MELD / CONTROLS

ARINC-429
ENGINEERING REFERENCE

From physical words to practical navigation, flight-plan and inertial data decoding

IMPLEMENTATION GUIDE • DRAFT REV 0.3 • 07 NOVEMBER 2026

Audience: firmware developers, ControlLogix programmers, avionics interface technicians, and bench-test engineers.

Scope: MELD-2501 Rev B default decoding/virtual processing, reviewed AFCS parser source, Garmin GAMA behavior, and ARINC-429 emulator results. This guide is original engineering documentation, not a replacement for licensed ARINC, Garmin, or aircraft-specific installation data.

SOURCE BASIS

MELD-2501 Rev B Core/Src (04 Nov 2026 ARINC files); STM32 v1.0.63 release notes (05 Nov 2026); AFCS eNet parser Rev D2 review candidate; prior MELD GNSS/waypoint chapter; ARINC 429 Part 1-17 and Garmin GTN Xi installation manual for cross-checking only.

REVIEW STATUS

Internal engineering draft. Some field mappings are format-specific or bench candidates. Do not use these notes alone to authorize an aircraft installation or change a flight-critical decoder.

APPLICATION NOTE / 04.1 • ARINC-429 / GARMIN GAMA 429

GNSS Position & Flight-Plan Waypoints

How coarse and fine position words form precise coordinates, and how the Garmin waypoint record stream is assembled into an active flight-plan leg.

PURPOSE OF THIS CHAPTER

This is an original MELD Controls implementation note based on our Garmin GTN 650 GAMA-429 decoding, PLC parser, MELD recorder, and bench validation work. It is not a reproduction of a manufacturer installation manual and does not replace the applicable equipment ICD or approved installation data.

Two different kinds of position data

An ARINC-429 receiver can see both the aircraft's continuously updating present position and coordinates for waypoints that belong to the flight plan. The labels look similar, but combining them as though they were one record produces incorrect navigation results.

LIVE AIRCRAFT POSITION

310 (oct) + 220 (oct) → Latitude

311 (oct) + 221 (oct) → Longitude

Coarse and fine words are paired by coordinate axis; sign is carried by the coarse word.

FLIGHT-PLAN WAYPOINT RECORDS

075 (oct) → active FROM / TO record indices

303 (oct) → waypoint header / record number

304 / 305 → identifier characters

306 / 307 → waypoint latitude / longitude

Reference label map

Octal label	Data family	Role in our implementation
075	Leg reference	Identifies FROM and TO waypoint record numbers
303	Waypoint header	Begins / identifies a waypoint record and record type
304 / 305	Waypoint text	Contribute waypoint identifier
306 / 307	Waypoint BNR	Latitude and longitude of that record's waypoint
310 / 311	Present-position BNR	Aircraft latitude / longitude coarse words
220 / 221	Fine position	Low-order latitude / longitude position fractions
114 / 115 / 116 / 251	Guidance cross-check	Desired track, waypoint bearing, cross-track error, distance to go

Octal is significant. "310" means octal 310 (decimal 200), not decimal 310. The decoder's label byte must be normalized exactly once before interpreting the number.

1. Assemble a flight-plan waypoint record

In the tested GAMA stream, waypoint information is transmitted in multiple ARINC words. Treat it as a record, not independent coordinates. In particular, a received 306/307 pair does not prove that the pair is the current TO waypoint.

Step	Incoming information	Receiver action
1	075 — leg reference	Store the active FROM and TO record numbers.
2	303 — waypoint header	Start/stage a record; extract its waypoint number and type.
3	304 / 305 — identifier	Accumulate the record's waypoint identifier as available.
4	306 — latitude	Decode and stage latitude for the same record.
5	307 — longitude	Decode and stage longitude for the same record.
6	Record complete	Commit only after matching index and both coordinates are available; then compare 303 number with 075 TO.

Why the 075 and 303 association matters

When the stream cycles among several route waypoints, the latest 306 and 307 may belong to different records unless assembly is controlled. Our working approach uses the number in the 303 header to associate the following latitude/longitude with a staged waypoint. The current 075 TO record identifies which staged record is the active target.

ATOMIC RECORD COMMIT

Build the waypoint in a temporary structure. Do not expose the new coordinates as "active" until the record number, both coordinate words, and selected validity/freshness rules agree. This two-phase commit prevents a new latitude being combined with the previous waypoint's longitude.

Worked waypoint selection

Observed / derived item	Example from our verification
075 TO record	02
303 record number	02
Identifier (304 / 305)	MAPWPT
306 latitude	45.250°
307 longitude	−110.250°
Selection	Record 02 becomes the selected active TO waypoint
Independent cross-check	Bearing computed from independent GNSS position agreed with navigation-bearing data

The coordinate pair and selected record above are based on a prior working waypoint test. The next page's binary numbers are newly constructed teaching vectors, not a claim that we captured those exact raw ARINC words.

