly	individual LEDs plus rpm and fuel-total

Four rules for order

- Every WHOAMI name is unique.
- Each route targets one controller; use two routes for duplication.
- Do not duplicate channel numbers or wire names inside one controller.
- Keep a small build table listing assembly, power supply, port, protocol and purpose for each controller.

DELETING A CONTROLLER

Deleting a controller row does not move its routes to another device. Those routes are unassigned and disabled so they cannot accidentally operate different hardware.

22. Save and document changes

Saving behavior

- Table changes are stored locally in the viewer settings.
- SAVE explicitly stores and reapplies the configuration.
- The user file is %LOCALAPPDATA%\BmsLiveMonitor\viewer-settings.json.
- Saving writes a temporary file first and then replaces the previous one.

COPY SUMMARY

This button copies a readable list of controllers, protocols and routes to the Windows clipboard. It is useful as a build plan, support attachment or change record.

```
BMS LIVE MONITOR / MICROCONTROLLER
- ACTIVE / LED001 / MICROCONTROLLER / BASCOM LED 64 / 115200 baud
- GLARESHIELD / MASTER CAUTION -> LED001 / packet output 27
- ENGINE / RPM -> GAUGE001 / rpm#value / delta 0.5
```

Before larger changes

1. Copy the summary and save it with a date.
2. Change only one controller or route group at a time.
3. Verify it in the simulator.
4. Only then test real hardware.

23. Safe first commissioning from A to Z

1. Define the cockpit assembly and electrical load; do not connect high-current loads yet.
2. Write down a unique WHOAMI name, transport and protocol.
3. Create the same virtual controller in the simulator.
4. Run WHOAMI and adopt the result.
5. Create exactly one LED or raw-data route.
6. Check channel, wire name, decimals, delta and safe value.
7. Load a Falcon mission and enter the pit.
8. Verify the live message and safe state in the simulator.
9. Copy the summary and preserve it as the checked target configuration.
10. Create real firmware using the separate Arduino/microcontroller manual.
11. Connect the real USB or LAN device with one harmless output only.
12. Check WHOAMI, port, baud and status; repeat the single-output test.
13. Add routes one at a time and verify after each group.
14. Add motors, servos and high-current loads last, with drivers, limits and a local timeout.

STOP CONDITION

If the wrong LED reacts, anything moves unexpectedly, hardware becomes hot, smells, power flickers, a connection fails or the safe state is unclear: remove power from the affected hardware and trace the last single change.

24. Status messages and troubleshooting

Status or symptom	Meaning	Focused check
AUTOMATION WAITING FOR PIT	Configuration exists, but the 3D cockpit is inactive	Load a mission and enter the pit
NO SAVED COM PORT	USB row has no endpoint	Run WHOAMI or enter the COM port
PORT NOT AVAILABLE	COM port is missing, busy or cannot open	Check port name and other serial programs
NO WHOAMI RESPONSE	Device did not answer in time	Check baud, firmware and CR terminator
WRONG WHOAMI RESPONSE	Answer does not match expected identity	Compare names on both sides
SIMULATOR UNREACHABLE	Local simulator endpoint is not running	Start simulator and its controller
LAN UNREACHABLE	Saved IP/TCP port does not answer	Check LAN, IP, data port and local firewall
SEND FAILED	An existing path broke	Check cable, power and endpoint
SAFE STATE FAILED	Final safety command could not be written	Check firmware watchdog and hardware safe state
LIVE value stays blank	Not in pit, route inactive or not assigned	Check header, ACTIVE and controller
LED flashes in LIVE	Logical state is active and a flash mode applies	Read BMS STATUS and MODE under LIVE DECISIONS
Too many messages	Delta is too small or many fields change	Raise delta carefully; check PAUSE and routes
Gauge moves in coarse steps	Delta too large or firmware has no smoothing	Lower delta; add smoothing later in firmware
Wrong channel reacts	Duplicate or incorrect assignment	Enable one route and check channel list

25. Data-field catalog - Flight instruments

The wire name appears to the left of #. The PC sends the documented value without any extra instrument scaling that is not explicitly stated here.

