

What is a SID/STAR, what is a Transition?

Introduction

In the context of PBN which uses area navigation, there is no official definition of the term “Transition” in ICAO. However it is a frequently used term in the PBN community, for example amongst FMS manufacturers, procedure designers, pilots and controllers. It also appears on a lot of RNAV and RNP charts.

RNAV and RNP Standard Instrument Departures (SIDs) are instrument flight procedures that connect a runway to the en-route airspace. RNAV and RNP Standard Instrument Arrivals (STARs) are instrument flight procedures that connect the en-route airspace to an Approach to a particular runway. These procedures are coded and stored in an aircraft navigation database and can be loaded in the flight plan of the aircraft's navigation system or Flight Management System (FMS). An FMS flight plan can only contain one SID for departures or one STAR and one Approach for arrivals.

Note: RNAV/RNP ATS Routes, SIDS/STARs as well as RNP approach procedures are punctuated by waypoints. These must have a unique identifier. Typically, five letter name codes (5LNC) are used for waypoints on en-route ATS Routes or to denote a strategic or significant waypoint on an IFP chart. Alpha-numeric waypoints, however, are generally used on instrument flight procedures such as SIDs, STARs and IAPs. In order to facilitate the mapping and read-across between ICAO and ARINC 424 coding possibilities which are central to this paper, 5LNC are used throughout this paper in all the examples/diagrams.

Problem statement

For airspace design purposes, planners often need to design additional route segments between the RNAV or RNP STAR and the approach or between the RNAV or RNP SID or STAR and the RNAV en-route network. A question which is often asked (mainly by airspace or procedure designers) is: “Can I link a SID to another SID or a STAR to another STAR in the same procedure?” The answer, from an ICAO perspective, is no, and as such ICAO provisions appear to have no designation method for ‘second’ STARs or SIDs in the same procedure. As will be seen below, a technology solution does exist provided by ARINC 424 coding. This ARINC coding terminology has been brought into the public domain and results in chart designations/titles which are not defined in ICAO.

ARINC 424 STAR & SID Coding

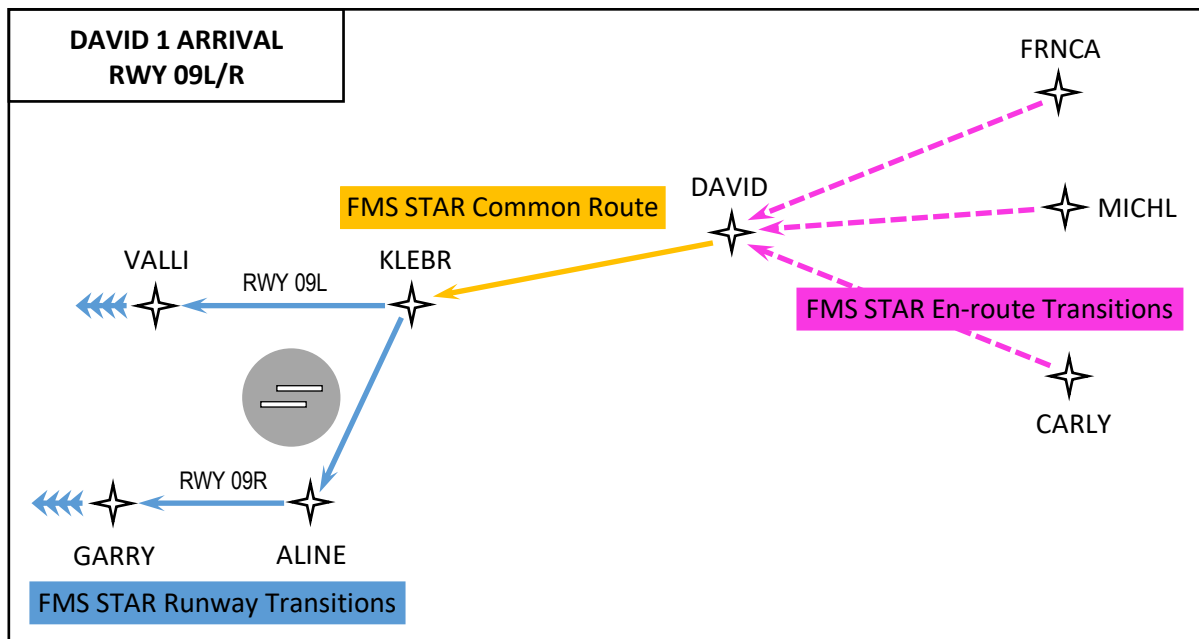
FMS manufacturers have developed clear definitions that allow SIDs, STARs and Approach Procedures to be broken down in several components using ARINC 424 data base coding. For example, as indicated in Figure 1 below, the ARINC 424 standard allows an STAR procedure to be split in three components for encoding in the FMS database:

- a STAR En-route Transition,
- a STAR Common Route and
- a STAR Runway Transition.

This ‘split’ capability in the FMS STAR has two key benefits: flexibility in the design of the procedures and coding efficiency. One STAR Common Route element can have multiple STAR En-Route Transitions and multiple Runway Transitions (one for each runway end). The STAR Common Route element of these procedures only has to be coded once in the database.

Figure 1: STAR – ARINC 424 coding options

STANDARD INSTRUMENT ARRIVAL (STAR)



ARINC 424 STAR & SID coding benefits

The single coded STAR “DAVID 1 ARRIVAL” using the ICAO designation, is an example of the ARINC 424’s ‘three-in-one’ capability i.e. it is one STAR with a single STAR Common Route as well as multiple STAR En-Route and STAR Runway Transition choices. A pilot programming the STAR in the flight plan of the navigation system, will have the option to select a STAR En-Route Transition. Usually the STAR En-Route transitions are identified by the first waypoint of the transition, in Figure 1 above, FRNCA, MICHL or CARLY. The correct STAR Runway Transition, which is coded for a specific runway, will be automatically selected by the navigation system after the pilot has inserted the runway identifier. Note that if there would have been only one runway in the example of Figure 1, there would have been no need to split the STAR into two STAR RWY Transitions. Instead the STAR would just continue as a STAR Common Route to the start of the approach to the single runway.

