BACAR-14 2026

Two Cubes. One Flight. An Engineering Post-Mortem

AeroLink Cube V2 | Lumina Stratos Cube V2

Technical report, frequency-plan analysis and speaker guidance

Mission: Saturday 17 October 2026 • Presentation: Saturday 24 October 2026

Prepared from the owner's post-flight account, the supplied BACAR-14 payload-train frequency plan, and retrieved development code/log excerpts.

Evidence classification:

OBSERVED = owner-reported operational observation;

LOG-VERIFIED = retained development or post-recovery output;

HYPOTHESIS = plausible failure mechanism requiring testing;

PROPOSED = next-version improvement.

Important correction:

The Lumina Stratos samples, images, videos and Pi→ESP32 I^2C acknowledgement seen in 17 October logs were obtained after the recovered cube was powered on. They are NOT evidence that Lumina Stratos operated during balloon flight.

Executive summary

BACAR-14 was a useful but sobering demonstration of system-level integration. The balloon reportedly reached about 27 km before bursting; this is a mission-level estimate and cannot be attributed to a Lumina Stratos GNSS measurement. Both payloads met important pre-flight integration milestones, but their airborne results diverged sharply.

Payload	Pre-flight	In-flight outcome	After recovery
Lumina Stratos V2	Sensor logger, GPS interface, camera pipeline and local Pi→ESP32 telemetry tested	No flight data, photographs or video recovered; GPS had not locked before launch	After manually powered on, GPS acquired quickly; data logging and media capture operated
AeroLink V2	Both cross-band directions worked; voice quality and radio contacts reported satisfactory	Worked well for roughly first 10 minutes; later mostly unavailable, with occasional intermittent triggering and strong RF coexistence symptoms	Unit reportedly still powered at recovery; broken antenna support limits post flight reproduction

One central finding: successful bench tests did not constitute a fully validated end-to-end mission. For Lumina, power/start-up or storage reliability dominated the outcome; for AeroLink, collocated-transmitter coexistence, receiver blocking and control-loop behaviour became critical.

1. Mission architecture and ground truth

The provided frequency chart places Lumina Stratos in payload train position 5 (432 MHz), and AeroLink in position 14 (VHF 145.250 MHz;, UHF 435.350 MHz; 868.925 MHz control allocation). Other collocated transmitters included SSTV and multiple UHF/VHF repeaters. Frequencies on a shared balloon train describe exceptionally strong local RF exposure, not the more benign separated-transmitter conditions of ordinary terrestrial use.

Reported ascent culminated at approximately 27 km. Unfortunately no independent altitude trace or verification method has been supplied by the cubes, so label this an approximate mission altitude, not a measured result from either cube.

2. Lumina Stratos Cube V2 — design intent and choices

Lumina was intended as a self-contained high-altitude instrument: environmental sensing, motion measurement, GPS/time, still imaging, H.264 recording, nonvolatile logging and telemetry. The Raspberry Pi Zero 2 W was selected to simplify concurrent camera control, Linux data storage, GPSD and Python data processing. An ESP32-S3 was used as a secondary real-time radio/interface processor on I^2C bus 1 at address 0x42.

Component / system	Function	Engineering rationale
Raspberry Pi Zero 2 W	Flight app, local storage, video and photographs	Linux camera tools, Python libraries, filesystem/logging
Combined sensor HAT: BME280, TSL2591, LTR390, SGP40, ICM20948	Weather, visible/IR and UV response, VOC raw, 9-axis motion	Compact bus integration, fewer discrete daughterboard and wires
Additional GY-88 measurements (tested)	Magnetometer and supplementary motion/pressure channels	Potential complementary sensing; exact flight configuration not confirmed
u-blox USB GNSS + gpsd	Position, speed, altitude, time when lock exists	Standardized TPV/SKY access and independent raw logs
OV5647 camera	JPEG stills and H.264 footage	Raspberry Pi camera pipeline; stored locally rather than streaming large media
ESP32-S3 + SX1278 at 432 MHz	Planned telemetry downlink	Separate radio handling from computational logging; radio reception not demonstrated in flight

2.1 Software operation

- Python sensors were configured to log approximately once per second, with timestamps and error fields; GPSD TPV reports and raw JSON data had separate files.
- The main camera sequence captures an initial still, then requested 120-second H.264 clips at 1296×972/20 fps, inserting full 2592×1944 JPEG stills with separately saved text overlays between segments.
- systemd launched the relevant applications for unattended operation; a timer previously existed for short road tests but is not evidence of flight shutdown.
- The demonstrated Pi→ESP32 packet was 15 bytes with protocol version, sequence, uptime, fixed-point BME280 data, status and CRC-8; a five-byte bus acknowledgement verified LOCAL acceptance only.