Wire name	Selection	Unit / contract	How to read it
kias	Airspeed / KIAS	kt; indicated airspeed	450.2 means 450.2 knots
mach	Mach	Mach number	0.82 means Mach 0.82
altitude	Altimeter / AAU	ft; barometric AAU altitude	15234.5 ft
altcal	Altimeter pressure	AltCalReading; unit from altcaltype	2992 or 1013, depending on mode
altcaltype	Altimeter Cal Type	1 = inHg, 0 = hPa	Read together with altcal
pneuflag	Altimeter PNEU Flag	1 = visible, 0 = hidden	Digital yes/no value
vvi	Vertical Velocity	ft/min; calculated from -zDot x 60	-1200 means descending at 1200 ft/min
aoa	Angle of Attack	degrees; alpha	12.50 degrees
pitch	ADI Pitch	radians; raw BMS value	Degrees = radians x 180 / Pi
roll	ADI Roll	radians; raw BMS value	Degrees = radians x 180 / Pi
turnrate	ADI Turn Needle	degrees per second	The sign indicates direction
sideslip	ADI Slip Ball	degrees; sideSlipdeg	0 = centered
ilsh	ILS needle horizontal	BMS position	Do not interpret the raw position as degrees
ilsv	ILS needle vertical	BMS position	Do not interpret the raw position as feet
g	Current G meter	g	1.00 = normal Earth gravity
gmax	G meter maximum	g; stored maximum	For the maximum telltale needle
gmin	G meter minimum	g; stored minimum	For the minimum telltale needle

26. Data-field catalog - Compass, HSI and engine

The wire name appears to the left of #. The PC sends the documented value without any extra instrument scaling that is not explicitly stated here.

Wire name	Selection	Unit / contract	How to read it
heading	Current heading	degrees; currentHeading	0/360 = north, 90 = east
compass	Compass rose	0 to 360 degrees; calculated from yaw	Already normalized to 0 through 360
headingbug	Heading Marker	degrees; desiredHeading	Selected heading
course	Course Arrow	degrees; desiredCourse	Selected HSI course
coursedev	Course deviation	raw BMS value	Do not assume degrees
bearing	Bearing Pointer	degrees to the beacon	Pointer direction
rpm	Engine RPM	percent; BMS range 0 to 103	75.3 = 75.3 percent
nozzle	Nozzle Position	percent; 0 closed, 100 open	Engine nozzle position
ftit	FTIT	raw BMS FTIT value	No additional scaling is performed on the PC
oil	Oil Pressure	psi; 0 to 100	Oil-pressure indication
fuelflow	Fuel Flow	pph	Fuel flow per hour

27. Data-field catalog - Fuel, hydraulics, trim and general indications

The wire name appears to the left of #. The PC sends the documented value without any extra instrument scaling that is not explicitly stated here.

Wire name	Selection	Unit / contract	How to read it
fuel-fwd	FWD Fuel	raw BMS value	Forward fuel-tank indication
fuel-aft	AFT Fuel	raw BMS value	Aft fuel-tank indication
fuel-total	Total Fuel	lb	Total fuel
fuel-internal	Internal Fuel	lb	Internal fuel
fuel-external	External Fuel	lb	External fuel
epu-fuel	EPU Fuel	percent	EPU fuel level
hyd-a	Hyd Pressure A	psi	Hydraulic system A
hyd-b	Hyd Pressure B	psi	Hydraulic system B
cabin-alt	Cabin Pressure Alt	ft	Cabin pressure altitude
trim-pitch	Pitch Trim	-0.5 to +0.5	0 = neutral
trim-roll	Roll Trim	-0.5 to +0.5	0 = neutral
speedbrake	Speedbrake Position	0 closed to 1 open	0.5 = half travel
current-time	Simulator clock	seconds since 00:00	3661 = 01:01:01

28. Data-field catalog - Text displays, radio, TACAN and CMDS

The wire name appears to the left of #. The PC sends the documented value without any extra instrument scaling that is not explicitly stated here.

Wire name	Selection	Unit / contract	How to read it
ded	DED	5 x 25 characters; separator |	One complete text packet
pfl	PFL	5 x 25 characters; separator |	One complete text packet
uhf-channel	Active backup-UHF channel	CHAN; uhf_panel_preset	Integer channel number
uhf-frequency	Active backup-UHF frequency	raw kHz value	Do not format as MHz
tacan-ufc-channel	UFC TACAN Channel	1 to 126	UFC input
tacan-aux-channel	AUX TACAN Channel	1 to 126	AUX panel
tacan-ufc-band	UFC TACAN Band	1 = X, 0 = Y	Digital selection value
tacan-aux-band	AUX TACAN Band	1 = X, 0 = Y	Digital selection value
tacan-ufc-mode	UFC TACAN Mode	1 = A/A, 0 = ground	A/A means air-to-air
tacan-aux-mode	AUX TACAN Mode	1 = A/A, 0 = ground	A/A means air-to-air
cmds-chaff	Chaff Count	units; CH window	Remaining chaff count
cmds-flare	Flare Count	units; FL window	Remaining flare count
cmds-mode	CMDS Mode	0 OFF, 1 STBY, 2 MAN, 3 SEMI, 4 AUTO, 5 BYP	Translate the number into a mode