Contrasting ARINC 424 with ICAO provisions

Notably, however, this ARINC 424 navigation database flexibility offers more possibilities than the ICAO designation provisions, which is why it can be challenging to align the two ways of designating procedures. First, ICAO Annex 11 Appendix 3 requires a STAR to be named after the first significant waypoint of that procedure. So from an Annex 11 point of view the ‘three-in-one’ “DAVID 1 ARRIVAL” is not possible. Secondly, a different path in space requires a different STAR name, where the DAVID 1 enabled by ARINC 424 has multiple trajectories passing through a common segment sharing one name. Three solutions to the first mentioned problem could be:

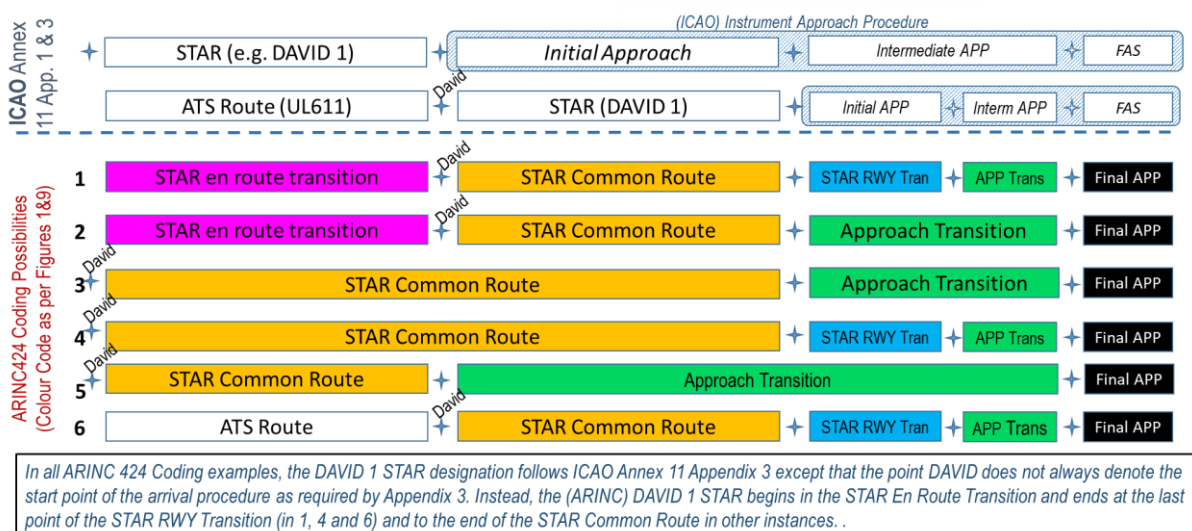
- (i) to have three separate STARs named FRNCA 1A, MICHL 1A and CARLY 1A, which would be inefficient and use excessive data storage. Alternatively,
- (ii) the ARINC 424 En-route Transition from CARLY (or FRNCA/MICHL) to DAVID are not considered part of the STAR, but rather an ATS route ending at ‘DAVID’ designated as per Appendix 1 of Annex 11. Alternatively,
- (iii) ICAO Annex 11 gets updated by accepting and describing the coding solutions which ARINC 424 offers and by introducing a compatible naming scheme.

The three-in-one efficiency of ARINC 424 which includes the STAR En-route Transitions in the STAR, makes it possible for the segment between CARLY and DAVID to be coded without ATS route identifier and to be identified by its first significant waypoint (CARLY). Note that ARINC 424 also allows to give the STAR En-Route Transitions in the FMS database a name defined by a government authority. That offers pragmatically the option to link one STAR segment to another.

In this particular example, using the STAR Common Route, Runway and En-route Transitions, the ATC clearance based on ICAO Appendix 3, could be “DAVID 1 ARRIVAL RWY 09L” The aircraft would enter the airspace for example via waypoint CARLY, which is already specified in the ATC flight plan. Therefore it would not be strictly necessary to explicitly include “CARLY” in the ATC clearance, as it is obvious for both pilot and controller that the aircraft will enter the airspace via CARLY. However, if necessary to explicitly identify the entry point of the STAR En-Route Transition, the ATC clearance could also be “CARLY, DAVID 1 ARRIVAL RWY 09L”.

Figure 2 below clearly contrasts the more constrained ICAO STAR/IAP construction to the ARINC 424 coding construct.

Figure 2: (Limited) Mapping between ICAO STAR designations and ARINC 424 coding possibilities



ICAO Annex 11 Appendix 3, offers a single STAR possibility and provides a naming convention for that single STAR. In contrast, the ARINC 424 coding offers multiple STAR and approach possibilities as well as defined technological names, which solve the problem of the ‘second STAR’ identified at the start of this paper.

Given the ARINC 424 coding flexibility, its extensive use by datahouses and its visibility to the pilot on the flight deck, this may explain why ARINC 424 coding STAR and Approach terminology has been brought into the public domain. It has also found its way onto chart titles in the forms of: RNAV Transition, Arrival Transitions, FMS Transitions, GPS Transitions to designate the second predicated track following a STAR.

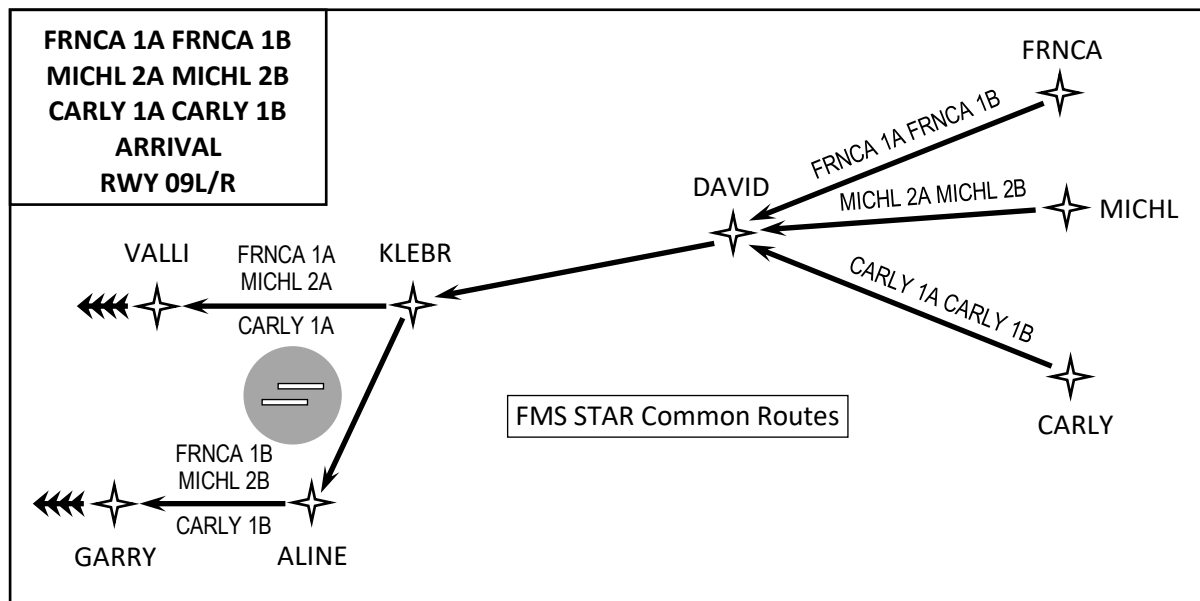
For SIDs, the database coding standard ARINC 424 offers the same principle: one SID can consist of a single SID Common Route linked to multiple runways through SID Runway Transitions. The SID Common Route can also link to multiple en-route airspace entry points through SID En-route Transitions.