2. Reconstruct present position from coarse + fine

The aircraft's present-position latitude and longitude are assembled from two label pairs. The coarse word carries a 20-bit field and hemisphere/half-range information; its associated fine word supplies the least-significant 11-bit fraction. Treat latitude and longitude independently.

Axis	Coarse word	Fine word	Result
Latitude	310 (octal)	220 (octal)	Present latitude in signed degrees
Longitude	311 (octal)	221 (octal)	Present longitude in signed degrees

Exact field extraction used in our revised parser

```
coarse20 = (coarseWord & 0x0FFFFF00u) >> 8;     // ARINC bits 9..28
fine11   = (fineWord   & 0x0FFE0000u) >> 17;   // ARINC bits 18..28

counts31 = ((uint64_t)coarse20 << 11) | (fine11 & 0x7FFu);
degrees  = (double)counts31 * (180.0 / 2147483648.0);
if ((coarseWord & 0x10000000u) != 0) degrees -= 180.0;
```

This is the project's angle/hemisphere convention. When bit 29 is set, subtract 180° from the reconstructed 0…180° half-range value. Do not blindly negate the magnitude or apply this transformation to unrelated ARINC labels.

Bit-level explanation

Input field	Bits in assembled 32-bit word	Interpretation
Coarse 310 / 311	9–28	20-bit integer; upper portion of angle fraction
Fine 220 / 221	18–28	11-bit lower fraction appended to coarse count
Coarse bit 29	29	Second semicircle / signed-half selector in this implementation
Status bits	30–31	Interpret according to numeric BNR SSM and receiver policy
Parity	32	Check odd parity across the whole ARINC word

A REVISION WORTH DOCUMENTING

Early code treated 220/221 as 5-bit fractions from bits 9–13, producing a 25-bit composite. The later parser correction uses 11 bits from bits 18–28 and a 31-bit composite. The published guide must show the revised formula, not the legacy variable names "Fine5" or "counts25".

Implementation caution: the composite fits within an unsigned 31-bit integer; calculate its scaled value with 64-bit or double-precision intermediate arithmetic. Single-precision REAL can discard some of the lowest-order fine bits.

3. Numerical position-decoding example

The following teaching vector reconstructs 45.250° latitude and −110.250° longitude using the 31-bit composition. It is synthetic by design so every integer is traceable and independently repeatable.

Value	Latitude	Longitude
Target degrees	+45.250000°	−110.250000°
Sign / half-range bit29	0	1
Half-range encoded	45.25°	69.75° (= −110.25° + 180°)
Coarse20 count	263,600	406,323
Fine11 count	728	410
Composite31 count	539,853,528	832,149,914
Reconstructed degrees	+45.249999985°	−110.249999966°

Illustrative 32-bit words (not captured telemetry)

Label	Illustrative word	Purpose
310 (lat coarse)	0x6405B013	Coarse latitude + SSM + parity
220 (lat fine)	0x65B00009	Fine latitude fractional count
311 (lon coarse)	0x76333393	Coarse longitude + signed half
221 (lon fine)	0xE3340089	Fine longitude fractional count

These words use the project's assembled-word convention, reversed on-wire label octet, SSM = normal, and odd parity. Hardware drivers sometimes return already normalized label bytes; check one known label before applying another bit reversal.

What the extra 11 bits actually provide

Mathematically, $180°/2^{31}$ is about 0.0000000838° per composite count (roughly 0.03 ft of latitude). That is the encoding step size, NOT the navigator's absolute positioning accuracy. Actual useful precision also depends on update timing, GNSS solution quality, and numeric precision in the receiver.

DO NOT MIX STREAMS

The 310/311 + 220/221 pairs describe the aircraft position. The 303 + 306/307 records describe route waypoints. The value obtained from a 306/307 record is not a replacement for live position, and the fine 220/221 fractions do not belong to 306/307 waypoint coordinates.

4. Verify the selected leg against guidance data

Once both streams are decoded, independent navigation labels provide a powerful consistency check. For each selected TO waypoint, compute a bearing and range from the current GNSS position to the selected waypoint coordinates, then compare them against the navigator's own bearing and distance outputs.