29. Lamp catalog - LightBits, part 1

This list contains the actual selectable physical lamp cells. Live Monitor supplies the final ON/OFF phase; the source column is included so the signal remains traceable.

Category	LED-assignment selection	Official source	Note
GLARESHIELD	MASTER CAUTION	LightBits 0x00000001	Final Falcon lamp state
GLARESHIELD	TF	LightBits 0x00000002	Final Falcon lamp state
GLARESHIELD	OXY BROW	LightBits 0x00000004	Final Falcon lamp state
CAUTION PANEL	EQUIP HOT	LightBits 0x00000008	Final Falcon lamp state
GLARESHIELD	ENG FIRE	LightBits 0x00000020	Final Falcon lamp state
CAUTION PANEL	CONFIG	LightBits 0x00000040	Final Falcon lamp state
GLARESHIELD	HYD/OIL PRESS	LightBits 0x00000080	Final Falcon lamp state
FLCS	FLCS A/B/C/D · GROUP BIT	LightBits 0x00000100	Legacy group bit; individual channels A through D are available separately
GLARESHIELD	FLCS	LightBits 0x00000200	Final Falcon lamp state
GLARESHIELD	CAN	LightBits 0x00000400	Final Falcon lamp state
GLARESHIELD	T/L CFG	LightBits 0x00000800	Final Falcon lamp state
AOA INDEXER	AOA ABOVE	LightBits 0x00001000	Final Falcon lamp state
AOA INDEXER	AOA ON	LightBits 0x00002000	Final Falcon lamp state
AOA INDEXER	AOA BELOW	LightBits 0x00004000	Final Falcon lamp state
AR/NWS INDEXER	REFUEL RDY	LightBits 0x00008000	Final Falcon lamp state

30. Lamp catalog - LightBits, part 2

This list contains the actual selectable physical lamp cells. Live Monitor supplies the final ON/OFF phase; the source column is included so the signal remains traceable.

Category	LED-assignment selection	Official source	Note
AR/NWS INDEXER	REFUEL AR / NWS	LightBits 0x00010000	Final Falcon lamp state
AR/NWS INDEXER	REFUEL DSC	LightBits 0x00020000	Final Falcon lamp state
CAUTION PANEL	FLT CONTROL SYS	LightBits 0x00040000	Final Falcon lamp state
CAUTION PANEL	LE FLAPS	LightBits 0x00080000	Final Falcon lamp state
CAUTION PANEL	ENGINE FAULT	LightBits 0x00100000	Final Falcon lamp state
CAUTION PANEL	OVERHEAT	LightBits 0x00200000	Final Falcon lamp state
CAUTION PANEL	FUEL LOW	LightBits 0x00400000	Final Falcon lamp state
CAUTION PANEL	AVIONICS	LightBits 0x00800000	Final Falcon lamp state
CAUTION PANEL	RADAR ALT	LightBits 0x01000000	Final Falcon lamp state
CAUTION PANEL	IFF	LightBits 0x02000000	Final Falcon lamp state
MISC PANEL	ECM ENBL	LightBits 0x04000000	Final Falcon lamp state
CAUTION PANEL	HOOK	LightBits 0x08000000	Final Falcon lamp state
CAUTION PANEL	NWS FAIL	LightBits 0x10000000	Final Falcon lamp state
CAUTION PANEL	CABIN PRESS	LightBits 0x20000000	Final Falcon lamp state
TFR	TFR STBY	LightBits 0x80000000	Final Falcon lamp state

31. Lamp catalog - RWR and CMDS

This list contains the actual selectable physical lamp cells. Live Monitor supplies the final ON/OFF phase; the source column is included so the signal remains traceable.