Regional Application of ARINC424/ICAO STARs and Transitions

Many airports in North America are using the concept of En-route and Runway Transitions as defined in ARINC 424. In Europe, it is currently not used very often. The picture below shows the same route structure using a classical ICAO-STAR designation which is most often used in Europe today.

Figure 3: STARs ICAO Designation (open procedures)

STANDARD INSTRUMENT ARRIVAL (STAR)



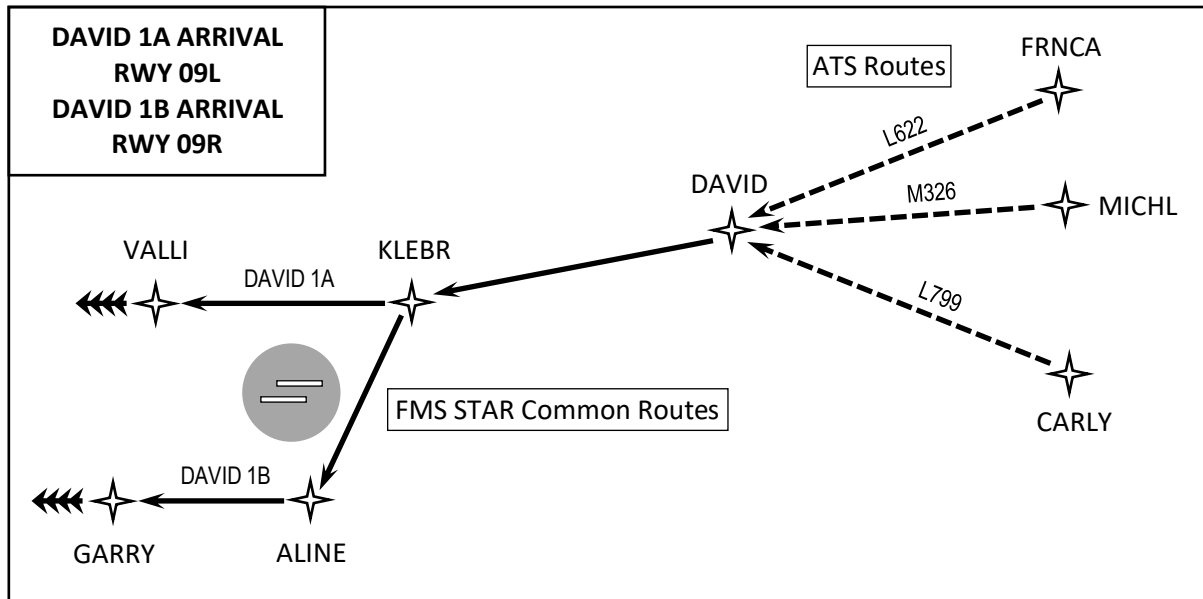
In Figure 3 above, every possible route has its own designation which leads to six STAR identifiers on the chart instead of one. According to ARINC 424, they are coded as six independent STAR Common Routes. From a cockpit perspective, this is less efficient because there are more procedure names to choose from in the FMS menu listing the available STARs. In addition, the chart used on the flight deck could appear more cluttered as several STARs are placed on one chart, or alternatively there are more charts to choose from if every procedure is printed on a separate chart. In the aircraft database, the six STARs would all be coded as STAR Common Routes. Therefore, there will be six STAR Common Routes without any STAR En-route Transition or STAR Runway Transition. This will require significantly more memory. In this particular example, 27 route segments between subsequent waypoints would be coded instead of nine route segments if ARINC 424 En-Route and Runway Transitions were applied.

However, with the ICAO approach used in Europe, the ATC clearance would be slightly shorter as the runway identifier does not yet need to be mentioned. E.g.: "CARLY 1A ARRIVAL". The ATC clearance could, however, continue with an expectation of the approach and landing runway e.g. 'CARLY 1A ARRIVAL, EXPECT RNP APCH RWY 09L'. The pilot should verify though that the CARLY 1A arrival is the procedure that will lead to the downwind leg for the expected runway, in this case RWY 09L.

An alternative in which the routes from FRNCA, MICHL and CARLY to DAVID are designed and coded as ATS routes is illustrated in Figure 4. In this case there are 2 (ARINC 424) STAR Common Routes, DAVID 1A and DAVID 1B, without any STAR En-route or STAR Runway Transitions. Note that the ATS routes in Figure 4 are drawn only for illustrative purposes as usually, ATS routes are not indicated on STAR charts.