Octal label	Decoded quantity	What it helps detect
114	Desired track (true)	Route-course direction; should not be mistaken for bearing to waypoint
115	Waypoint bearing (true)	Cross-check calculated bearing to selected TO waypoint
116	Cross-track error	Lateral departure relative to the current course/leg
251	Distance to waypoint	Cross-check geodesic distance to selected TO waypoint
121	Horizontal command	Optional autopilot roll-steering / guidance output; not a waypoint coordinate

Robust receiver state machine

```
on 075: selectedFrom = FROM_index; selectedTo = TO_index
on 303: begin temporary record keyed by waypoint_number
on 304/305: append identifier to that temporary record
on 306: stage latitude, mark LAT_PRESENT
on 307: stage longitude, mark LON_PRESENT

if (matching_record && LAT_PRESENT && LON_PRESENT && valid):
   publish a complete waypoint record atomically
   if waypoint_number == selectedTo: set active TO waypoint

if any required field is stale, incomplete, or invalid:
   retain last valid result or mark invalid; never mix records
```

Practical verification sequence

- Record the raw octal label, 32-bit hex word, channel, timestamp, parity, SSM, and decoded value for each received word.
- Confirm GAMA configuration and ARINC speed. Our GTN 650 GAMA 9 stream was observed at high speed (100 kb/s); a low-speed receiver can misinterpret or lose labels.
- Compare selected TO record number from 075 with header record number from 303; check the identifier assembled from 304/305.
- Check 306/307 coordinates and present-position 310/311 + 220/221 against a separate GNSS reference.
- Calculate range/bearing independently and compare with 115/251, accounting for a changing aircraft position and timestamp offsets.
- On leg changes, verify that the published waypoint never temporarily combines old and new records.

5. Failure modes and field lessons

Symptom	Most useful first check
Only one or two labels appear	Confirm actual transmitter bit rate, receiver configuration, and label bit reversal.
Correct labels, wrong identity	Check octal vs decimal interpretation and normalized vs on-wire label octet.
Latitude or longitude jumps in coarse steps	Inspect 220/221 arrival rate, freshness, 11-bit extraction, and precision of intermediate arithmetic.
Waypoint moves unexpectedly on leg transition	Check 075/303 record-number match and atomic record commit.
Correct coordinates, wrong bearing	Verify current present-position timing, degrees vs radians, and true vs magnetic bearings.
Positions look plausible but stale	Track independent freshness for each coordinate and invalidate aged partial pairs.
Coordinates nonsensical but parity passes	Inspect SSM, correct half-range behavior, bitfield masks and source-specific format.

Editorial rules for the public MELD reference

- Use a three-digit octal label and show decimal/hex only when helpful. Explicitly mark which labels are Garmin/GAMA-format-specific.
- Call out differences between GTN 650 and GTN Xi; do not imply the same word layout or configuration is guaranteed for every navigator.
- Distinguish “observed in our bench or integrated tests” from “standard ARINC behavior” and from “constructed teaching examples”.
- Do not reproduce the ARINC 429 standard or Garmin manuals. Cite the relevant publisher document and link to authorized editions instead.
- Use this as a data-acquisition and test-engineering guide, not as installation approval, safety-critical navigation guidance, or certification evidence.

Sources and implementation lineage

MELD Controls internal development: GTN 650/GAMA 429 captures; MELD-2501 waypoint receiver validation and endurance tests; Logix eNet parser and Fine11 field-extraction revision. Third-party references consulted for verification: ARINC Specification 429 Part 1-17 (2004 historical edition) and Garmin GTN Xi Series TSO Installation Manual 190-02327-02 Rev 15 (June 2025). Product- and revision-specific interpretation takes precedence over this working note.

STATUS

This chapter is a working editorial draft for the larger MELD Controls ARINC-429 Practical Engineering Reference. The reference-library website release remains separate until reviewed and explicitly deployed.

PART II — Decoded-label inventory and engineering examples

The preceding GNSS/waypoint chapter documents the most difficult composite decoding. This part expands the reference to the other labels handled by the reviewed AFCS parser and MELD-2501 Rev B source. It is deliberately a source-level inventory, not an assertion that each word was observed in flight or that every source profile is installed.

6. How to read this inventory

Inventory term	Meaning
MELD default decoder	arinc429_decode.c provides an initial numeric parser/scale for this octal label. User-configured saved settings may override it per channel.
AFCS parser	A matching field or case appears in the reviewed ControlLogix parser source. The retrieved copy is a review/bench candidate, not a verified installed-aircraft export.
Observed / paired	The feature is represented in the previous GNSS/waypoint work or source behavior. Exact compatibility still depends on the producer and configuration.
Named/raw only	A name appears in the HMI reference or the raw word is available, but no numeric default is installed. Do not print a numeric scaling or imply validation.
Virtual label	An internal MELD-to-PLC output identity; NOT an on-wire ARINC label. Decimal L400..L420 is a separate namespace.