Instrument qualification caution: the Bosch BME280 specified full-accuracy pressure range is 300–1100 hPa, so it cannot be treated as a qualified 27 km pressure sensor. This is a component limit independent of the flight start-up failure.

3. Lumina — mechanical improvements since the previous mission

Change	Intended improvement / benefit
Removed insulation foam	Eliminated loose foam and simplified the interior; thermal effect requires actual temperature testing
Secured all electronics	Reduced mechanical movement, vibration and connector stress
Reduced inter-module wiring	Fewer potential intermittent connections and less conductor movement
Upgraded the camera	Improved camera implementation; exact optical improvement has not been independently quantified
Replaced discrete sensors with a combined HAT	Reduced wiring and simplified integration on a common I^2C bus
Added 432 MHz LoRa telemetry hardware	Provided a proposed live downlink absent on the previous mission; in-flight successful reception not confirmed

These are real design changes even though the mission failed to generate flight data. Do not describe them as flight-proven improvements until tested under representative environmental and launch conditions.

4. Lumina — actual results, failure boundary and diagnosis

Mission phase	What is established
Before launch	GPS was unable to obtain lock that day; ground tests had previously exercised sensors, camera and I^2C interface
Launch and ascent	No evidence of active logging, imaging or video; no useful data were recovered for the flight itself
Recovery	Storage inspection found no new mission photos, videos or logged flight data
After manually powering on	Cube restarted successfully; GPS locked within seconds; sensor logger, original JPGs, overlay JPGs and H.264 videos functioned
Example post-recovery log	At 16:45:48 one completed H.264 clip was 143,356,449 bytes; around 16:45:53 image and overlay save events appeared; repeated 15-byte I^2C packets were acknowledged

This outcome establishes that at least some subsystems were functional after recovery. It does not establish why the system was inactive or why storage was empty during flight. The suspected intermittent power switch is a reasonable candidate, but I cannot confirm this was the root cause.

4.1 Root-cause hypotheses to discriminate

Hypothesis	Evidence for / against	Required diagnostic
Power switch, connector or battery dropout	Fully empty flight capture and later normal power-up are consistent with no power; not proof	Continuity and vibration testing; measure rail voltage; latch brownout/boot events
Boot, systemd or filesystem startup failure	Could prevent recording even if the battery supplied power	Cold-boot tests; persistent journal; boot-counter/LED; watchdog event
SD/storage failure or wrong path	Could produce absent files despite running app	Verify mounts, permissions, file creation, free space, forced-power-removal tests
GPS antenna/sky view or cold-start issue	No fix before launch, rapid fix after recovery	Log raw satellites, module supply, antenna placement and time-to-first-fix outdoors
Thermal/mechanical effect	Possible in balloon handling/launch vibration, but no direct measurement	Thermal soak and vibration/shake tests while the logger is operating

4.2 High-priority corrective action

- Fit a positive-latching flight switch with mechanical retention; route power through a monitored path and log battery/rail status continuously.
- Provide an independent boot heartbeat and a tiny backup microcontroller/logging path that records start, reset and voltage history even if Linux never reaches the logger.
- Introduce a mandatory arming check: visible heartbeat, one recent CSV row, GPS status (not necessarily a fix), a new photograph and a ground-received radio test packet.
- Perform multi-hour battery runtime, repeated cold-start, low-voltage and simulated intermittent-power tests with the complete final assembled cube.

5. AeroLink Cube V2 — design and rationale

AeroLink provided analogue cross-band voice using DRA818V and DRA818U modules controlled by an RP2040-Zero. For the flight, the three listed repeater missions were arranged to receive on UHF and retransmit on VHF. AeroLink's operational pairing was UHF RX 435.350 MHz → VHF TX 145.250 MHz. The firmware architecture also enabled cross-band operation in the opposite direction during ground testing.