Figure 4: ICAO STAR designation (Annex 11, Appendix 3)

STANDARD INSTRUMENT ARRIVAL (STAR)



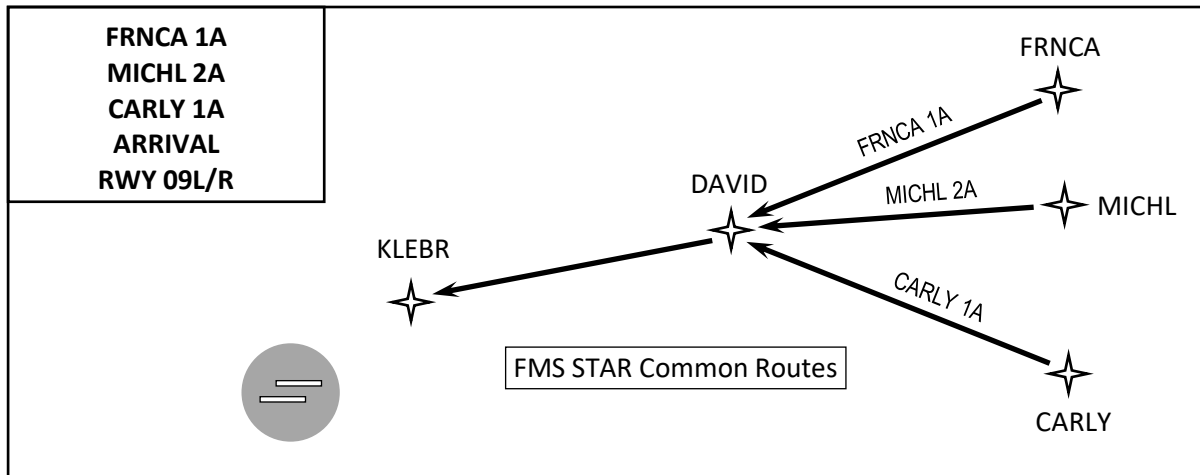
Open and Closed procedures

A final point to be made about STARs with or without using the concept of STAR Runway Transitions, is that they may be characterised as open or closed procedures. Open procedure examples are shown in Figure 1, Figure 3 and Figure 4. Open procedures mean that the aircraft's track is not predicated to the final approach segment as is the case with closed procedures. The STAR completion can be achieved by ATC vectoring. A closed procedure means that it connects directly to an Instrument Approach Procedure such as an RNP APCH or an ILS. The connection between STARs and IAPs is discussed later in this paper.

In Europe, both the concepts of open ended (and closed procedures) are applied. In Figure 5 and Figure 6 a closed route structure is illustrated. The initial route structure is the same as in Figure 3: three entry points FRNCA, MICHL and CARLY which merge via DAVID to KLEBR. Either Three independent designated STARs could be designed or alternatively 1 designated STAR with 3 STAR En-Route Transitions. This design choice has no further impact on the discussion that follows. In the example below, 3 independent designated STARs (without any STAR En-route Transitions) are chosen, as STAR En-Route Transitions are currently not often used in Europe today.

Figure 5: Independent designated STARs (ICAO compliant)

STANDARD INSTRUMENT ARRIVAL (STAR)



Connecting the STARs and IAPs using ARINC 424 coding

Similar to the ARINC 424 STAR construction (i.e. STAR En-route Transitions; a STAR Common Route and STAR Runway Transitions) the FMS Approach construction provides for two elements:

- Approach Transition / Initial Approach;
- Final Approach

As illustrated in Figure 6 and Figure 7 below, the arrival routes are continued from KLEBR via FMS Approach Transitions to either the Final Approach ILS RWY 09L or the Final Approach ILS RWY 09R. In ICAO PANS-OPS, those Approach Transitions are called Initial Approaches. They start at the Initial Approach Fix (IAF, in this case KLEBR) and end at the Intermediate Fix (IF) or directly at the Final Approach Fix (FAF). An Approach Transition is part of an Instrument Approach Procedure. ARINC 424 allows the coding of multiple Approach Transitions connected to one Final Approach which starts from either the IF or the FAF and includes the missed approach. In the example below there are two Approach Transitions for the ILS RWY 09L (one from KLEBR and one from NATLI, Figure 6) and two Approach Transitions for the ILS RWY 09R (one from KLEBR and one from RICKK, Figure 7),. The Approach Transitions are usually identified by the name of the first waypoint (the IAF, in this case KLEBR, NATLI or RICKK). They can also be identified in an FMS database by a name provided by a government source, if desired.

Figure 6: Instrument Approach Procedure RWY 09L

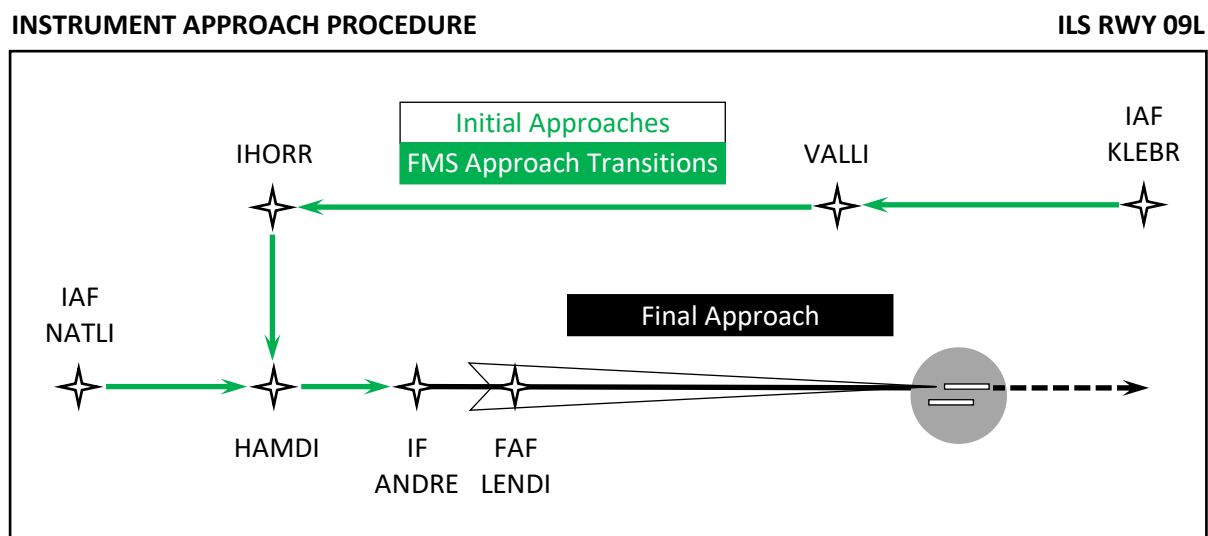
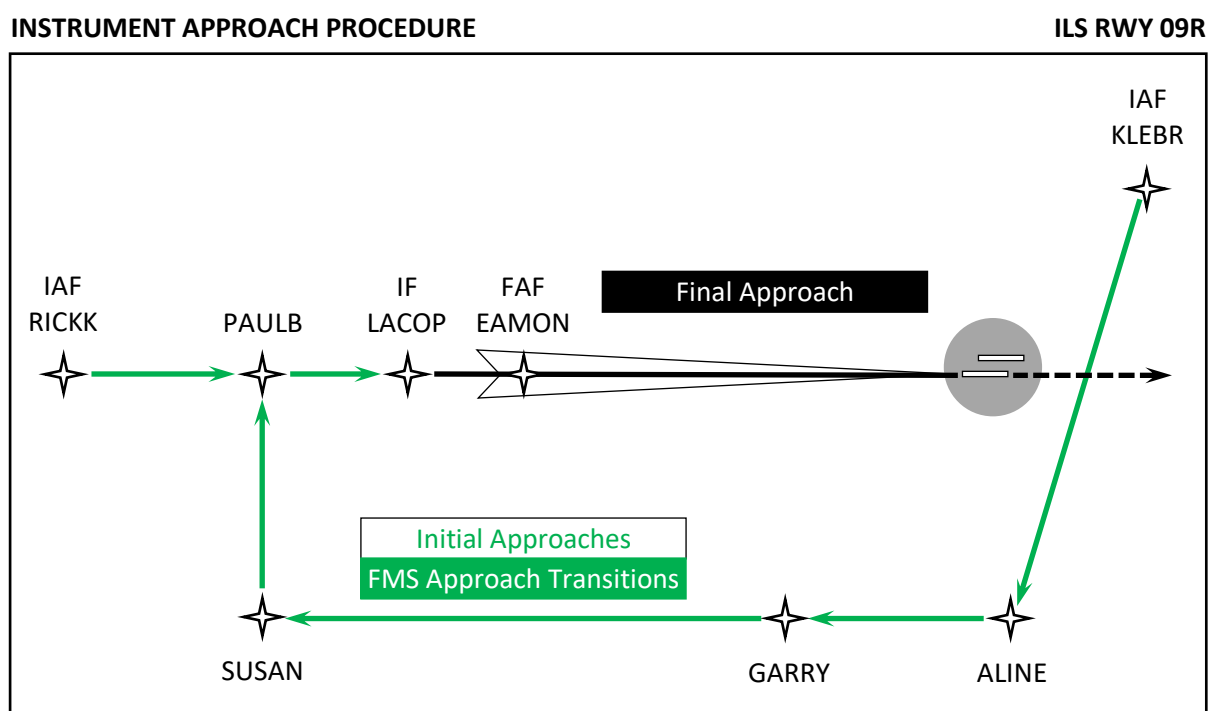