7. ARINC-429 word anatomy and normalization

Each ordinary ARINC-429 transfer carries 32 bits. This reference uses ARINC bit numbers (1-based), not C bit indexes (0-based). A receiver may return the raw transmitted octet or a normalized label; apply the label reversal once and only once.

ARINC bit(s)	Field	Decoder note
1–8	Label	Three-digit octal identifier; label octet is transmitted with reversed significance relative to its conventional numeric representation.
9–10	SDI	Source/destination identifier where used; some special formats repurpose these positions.
11–29	Data	BNR, BCD, discrete, or multiword payload. Sign bit 29 is part of the data field for many BNR formats.
30–31	SSM	Status/validity depends on word class and equipment. Never reuse the same SSM interpretation indiscriminately.
32	Odd parity	Check parity over all 32 bits before consuming an engineering value.

Label 075 (octal) = decimal 61 = canonical byte 0x3D.

Transmitted label octet interpreted by receiver = bit-reversed 0xBC.

Label 313 (octal) = decimal 203 = canonical byte 0xCB.

Bit-reversed transmitted label octet = 0xD3.

PRACTICAL WARNING

Octal 313 must not be treated as decimal 313, and an already-normalized word must not have its label reversed a second time. Our bench work found this to be a common cause of apparently missing labels.

8. Navigation, course and flight-plan labels

The following source-defined labels form the principal Garmin navigation group. “M” means an initialized MELD-2501 Rev B numeric/special decoder. “A” means a corresponding case appears in the reviewed AFCS parser. A named raw-only label is not a numeric decoder.

Label (oct)	Quantity	Decoder profile	Source coverage
012	Ground speed, BCD	BCD, tenths kt	M; no matching A case in inspected excerpt
075	Active FROM/TO waypoint selector	Special BCD; TO digits	M + virtual record observer; FROM not verified
076	GNSS altitude (MSL)	20-bit signed magnitude × 0.125 ft	M / A
100	Selected course 1	Semicircle/angle; source-specific	A; M HMI name only
114	Desired track, true	12-bit semicircle × 180/4096°	M / A
115	Bearing to waypoint, true	12-bit semicircle × 180/4096°	M / A
116	Cross-track distance	18-bit signed legacy fine variant × 0.001 NM	M / A; layout requires independent validation
121	Horizontal autopilot command	14-bit signed × 180/16384°	M / A
125	UTC time / GMT	BCD HHMM plus 0.1 minute	M; HMI/Garmin variant
164	Radio height	16-bit unsigned × 0.125 ft	M / A
165	Vertical velocity	20-bit signed ÷ 32 fpm	M / A
206	Computed / indicated airspeed	14-bit unsigned × 0.0625 kt	M / A
220	GNSS latitude fine	M generic: 5-bit value; virtual path: 11 bits	M / A; implementation paths differ

Label (oct)	Quantity	Decoder profile	Source coverage
221	GNSS longitude fine	M generic: 5-bit value; virtual path: 11 bits	M / A; implementation paths differ
251	Distance to go	15-bit unsigned × 0.125 NM	M / A
252	Time to go	10-bit unsigned, minutes in default	M; field validation still required
260	GNSS/UTC date	Special mixed-width BCD date	M; format-specific
303	Waypoint record header	Raw record number/type	M raw + assembler / A assembler
304	Waypoint identifier characters 1–3	Raw word / grouped record only	M virtual inspector; no numeric default
305	Waypoint identifier characters 4–6	Raw word / grouped record only	M virtual inspector; no numeric default
306	Waypoint latitude	20-bit signed half-range angle	M / A
307	Waypoint longitude	20-bit signed half-range angle	M / A
310	Present-position latitude, coarse	20-bit + bit29; pair with 220	M / A
311	Present-position longitude, coarse	20-bit + bit29; pair with 221	M / A
312	Ground speed	15-bit unsigned × 0.125 kt	M / A
313	Track angle, true	12-bit semicircle × 180/4096°	M / A; AFCS track-source caution

Label (oct)	Quantity	Decoder profile	Source coverage
315	Wind speed	8-bit unsigned × 1 kt	M / A; validate operating profile
316	Wind angle, true	8-bit semicircle × 180/256°	M / A; compare against measured values

Label (oct)	Quantity	Decoder profile	Source coverage
320	Magnetic heading	15-bit semicircle × 180/32768°	M / A; source-specific naming
366	North / South velocity	15-bit two's complement × 0.125 kt	M / A
367	East / West velocity	15-bit two's complement × 0.125 kt	M / A

9. Worked navigation decoding examples

These calculations illustrate the source formulas. Counts are synthetic and should not be read as captured flight values. Any application must also check odd parity, SSM, freshness, and the actual transmitter format.