Element	Design role	Why selected
RP2040-Zero	Two UARTs, squelch monitoring and PTT sequencing	Small, fast control board for deterministic analogue relay control
DRA818U 435.350 MHz / DRA818V 145.250 MHz	Dedicated FM receiver/transmitter modules	Integrated squelch, audio interface and programmable channel settings
SX1262 LoRa 868 MHz	Out-of-band commands/health concept	Configuration independent of FM voice frequencies; bench command tests were reported, flight use not independently confirmed
Four parallel 800 mAh LiPo cells	Approximate nominal 3200 mAh parallel pack	Modest mass and shared capacity; actual usable energy/runtime not instrumented
Boost conversion to ~4.1 V	Stable supply rail for radio modules	Meets radio module supply need; RF-current transients require actual test
Whip/monopole SMA antennas	Compact externally mounted radiators	Easy packaging, but counterpoise and isolation are questionable on a very small enclosure
Five-pole RF low-pass filtering	Transmitted spurious/harmonic reduction	Not equivalent to selective reception band-pass filtering

Ground testing established successful two-way cross-band contacts. A significant power problem was also corrected: leaving DRA818 H/L floating selected the higher power mode and was associated with rail droop; grounding H/L selected approximately 0.5 W mode. The DRA818U manufacturer identifies H/L low = 0.5 W and floating = 1 W.

Firmware caution: a retrieved development sketch directly mirrored each receiver SQ input into the other radio PTT. Without directional arbitration this permits competing requests if BOTH inputs indicate squelch activity; the exact final flashed image is not preserved here.

6. AeroLink — actual flight performance

Stage	Observed behaviour
Pre-launch tests	Cross-band function and audio worked well; frequency-change commands were reportedly tested privately
Launch to approximately minute 10	Repeater worked successfully and supported radio contact
After approximately minute 10	Mostly stopped responding; occasional triggering remained possible
UHF reception vs VHF retransmission	VHF TX/relay sometimes did not hold even while the UHF side appeared to receive continuously
RF environment	High levels of frequency bleedthrough and audible SSTV interference were reported throughout the payload train
Post-recovery	Radio cube remained powered; antenna mounting damaged, so clean follow-up RF tests were not possible

Avoid the word “perfect” for whole-flight performance. The flight demonstrated an initial interval of real operation followed by intermittent/unreliable service. Exact QSO count, link margin and failure transition are not recorded.

7. Shared payload train — frequency coexistence

The following data are transcribed directly from the supplied BACAR-14 chart. All offsets are absolute differences between listed frequencies, not measured filter isolation.

Payload / role	TX (MHz)	AeroLink UHF RX separation
#4 UHF SSTV	433.400	1.950 MHz
#16 repeater UHF receiver	433.450 RX	1.900 MHz
#13 additional payload	433.775	1.575 MHz
#7 additional payload	434.000	1.350 MHz
#12 Meshtastic/APRS	434.950	0.400 MHz
#14 AeroLink receiver	435.350 RX	0
#3 repeater receiver	435.950 RX	0.600 MHz

Noteworthy pair: SSTV 433.400 MHz and repeater #16 RX 433.450 MHz are separated by just 50 kHz. On VHF, AeroLink TX 145.250 MHz and repeater #16 TX 145.350 MHz are 100 kHz apart; repeater #3 TX 145.850 MHz is 600 kHz above AeroLink. No transmitter power or measured coupled power is supplied, so desensitization severity cannot be calculated from frequency spacing alone.

No	Train position	Mission Name	Description	TX1	TX2	TX3	TX4	RX	RX2
1	1	ZS6SRC	Shuttle + SPOT	868	1616,25			868	
2	2	ZS6BAM	PiCamera Still & Video payload						
3	3	Hamnet_ER	WouxBand X band	145,85				435,95	
4	4	ZS6STN1	UHF SSTV	433,4	869,525			869,525	
5	5	ZS6HJH	Project Lumina Stratos	432				432	
6	6	ZS4SRK	APRS	144,8					
7	7	ZS6PQ	Warp drive + lora telemetry	868,525	434				
8	8	Hammies	Jeugland SSTV	144,6					
9	9	BACAR	ADSB/ModeS/C Transponder	1090					
10	10	Dylan	HoloCube pyramid						
11	11	ZR6BN	Blackbox	GSM				GSM	
12	12	Hamnet_ER	Meschtastic+APRS	434,95	144,825			434,95	
13	13	BACAR	Lora APRS, Lora Mode 2,	433,775	433				
14	14	ZS6HJH	Project AeroLink x band repeater	145,25	868,925			435,35	868,925
15	15	ZS4SRK	BBS	144,65				144,65	
16	16	ZS4SRK	X BAND	145,35				433,45	
17	17	ZR6WT	WSPR Hdefn Camera	50,293					
18	18	ZS6WBT	Lora, camera	868				868	
			Miscellanious, ropes rings ducktape cable ties						

Figure 1. BACAR-14 payload-train frequency plan.

8. RF root-cause analysis — plausible, not proven

Receiver blocking/desensitisation. Strong nearby UHF transmitters may overload an RF frontend and mask a much weaker signal from ground; a 435.350 MHz input BPF/preselector is likely more relevant than only a TX low-pass filter. Real attenuation depends on bandwidth, insertion loss, measured blocker levels and module selectivity.