Category	LED-assignment selection	Official source	Note
THREAT WARNING PRIME	HANDOFF · DIAMOND	LightBits2 0x00000001	RWR power and lamp test are already included
THREAT WARNING PRIME	HANDOFF · H	RwrInfo onpwr	Static legend cell while RWR power/test is active
THREAT WARNING PRIME	LAUNCH · LAUNCH	LightBits2 0x00000002	May flash at 4 Hz
THREAT WARNING PRIME	LAUNCH · MISSILE	LightBits2 0x00000002	Same logical launch state
THREAT WARNING PRIME	MODE · PRI	LightBits2 0x00000004	May flash at 4 Hz
THREAT WARNING PRIME	MODE · OPEN	RwrInfo onpwr + PriMode inverted	Opposite indication to PRI
THREAT WARNING PRIME	NAVAL	LightBits2 0x00000008	RWR power and lamp test are already included
THREAT WARNING PRIME	UNKNOWN · U	LightBits2 0x00000010	May flash at 4 Hz
THREAT WARNING PRIME	UNKNOWN · UNKNOWN	RwrInfo onpwr	Static legend cell
THREAT WARNING PRIME	TGT SEP · T / TGT SET	LightBits2 0x00000020	Dynamic T cell
THREAT WARNING PRIME	TGT SEP · TGT SEP	RwrInfo onpwr	Static legend cell
CMDS	GO	LightBits2 0x00000040	Final Falcon lamp state
CMDS	NO GO	LightBits2 0x00000080	Final Falcon lamp state
CMDS	DEGR	LightBits2 0x00000100	Final Falcon lamp state
CMDS	DISPENSE RDY	LightBits2 0x00000200	Final Falcon lamp state
CMDS	CHAFF LOW	LightBits2 0x00000400	Final Falcon lamp state
CMDS	FLARE LOW	LightBits2 0x00000800	Final Falcon lamp state
THREAT WARNING AUX	SEARCH · S	LightBits2 0x00001000	May flash at 4 Hz
THREAT WARNING AUX	ACT/PWR · ACTIVITY	LightBits2 0x00002000	RWR power and lamp test are already included
THREAT WARNING AUX	ACT/PWR · POWER	RwrInfo onpwr	Static power cell
THREAT WARNING AUX	ALTITUDE · LOW	LightBits2 0x00004000	RWR power and lamp test are already included
THREAT WARNING AUX	ALTITUDE · ALT	RwrInfo onpwr	Static legend cell
THREAT WARNING AUX	POWER · SYSTEM	RwrInfo onpwr	Flashes at 2.5 Hz during the RWR system phase
THREAT WARNING AUX	POWER · POWER	RwrInfo onpwr	Constant power cell

32. Lamp catalog - LightBits2 and electrical

This list contains the actual selectable physical lamp cells. Live Monitor supplies the final ON/OFF phase; the source column is included so the signal remains traceable.

Category	LED-assignment selection	Official source	Note
ECM	ECM POWER	LightBits2 0x00010000	Final Falcon lamp state
ECM	ECM FAIL	LightBits2 0x00020000	Final Falcon lamp state
CAUTION PANEL	FWD FUEL LOW	LightBits2 0x00040000	Final Falcon lamp state
CAUTION PANEL	AFT FUEL LOW	LightBits2 0x00080000	Final Falcon lamp state
EPU	EPU RUN	LightBits2 0x00100000	May flash at 2 Hz
ENGINE START	JFS RUN	LightBits2 0x00200000	Slow 1 Hz or fast 2 Hz
CAUTION PANEL	SEC	LightBits2 0x00400000	Final Falcon lamp state
CAUTION PANEL	OXY LOW	LightBits2 0x00800000	Final Falcon lamp state
CAUTION PANEL	PROBE HEAT	LightBits2 0x01000000	May flash at 4 Hz
CAUTION PANEL	SEAT NOT ARMED	LightBits2 0x02000000	Final Falcon lamp state
CAUTION PANEL	BUC	LightBits2 0x04000000	Final Falcon lamp state
CAUTION PANEL	FUEL/OIL HOT	LightBits2 0x08000000	Final Falcon lamp state
CAUTION PANEL	ANTI SKID	LightBits2 0x10000000	Final Falcon lamp state
TFR	TFR ENGAGED	LightBits2 0x20000000	Final Falcon lamp state
LANDING GEAR	GEAR HANDLE	LightBits2 0x40000000	Gear movement or an unlocked position
GLARESHIELD	ENGINE	LightBits2 0x80000000	Final Falcon lamp state
ELEC	FLCS PMG	LightBits3 0x00000001	Final Falcon lamp state
ELEC	MAIN GEN	LightBits3 0x00000002	Final Falcon lamp state
ELEC	STBY GEN	LightBits3 0x00000004	Final Falcon lamp state
ELEC	EPU GEN	LightBits3 0x00000008	Final Falcon lamp state
ELEC	EPU PMG	LightBits3 0x00000010	Final Falcon lamp state
ELEC	ACFT BATT TO FLCS	LightBits3 0x00000020	Final Falcon lamp state
ELEC	FLCS RLY	LightBits3 0x00000040	Final Falcon lamp state
ELEC	BAT FAIL	LightBits3 0x00000080	Final Falcon lamp state