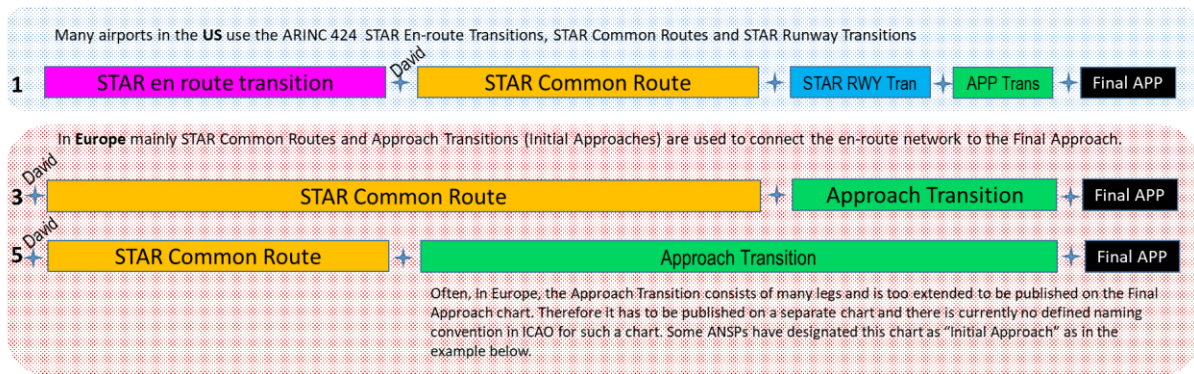
Figure 7: Instrument Approach Procedure RWY 09R



An ATC clearance “CARLY 1A” and thereafter “ILS RWY 09R VIA KLEBR” would be given to connect the STAR in Figure 5 and the Approach to RWY09 R in Figure 7.

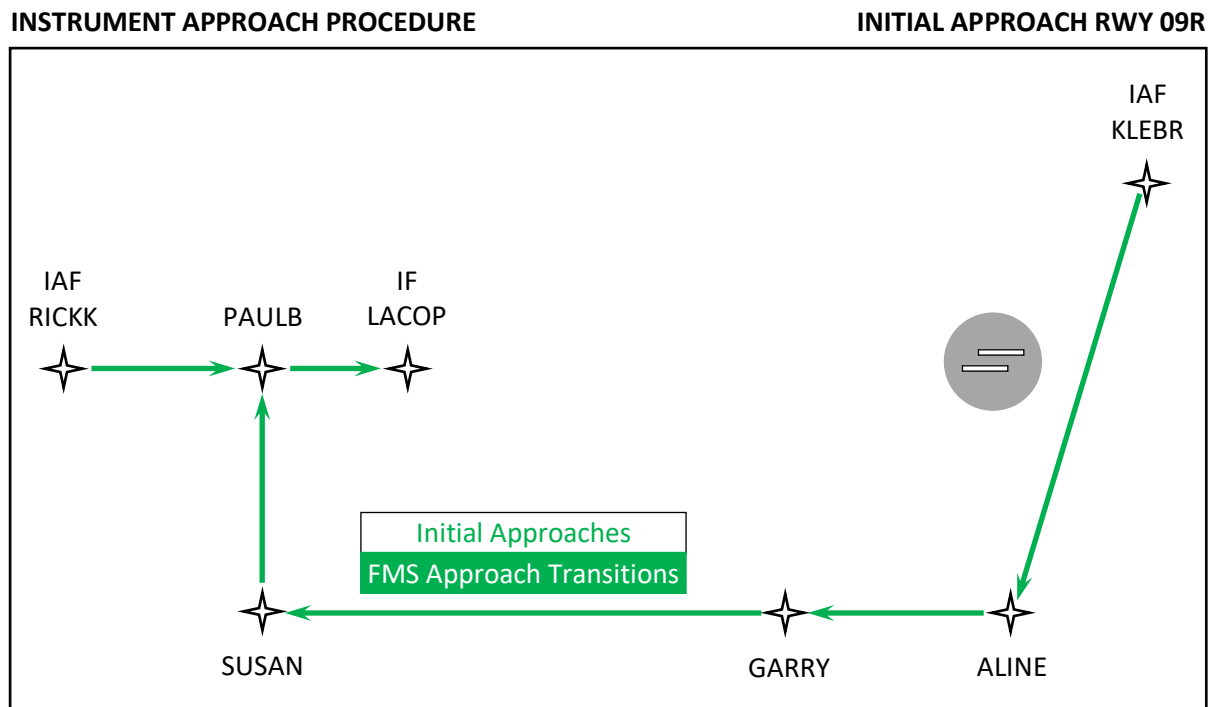
The ARINC 424 ‘toolbox’ for STARs and the Approach is applied differently in the US and Europe.