Intermodulation / spurious products. Multiple collocated transmitters and nonlinear hardware can generate mixing products or unintended responses. A spectrum capture or controlled two-tone/multi-signal test is needed before assigning an exact mechanism.

Antenna system and coupling. Small whip monopoles may have an inadequate counterpoise and unpredictable feed line radiation; a dipole can provide a self-contained radiator, but requires suitable mechanical deployment, matching, orientation evaluation and choke/balun control.

Cross-band PTT and power behaviour. If input squelch fluctuates or both channels compete for the transmission state, a naive direct-SQ-to-PTT design can chatter, reverse-key or drop audio. Battery and boosted 4.1 V rails may droop under TX current peaks; no in-flight rail log exists.

Shielding. A bonded metal enclosure can reduce unwanted ingress through electronics and cabling, but it will not eliminate interference arriving at the intended receiver antenna port. Use filtered feedthroughs, good PCB return paths, coax shields and RF path testing. Never place the intended radiating elements inside a closed RF shield.

Manufacturer distinction: the DRA818 AT+SETFILTER instruction addresses analogue audio pre/de-emphasis and audio high/low-pass behavior; it must not be represented as a programmable RF input BPF.

9. Next AeroLink version — design action plan

Priority	Design change	Verification / engineering notes
P0	UHF receiver preselector/BPF near antenna input	Measure passband 435.350 MHz, rejection at 434.950/434.000/433.400 and total NF penalty
P0	Positive one-way UHF→VHF arbitration and transmitter time-out	Timestamp SQ/PTT; prevent simultaneous invalid TX; test interruptions and reset
P0	Continuous evidence capture	Independent RTC timebase, battery voltage/current, PA rail, dual SQ/PTT signals and both AF audio paths to SD
P1	Deployable dipoles with RF choke and coax matching	NanoVNA tune in deployed arrangement; measure SWR, impedance, radiation orientation and isolation
P1	Shielded/grounded metal chassis and feedthrough practice	Bond mechanical seams, include controlled RF return, keep antennas outside shield
P1	Custom PCB and shorter interconnects	Separate RF/audio/power domains; minimize loop area and coupling; avoid unplanned common-mode paths
P1	Receiver blocking bench test with other frequencies	Use attenuated/safely combined RF sources and record threshold for degraded SINAD/audio and PTT reliability

Recording BOTH receive audio and forwarded/transmit audio is particularly valuable. In future analysis it lets you determine whether the initial receive audio was already corrupted or whether the repeater control/forwarding stage failed. Record audio alongside logic-level SQ, actual PTT states, rail voltage and absolute timestamps.

10. Test matrix before a repeat mission

Test	Acceptance evidence to preserve
Cold start / arming test	Boot counter, power rail, sensor row, test image, LoRa packet physically received on ground
Sustained full-load runtime	Voltage/current vs time and all expected output files for longer than planned flight
Controlled RF coexistence	RSSI/blocker power, bit-for-bit command responses, dual audio waveforms, squelch/PTT transition log
Mechanical vibration & switch retention	Continuous activity through handling, transport, and shaker/hand tests; no resets
Antenna return loss / RF isolation	NanoVNA S11, cable and filter insertion loss, antenna separation and induced coupling
Recovery proof / event annotation	RTC timestamps mapped to launch, ascent, burst, descent, touchdown and power-on

11. Sources / interpretation limits

- Primary field account: user's detailed post-flight recollections supplied 22 October 2026 and user-provided BACAR-14 frequency chart (payload positions 1–18).
- Existing project evidence: Lumina Python flight application and 17 October 16:45 journal extract; AeroLink RP2040/DRA818 Arduino firmware snapshot. Event-day timestamp in the extract is after recovery.
- Dorji DRA818U manufacturer datasheet and reference page: https://www.dorji.com/docs/data/DRA818U.pdf
- Tektronix, "Receiver De-Sense and Blocking": https://www.tek.com/vn/documents/application-note/hunting-interference-tektronix-rf-scout
- Analog Devices, receiver preselectors and blocking: https://www.analog.com/en/resources/analog-dialogue/articles/2022/05/18/02/02/how-digitally-tunable-filters-enable-wideband-receiver-applications.html
- ARRL antenna counterpoise and dipoles: https://www.arrl.org/grounding
- Bosch Sensortec BME280 product specifications: https://www.bosch-sensortec.com/en/products/environmental-sensors/humidity-sensors/bme280/