33. Lamp catalog - LightBits3, FLCS and marker

This list contains the actual selectable physical lamp cells. Live Monitor supplies the final ON/OFF phase; the source column is included so the signal remains traceable.

Category	LED-assignment selection	Official source	Note
EPU	HYDRAZINE	LightBits3 0x00000100	Final Falcon lamp state
EPU	AIR	LightBits3 0x00000200	Final Falcon lamp state
CAUTION PANEL	ELEC SYS	LightBits3 0x00000400	May flash at 2 Hz
CAUTION PANEL	LEF FAULT	LightBits3 0x00000800	Final Falcon lamp state
FLCS	FLCS BIT RUN	LightBits3 0x00002000	Final Falcon lamp state
FLCS	FLCS BIT FAIL	LightBits3 0x00004000	Final Falcon lamp state
GLARESHIELD	DBU ON	LightBits3 0x00008000	Final Falcon lamp state
LANDING GEAR	NOSE GEAR DOWN	LightBits3 0x00010000	Final Falcon lamp state
LANDING GEAR	LEFT GEAR DOWN	LightBits3 0x00020000	Final Falcon lamp state
LANDING GEAR	RIGHT GEAR DOWN	LightBits3 0x00040000	Final Falcon lamp state
CAUTION PANEL	CADC	LightBits3 0x00400000	Final Falcon lamp state
SPEEDBRAKE	SPEEDBRAKE	LightBits3 0x00800000	Final Falcon lamp state
THREAT WARNING PRIME	SYS TEST · ON	LightBits3 0x01000000	RWR power and lamp test are already included
THREAT WARNING PRIME	SYS TEST · SYS TEST	RwrInfo onpwr	Static legend cell
CAUTION PANEL	ATF NOT ENGAGED	LightBits3 0x10000000	Final Falcon caution; do not recreate its trigger logic
CAUTION PANEL	INLET ICING	LightBits3 0x20000000	Final Falcon lamp state
FLCS	FLCS CHANNEL A	MiscBits 0x00000002	Individual FLCS channel cell
FLCS	FLCS CHANNEL B	MiscBits 0x00000004	Individual FLCS channel cell
FLCS	FLCS CHANNEL C	MiscBits 0x00000008	Individual FLCS channel cell
FLCS	FLCS CHANNEL D	MiscBits 0x00000010	Individual FLCS channel cell
INSTRUMENT PANEL	AVTR	HsiBits 0x00002000	Final Falcon lamp state
MARKER BEACON	MRK BCN	HsiBits 0x0000C000	One lamp; MIDDLE at 4 Hz has priority over OUTER at 1 Hz

34. Lamp catalog - ECM programs 1 through 5

This list contains the actual selectable physical lamp cells. Live Monitor supplies the final ON/OFF phase; the source column is included so the signal remains traceable.