Figure 8: Comparing US and European ARINC 424 arrival constructs



Often, In Europe, the Approach Transition consists of many legs and is too extended to be published on the Final Approach chart. Therefore it has to be published on a separate chart and there is currently no defined naming convention in ICAO for such a chart. Some ANSPs have designated this chart as "Initial Approach" as in the example in Figure 9 below.

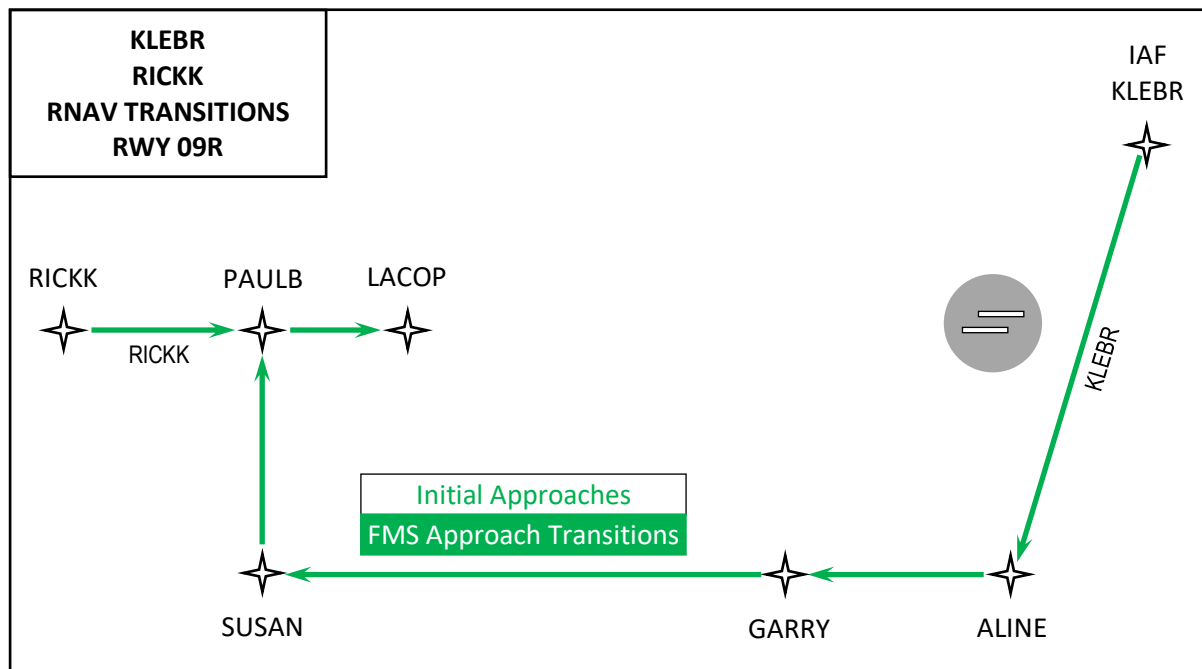
Figure 9: ARINC 424 coding of initial approach RWY 09R



Due to lack of an ICAO defined naming convention, other ANSPs have used the term "RNAV Transition" to designate charts containing initial approach procedures, as in the example in Figure 10 below.

Figure 10: RNAV Transition RWY 09R Chart

RNAV TRANSITION?



The term “RNAV Transition” is not always used consistently. Some examples have been found of airports where there are procedures between the en-route network and the Final Approach which are designated as “RNAV Transition” while they are coded in the aircraft database as STARs.

ARINC 424 Coding Summary

In summary, from an ARINC 424 point of view, an arrival procedure can consist of the following sequence in the FMS database (including between brackets the way how they are usually are designated):

- a **STAR En-route Transition** (first waypoint of the STAR En-Route transition, e.g. CARLY)
- a **STAR Common Route** (first waypoint of the STAR Common Route + validity indicator and route indicator if necessary, e.g. DAVID 1)
- a **STAR Runway Transition** (runway number, e.g. RWY09R)
- an **Approach Transition / Initial Approach** (Initial Approach Fix, e.g. KLEBR)
- a **Final Approach** including Missed Approach (Final Approach type + runway number, e.g. ILS RWY 09R)

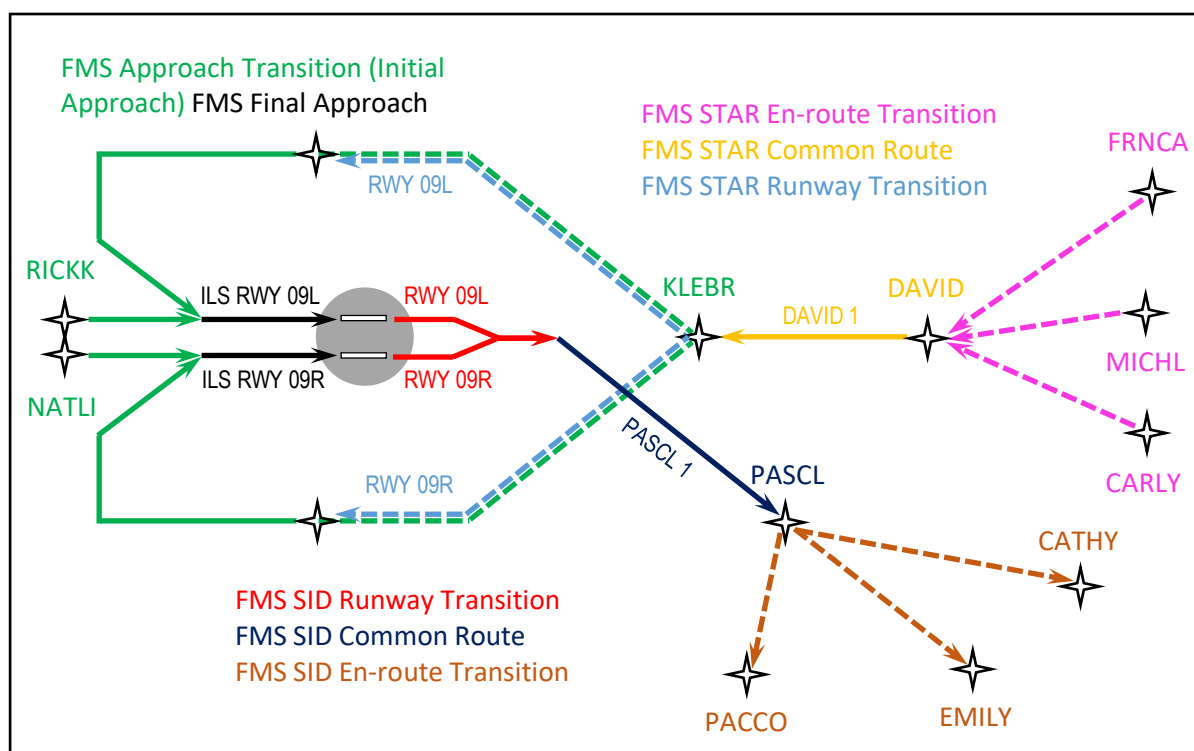
Similarly, a departure procedure can consist of (with usual designators between brackets):