Label (oct)	Illustrative counts	Decoded value
114	12-bit count = 2048; bit29 = 1	180 + 2048×180/4096 = 270.000° true desired track
115	12-bit count = 1024; bit29 = 0	1024×180/4096 = 45.000° true bearing
121	14-bit signed count = −100	−100×180/16384 ≈ −1.0986° command
251	15-bit count = 80	80×0.125 = 10.000 NM to go
312	15-bit count = 640	640×0.125 = 80.0 kt
206	14-bit count = 1480	1480×0.0625 = 92.50 kt
165	Signed 20-bit count = +3200	3200/32 = +100 fpm
366	Signed 15-bit count = −16	−16×0.125 = −2.0 kt north/south velocity

SPECIAL LABEL 116 CAUTION

The source-derived 116 XTK implementation joins a 15-bit field with a three-bit extension and interprets 18-bit signed counts at 0.001 NM/count. The existing extraction masks overlap at one boundary bit; this is documented as the legacy/fine variant under review, not an endorsed generic ARINC bit specification. Validate against known raw words and navigator geometry before operational use.

10. Track, vector and wind validation

The AFCS experiments showed that a correctly decoded angle is not necessarily the best navigation input. In particular, the revised control-path decision favored a ground-track vector derived from velocity components over treating label 313 as the sole reliable high-speed track source. The MELD reference should distinguish the decoded 313 field from the separately computed vector quantity.

```
North_kts = decoded(366);  East_kts = decoded(367);

Groundspeed_vector = sqrt(North_kts^2 + East_kts^2);

Track_true_deg = wrap360(atan2(East_kts, North_kts) × 180 / pi);
```

Validate the vector only when both components are fresh, parity-valid, status-valid, and within the expected range. Compare it with 312 ground speed, 313 track, and an independent GNSS/flight log if available. A transient stale or missing component must not silently become zero.

For wind labels 315 and 316, the MELD generic decoder uses an eight-bit speed and an eight-bit half-circle angle profile. The reviewed AFCS source also has wind handlers, but source-specific field conventions and update validity should be compared from actual packets before treating the labels as identical across implementations.

11. Time, date and flight-progress words

Time labels require special handling because the transmitted fields may be mixed-width BCD, not a single conventional signed integer. The MELD-2501 includes dedicated source-aware helpers for these Garmin variants.

Label	Observed decoder choice	Operational note
125	BCD hour/minute plus tenths of a minute; 0.1 minute = 6 seconds	Use the Garmin helper to validate hour/minute range. The display HHMMSS is derived, not a literal raw 32-bit integer.
260	Special mixed-width UTC calendar date	Validate month/day/leap years. The exported REAL encodes YYMMDD to avoid imprecise eight-digit floating representation; RawWord retains exact bits.
251	Distance to go in NM, 0.125 NM per count	For a selected-leg consistency test compare with reconstructed present position and selected TO waypoint.
252	Time to go candidate default	Configured MELD field; live Garmin behavior and units still require recorded-word verification. Do not conflate legacy 374 handling with 252.

12. Inertial and attitude label decoding

The MELD-2501 ships with defaults for a small group of ARINC heading, attitude and angular-rate labels. However, the currently installed helicopter AFCS AHRS is a Crossbow AHRS500 on RS-232; an ARINC AHRS profile in code or on a bench is not proof that it is the installed flight attitude source.

Label (oct)	Quantity	MELD generic decoder	Coverage caveat
320	Magnetic heading	Bits 14–28 × (180/32768); bit29 selects half-circle	Also appears in AFCS parser; verify source and convention.
324	Pitch attitude	Bits 15–28, 14-bit two's complement × 0.01°	Configured; confirm pitch polarity at the instrument.
325	Roll attitude	Bits 15–28, 14-bit two's complement × 0.01°	Configured; confirm roll polarity at the instrument.
336	Pitch rate	Bits 16–28, 13-bit two's complement × 0.015°/s	Configured; check signal source.
337	Roll rate	Bits 16–28, 13-bit two's complement × 0.015°/s	Configured; check signal source.
340	Yaw rate	Bits 16–28, 13-bit two's complement × 0.015°/s	Configured; check signal source.

These mappings are implementation defaults, not universal definitions for every AHRS. On another channel, a label number may identify a different equipment-specific parameter. Maintain channel + label + SDI + producer format as the decode identity.

13. Named labels versus actually decoded values

The MELD HMI contains a broad Garmin GAMA name list and a separate generic AHRS table. Those lists are for recognition and troubleshooting and do not imply every named word has a numeric decoder enabled. Raw recording and user-configured decoding still work independently.