Category	LED-assignment selection	Official source	Note
ECM PROGRAM LIGHTS	PROGRAM 1 · S STANDBY	ecmBits[0] state 0x08	S flashes at 2 Hz during ECM warm-up
ECM PROGRAM LIGHTS	PROGRAM 1 · A ACTIVE	ecmBits[0] state 0x10	Resolved ECM state cell
ECM PROGRAM LIGHTS	PROGRAM 1 · T TRANSMIT	ecmBits[0] state 0x20	Resolved ECM state cell
ECM PROGRAM LIGHTS	PROGRAM 1 · F FAIL	ecmBits[0] state 0x40	Resolved ECM state cell
ECM PROGRAM LIGHTS	PROGRAM 2 · S STANDBY	ecmBits[1] state 0x08	S flashes at 2 Hz during ECM warm-up
ECM PROGRAM LIGHTS	PROGRAM 2 · A ACTIVE	ecmBits[1] state 0x10	Resolved ECM state cell
ECM PROGRAM LIGHTS	PROGRAM 2 · T TRANSMIT	ecmBits[1] state 0x20	Resolved ECM state cell
ECM PROGRAM LIGHTS	PROGRAM 2 · F FAIL	ecmBits[1] state 0x40	Resolved ECM state cell
ECM PROGRAM LIGHTS	PROGRAM 3 · S STANDBY	ecmBits[2] state 0x08	S flashes at 2 Hz during ECM warm-up
ECM PROGRAM LIGHTS	PROGRAM 3 · A ACTIVE	ecmBits[2] state 0x10	Resolved ECM state cell
ECM PROGRAM LIGHTS	PROGRAM 3 · T TRANSMIT	ecmBits[2] state 0x20	Resolved ECM state cell
ECM PROGRAM LIGHTS	PROGRAM 3 · F FAIL	ecmBits[2] state 0x40	Resolved ECM state cell
ECM PROGRAM LIGHTS	PROGRAM 4 · S STANDBY	ecmBits[3] state 0x08	S flashes at 2 Hz during ECM warm-up
ECM PROGRAM LIGHTS	PROGRAM 4 · A ACTIVE	ecmBits[3] state 0x10	Resolved ECM state cell
ECM PROGRAM LIGHTS	PROGRAM 4 · T TRANSMIT	ecmBits[3] state 0x20	Resolved ECM state cell
ECM PROGRAM LIGHTS	PROGRAM 4 · F FAIL	ecmBits[3] state 0x40	Resolved ECM state cell
ECM PROGRAM LIGHTS	PROGRAM 5 · S STANDBY	ecmBits[4] state 0x08	S flashes at 2 Hz during ECM warm-up
ECM PROGRAM LIGHTS	PROGRAM 5 · A ACTIVE	ecmBits[4] state 0x10	Resolved ECM state cell
ECM PROGRAM LIGHTS	PROGRAM 5 · T TRANSMIT	ecmBits[4] state 0x20	Resolved ECM state cell
ECM PROGRAM LIGHTS	PROGRAM 5 · F FAIL	ecmBits[4] state 0x40	Resolved ECM state cell

35. Common misunderstandings

Incorrect idea	Correct explanation
The COM port is the identity.	The WHOAMI name is the identity; COM/LAN is only the current path.
Decimals make a sensor more accurate.	They only change text formatting.
Delta is a time value.	Delta is the minimum raw change since the last transmission.
BMS STATUS ACTIVE means the LED is always on.	A flashing output can be OFF during the current phase.
Every bit mask is a separate physical lamp.	Only named catalog cells are outputs; group/test masks are not extra lamps.
GEARHANDLE means nose gear down.	GEARHANDLE is the handle warning; NOSE GEAR DOWN is the green locked indication.
DED and PFL are arbitrary lines.	They are fixed, complete 5 x 25 packets.
A PC safe command guarantees every device is safe.	Disconnected hardware also needs a local firmware watchdog.
LAN requires router port forwarding.	The microcontroller LAN remains local and is never exposed to the internet.

WHEN IN DOUBT, RETURN TO THE SIMULATOR

One simulator route is the fastest way to understand a data name, channel, message, flash phase and safe state without risking physical cockpit hardware.

36. What follows in the separate Arduino manual

The PC side is fully described in this manual. The next document starts at the serial or LAN endpoint and contains concrete microcontroller code.

Planned Arduino-manual content

- Create a project and select the board and serial interface.
- Implement a non-blocking line buffer up to CR.
- Answer WHOAMI reliably.
- Decode LED# with exactly 16 hex characters into 64 bits.
- Parse individual commands such as 271 and 272 unambiguously.
- Validate name#value, negative numbers and decimal points.
- Split DED and PFL into five 25-character lines.
- Implement timeout watchdog, boot safe state and error handling.
- Connect pins, shift registers, drivers, servos and stepper motors safely.
- Provide complete example sketches for LED, display and mixed controllers.

CLEAR DOCUMENT BOUNDARY

This PDF is the operating and protocol manual for BMS Live Monitor. The later PDF is the firmware manual. A beginner can first understand the data path and then build the code step by step.

FALCON BMS MICROCONTROLLER

One signal.
One clear route.
One safe output.

FROM THE SIMULATOR TO REAL HARDWARE

Give every controller a unique WHOAMI name, test one route at a time, read the live decisions and use every pit exit as a safe-state test. Add real hardware step by step only after the protocol test passes.

Private cockpit project / English microcontroller documentation / 2 September 2026