- a **SID Runway Transition** (runway number, e.g. RWY 09L)
- a **SID Common Route** (last point of the SID Common Route + validity indicator and route indicator if necessary, e.g. PASCL 1)
- a **SID En-route Transition** (last waypoint of the SID En-route Transition, e.g. PACCO)

This is illustrated in the diagram below.

Figure 11: Range of ARINC 424 coding possibilities

ARINC 424 CODING POSSIBILITIES



From an ARINC 424 point of view, the difference between a STAR Runway Transition and an Approach Transition is that a STAR Runway Transition is part of a STAR (as is the STAR En-Route Transition) while an Approach Transition is part of an approach procedure. There can only be one STAR Runway Transition per runway and STAR Common Route combination. There can be multiple Approach Transitions for one Final Approach.

An Approach Transition can connect to the end of a STAR Runway Transition if there is one, or directly to the end of a STAR Common Route if there is no STAR Runway Transition. Note that some FMSs require that the Approach Transition and the last section of the STAR connect at a common waypoint. This means that a STAR with an open ending cannot be linked to an Approach Transition starting from a downstream waypoint that is not also part of the STAR.

A STAR coded using ARINC 424 will always have at least a STAR Common Route, but it is not mandatory to have both STAR En-Route Transitions and STAR Runway Transitions in the same procedure – see Figure 2 and

Figure 8, above. Procedures can have STAR En-Route Transitions and no STAR Runway Transitions and vice versa, or just consist of only a STAR Common Route.

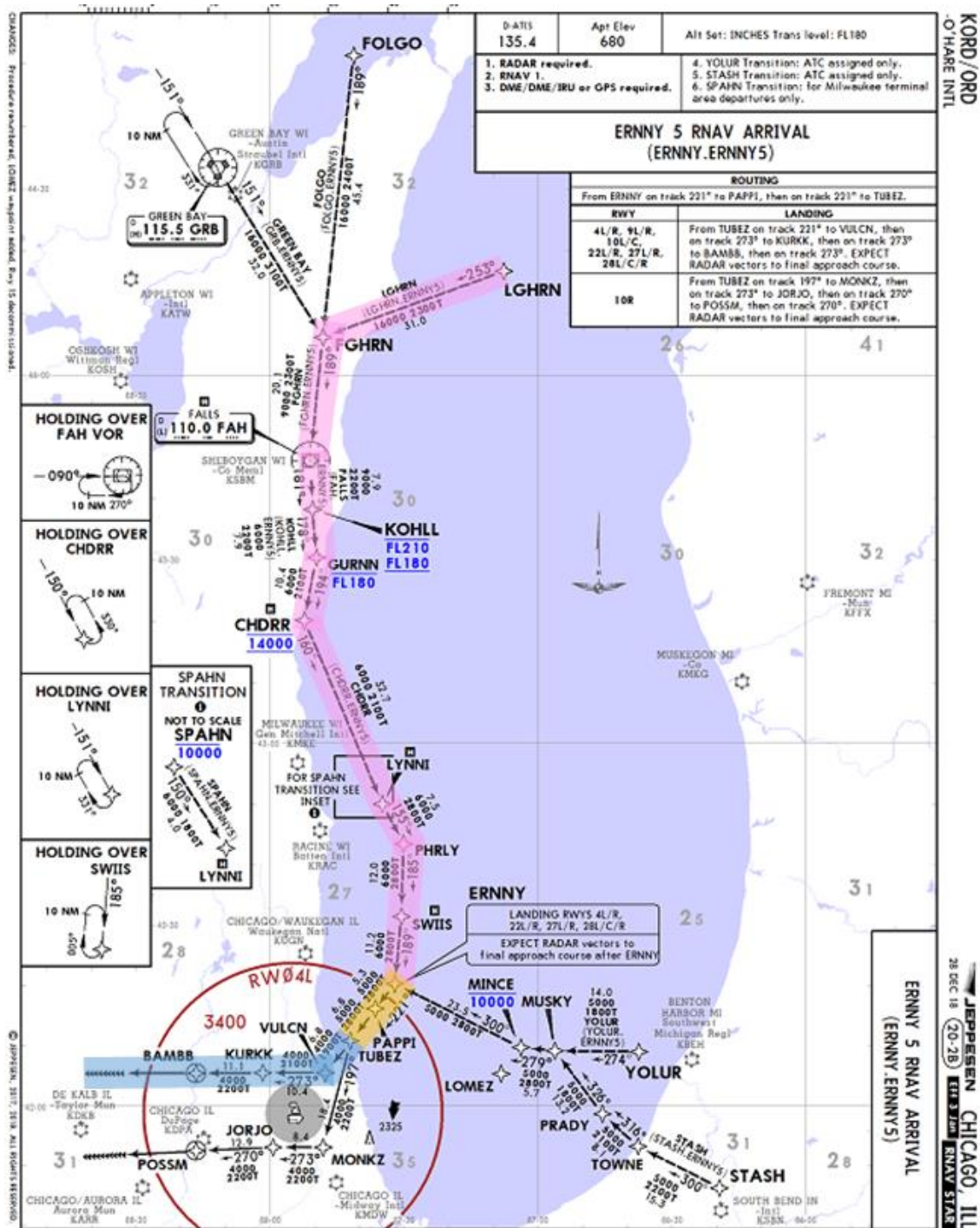
ARINC 424 Coding Example

To further illustrate the use of this technology on the flight deck, a picture of a B747 Multi-purpose Control and Display Unit (MCDU) is shown below in which the ERNNY 5 STAR is selected in Chicago O'Hare (KORD) with En-Route Transition LGHRN and the Runway Transition for runway 10C. This links the STAR to the ILS approach for runway 10C via the Approach Transition (Initial Approach) GIBNS.