Label group	Name examples	Default numeric status
074, 304, 305	GAMA data record header and waypoint identifier words	Record observer/raw capture; no generic numeric default for 074/304/305.
117, 173, 174	Vertical deviation, localizer deviation, glideslope deviation	HMI name only unless channel decoder is configured.
203, 204, 211, 213, 217	Pressure/barometric altitude, temperatures, static pressure	HMI name only in this source snapshot.
270, 314, 321	AHRS discrete; true heading; drift angle	Named/raw only (314/321 may be present in a producer-specific profile).
326, 327, 330	Generic body-axis rate names; Garmin may mean scale factors/conic course	Meaning can conflict by equipment profile; no generic default.

Label group	Name examples	Default numeric status
331, 332, 333	Body accelerations or Garmin-format acceleration names	Named but no default numeric scaling in checked-in decoder.
343, 351, 352	Extended acceleration and flight-plan destination metrics	HMI names only; verify producer-specific raw format.
364, 365, 370, 371, 377	Vertical acceleration/velocity, GPS height, equipment IDs	Name/raw monitoring; not equivalent to a validated default numerical field.

DO NOT COLLAPSE DIFFERENT DEVICES

For example label 330 is named “Body Yaw Rate” in the generic AHRS table, but “Conic Arc Inbound Course” in the Garmin GAMA table. The same octal number cannot safely be decoded without selecting the transmitter format.

14. MELD-2501 receive, record and PLC publication

The reviewed STM32 source routes ARINC words through independent receiver states, raw capture, configurable per-label decoding, selected UDP forwarding, logging and optional EtherNet/IP publication. Outputs are gated by product mode and channel routing. Not every captured label is automatically written to a PLC.

Layer	Published/recorded form	Engineering requirement
Receiver	RX1..RX4 with label normalization and parity checks	Keep source identity and per-channel speed. High/low speed are not mixed on one wire pair.
Decoded value	Value + RawWord + Valid; configurable per RX/label	Preserve raw word and distinct status; do not convert missing or stale to zero.
UDP	Selected raw record transport	A UDP subscription is not a guarantee of ordered, lossless transport.
MicroSD	Selected-label CSV and diagnostics with sampling limits	Do not confuse recorded subset with full-rate bus capture without checking route/throughput.
CIP	PLC ARINC_A / ARINC_B / ARINC_C / ARINC_D UDT roots	Publishing requires an enabled route, compatible destination tags and a healthy CIP session.
Waypoint transaction	306/307 staged with Seq; 303.Seq committed last	PLC uses the final 303 sequence marker to recognize a coherent complete record.

15. MELD virtual waypoint and position outputs

The current MELD software has a separate virtual processing system. It observes 074/075/303–307, manages per-receiver route generations, combines valid record components and can publish computed values. These are not ordinary ARINC labels: the decimal virtual slot names occupy L400–L420 in the PLC namespace.

Virtual slots	Meaning	Source/availability
L400 / L401	Active TO waypoint latitude / longitude	Selected complete record referenced by 075 TO index.
L402 / L403	TO+1 record latitude / longitude	Candidate following record, not proof of a valid future leg.
L404 / L405	Active / next record numbers	Record metadata associated with the committed group.
L408 / L409	TO+2 record latitude / longitude	Additional candidate from committed generation.
L411	TO+2 record number / grouped commit marker	Group publication includes sequence and consistent commit semantics.
L412 / L413	Calculated present latitude / longitude	Independent 20+11-bit coarse/fine observer; calculate by default but no automatic PLC publication.
L406, L407, L410, L414–L420	General-purpose or reserved slots	Configurable fields; do not invent semantics for unused slots.

The present-position virtual observer assembles four fresh, parity-checked, status-valid words: 310/220 and 311/221. Its combination uses the 20-bit coarse count plus bits 18–28 of the fine word (11 bits), then converts the composite

signed 32-bit representation by $180/2^{31}$. The generic 220/221 decoder still exposes 5-bit raw fields by default; the virtual observer is the precision-aware path.

```
join = ((coarse >> 8) & 0xFFFFF) << 11 | ((fine >> 17) & 0x7FF);
if (coarse & 0x10000000) join |= 0x80000000;
degrees = int32_t(join) * (180.0 / 2147483648.0);
```

NON-ATOMIC GNSS EPOCH

Receiving all four words within a time window is not proof that they were generated from exactly the same GNSS measurement epoch. The source explicitly calls this a candidate observer with age/span checks; verify against independent logged position before operational reliance.

16. Bench ARINC-429 emulation and timing notes

A useful reader needs physical, electrical and software checks. The following Rigol and STM32 work is included because label-decoding mistakes often masquerade as missing or electrically invalid words.

Test / item	Engineering note
Low speed	80 µs/bit corresponds to 12,500 bit/s. A 32-bit contiguous ARB word by itself repeats at 390.625 Hz.
Mandatory gap	A real ARINC stream includes at least four bit-times of interword null; 36 cells at 12,500 bit/s yield 347.222 words/s for a continuously repeated word.
28-word bench file	An observed working 28-word waveform was run at 12.400793 Hz as a waveform-frame setting; this is not the ARINC bit rate.
Label bit reversal	075 oct -> raw canonical 0x3D -> on-wire label octet 0xBC. 313 oct -> 0xCB -> 0xD3.
Differential waveform	Bipolar return-to-zero: nominal high +10 V, null 0 V, low −10 V line-to-line. Probe differential voltage and verify polarity.
Parity and status	Check odd parity and SSM before accepting a numeric update. An invalid word should not erase the last good value.
100 kbps	10 µs per bit for nominal high-speed ARINC; verify the entire generator/receiver chain before asserting 100-kbps operation.

In practice, compare the oscilloscope waveform, the receiver's raw 32-bit word, the normalized octal label, the selected decode profile, and the final engineering value. A receiver can detect a word electrically yet display the wrong number because of a double-reversed label, incorrect field mask, channel profile, or source-specific sign/status interpretation.

17. Engineering verification checklist

Check	Acceptance evidence
Word identity	Record receiver number, canonical octal label, on-wire label octet and raw 32-bit word.
Data validity	Odd parity, SSM, applicable SDI, range and field-encoding checks all pass.
Freshness	Per-label age and source-generation time are reasonable; stale values remain flagged rather than zeroed.
Position	310/220 and 311/221 composite match an independent GNSS display/log within realistic solution accuracy.
Flight plan	075 TO index matches a complete 303/306/307 generation and identifier raw words 304/305 are associated.
Navigation geometry	Derived bearing and distance to selected waypoint reasonably agree with 115 and 251.
Velocity	312 speed and 366/367 vector magnitude agree; compare vector track with 313 and independent receiver.

Check	Acceptance evidence
Rates and attitude	Check sign conventions with a physical source and known motion, not only a static fabricated word.
Publication	CIP .Valid, .Seq and generated groups are observed to arrive at the intended PLC UDT; no presumed aircraft certification.

18. Provenance, open items and revision control

This draft is derived from the checked-in MELD2501_RevB source, including Core/Src/arinc429_decode.c (31 Oct 2026), arinc429.c (04 Nov 2026), arinc429_cip.c (04 Nov 2026), hmi_server.c (05 Nov 2026), plus STM32 v1.0.63 bench release notes. It is cross-checked against the AFCS eNet parser Rev D2 review candidate and the existing MELD GNSS/Waypoint Chapter 04.1. There has been no assertion here that the reviewed AFCS source exactly matches the current flying L5X.

Items requiring further test or normalization

• Confirm the actual installed AFCS L5X and compare its enabled labels with the reviewed parser (including any program-specific channel mapping).

• Record raw 116 XTK words and verify the legacy/fine field boundary rather than copying the current overlapping extraction masks as a standard.

• Validate any transmitted 252 time-to-go units and field width with an actual Garmin 650 recording; do not reintroduce unsupported 374.

• Confirm the exact 075 FROM index field, 304/305 waypoint text encoding, and both classic GTN 650 and GTN Xi variants before publishing a device-specific universal table.

• Verify raw-to-engineering values for Garmin 315/316 wind, 320 heading, and source-specific AHRS rates against independent instrumentation.

• Bench-verify the MELD virtual 310/220/311/221 11-bit composition and the staged CIP waypoint sequence with a PLC session before any safety-related use.

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Revision log

Revision	Date	Change
0.1	07 Nov 2026	GNSS coarse/fine present position and Garmin flight-plan waypoint chapter.
0.2	07 Nov 2026	Source-checked MELD-2501/AFCS label inventory, decoder examples, raw-only distinctions, virtual CIP behavior, and bench notes.
0.3	07 Nov 2026	Receiver acceptance flow, independently checked raw-word GNSS vectors, leg-transition state table, and publication status classification.

PART III — Implementation and publication checks

This supplement turns the source inventory and proven teaching vectors into practical receiver checks. It also specifies which details are suitable for a public engineering reference and which require device-specific validation.

19. Receiver acceptance sequence

A useful ARINC label table must identify more than a label number. Before a receiver accepts a decoded engineering value, its producer/channel profile, word normalization, validity and freshness should be known. For multiword navigation data, association rules are equally important.

Gate	Verification	Accept / reject policy
Receiver	Correct channel, polarity and 12.5/100-kbit/s mode	Treat word acquisition as independent of engineering decode.
Label	Show three-digit octal label; check whether the driver has reversed the wire octet	Never reverse the label twice. Preserve raw 32-bit word.
Integrity	Odd parity across all 32 bits; inspect SDI and SSM in the selected equipment profile	Invalid words are logged for diagnosis, not promoted to a good numeric value.
Meaning	Look up format, bit field, sign, units and scaling for the actual transmitter	No universal decode solely from octal label number.
Age	Track each field and composite component independently	Do not silently interpret stale or missing data as zero.
Record	For 303/306/307 records, match the 303 record number with the selected 075 TO index	Commit complete, coherent waypoint records rather than unrelated latest values.

20. Traceable 20 + 11-bit GNSS position test vectors

The synthetic word quartet from Chapter 04.1 was independently rechecked for normalized label number, odd parity, ARINC SSM=3 and numerical reconstruction. These values are constructed regression vectors, not a claim that the same words were captured from a Garmin unit.

Label (oct)	Raw word (hex)	Wire byte	Expected extraction
310 — coarse latitude	0x6405B013	0x13	coarse20=263600; half-range bit29=0
220 — fine latitude	0x65B00009	0x09	fine11=728 from bits 18–28
311 — coarse longitude	0x76333393	0x93	coarse20=406323; half-range bit29=1
221 — fine longitude	0xE3340089	0x89	fine11=410 from bits 18–28

The latitude composite is 263600 × 2048 + 728 = 539,853,528, giving +45.249999985°. The longitude composite is 406323 × 2048 + 410 = 832,149,914; applying the project half-range rule gives −110.249999966°. All four constructed words have odd parity and the intended 0b11 SSM field.

Critical software difference: the MELD-2501 generic 220/221 numerical decoder still has a five-bit default interpretation, while the separate virtual position assembler uses eleven fine bits. Publish the virtual combined position only when the receiver-specific age, range and status rules pass; four fresh words do not alone prove they came from the same GNSS measurement epoch.

21. Flight-plan waypoint association during a leg change

A flight plan is a sequence of waypoint records, not a single changing 306/307 coordinate pair. The update sequence below is an illustrative scenario based on the working 075 + 303 record-number association, not an archived word-by-word bus capture.

Event	Reader staging action	Published TO waypoint
075 selects record 01	Store TO=01 and continue accepting complete records	Keep last validated record 01.
075 changes TO=02	Set pending TO=02. Do not adopt an unrelated last 306/307 pair.	Retain previous TO with validity/transition indication per application policy.
303 record 02 arrives	Open or identify temporary record 02; apply route generation and expiration rules.	Do not publish yet.
304 + 305 identifier	Attach text fragments to record 02 if present and valid.	Do not publish yet.
306 latitude then 307 longitude	Stage both coordinates under record 02; verify producer, SSM, parity, freshness and field range.	Do not publish partial coordinates.
Complete record 02 verified	Atomically commit the staged group; the PLC transport writes 303.Seq last when enabled.	Publish record 02 as selected TO.

Why this matters: if the source is cycling through route records, the most recent 306 word and the most recent 307 word need not belong to the same waypoint. A displayed position that looks numerically valid can still be logically wrong. The record number, route generation and complete-field gating prevent this class of error.

22. Public website label-reference editorial key

Website status	What the label table may claim	What it must not imply
MELD default decoder	An initialized numerical/special decoder exists in the reviewed source snapshot.	That every output has been tested on every Garmin/GAMA or AHRS profile.
Record assembler	The receiver stages fields into a grouped record, or provides a virtual engineering output.	That an identifier word is an ordinary scalar engineering value.
AFCS parser case	A corresponding case exists in the reviewed AFCS candidate parser.	That the current flying L5X necessarily executes the same logic.
HMI name/raw only	The label may be recognized, monitored or recorded in raw form.	That a calibrated default numeric decoder exists.
Needs field validation	A field mapping or engineering assumption is explicitly flagged for captured-word validation.	That it is an authoritative device ICD or suitable for flight-critical use.

Priority validation before public release: 116 XTK legacy/fine bit overlap; 252 time-to-go scaling; the exact 075 FROM field; 304/305 identifier character packing; Garmin 315/316 wind and 320 heading profiles; and AHRS source-specific rate/attitude polarity. Also compare the current flying AFCS L5X against the reviewed Rev D2 parser candidate.

Publication boundary: link to the publisher for ARINC and Garmin source manuals. Publish only original MELD implementation explanations, synthetic vectors, public-domain facts and product documentation whose rights are held by MELD Controls. The public label catalog should be searchable by octal, decimal, group and status while remaining readable without JavaScript.