Figure 12: MCDU 747



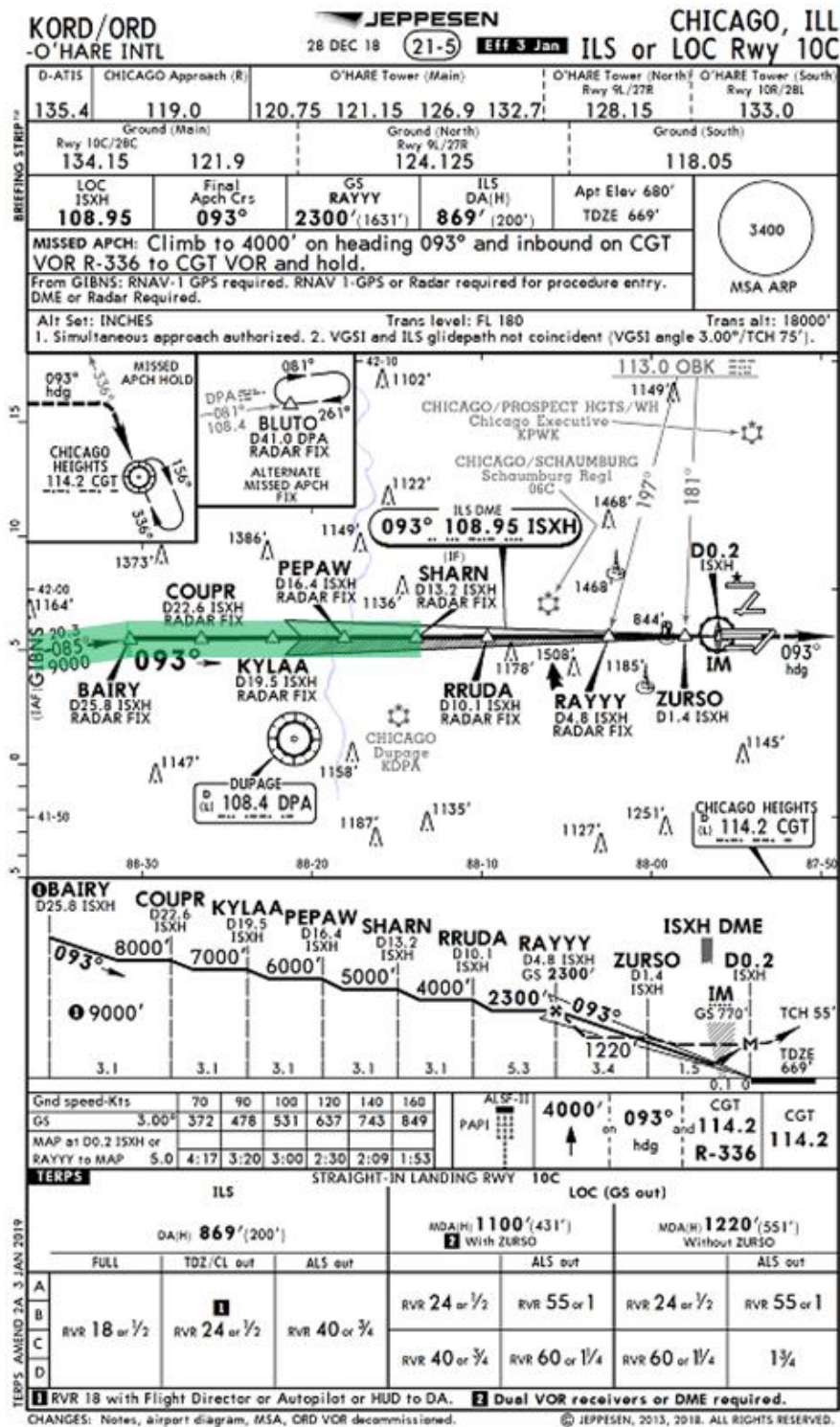
Figure 13: US Example ARINC 424 coding ERNNY 5 RNAV ARRIVAL



- STAR En-route Transition,
- STAR Common Route and
- STAR Runway Transition

Reminder: the designation of this STAR is based on the start of the STAR common route which is not in accordance with the ICAO naming convention.

Figure 14: Instrument Approach Procedure to RWY 10C at KORD/ORD



- Approach Transition / Initial Approach

Conclusion

This paper has shown that ICAO Annex 11 Appendix 3 offers a single STAR possibility and provides a naming convention for that single STAR. This offers limited flexibility which is not commensurate with the technological advancements on the flight deck. In contrast, ARINC 424 coding has kept up with on-board technological advancements, by offering multiple STAR and approach possibilities as well as defined technological names. The ARINC coding provides an avenue for solving the problem of the 'second STAR' identified at the start of this paper.

Clearly, however, varied use has been made of ARINC 424 coding in the naming of STARs/Transitions. The way to resolve this issue of diverse titles using ARINC 'solutions', will be for the ICAO provision for instrument flight procedure designation to be addressed. It would be preferable to base such a designation on the existing ARINC solutions so as to limit the cost to OEMs.

Recommendations

To improve the understanding of the term "Transition" and to reduce the confusion it often causes in the ATM community, EUROCONTROL proposes that definitions for SID/STAR Common Route, SID/STAR En-route Transition and SID/STAR Runway Transition are added to the ICAO provisions because they are already defined in ARINC 424 and used operationally. In addition, EUROCONTROL recommends a more consistent use of the term "Transition" on charts. These recommendations are as follows:

- The term "Transition" should *only* be used in the context of SID and STAR Runway and En-route transitions as defined in ARINC 424
- A ICAO SID/STAR procedure should *never* be designated as "(RNAV) Transition"
- An Approach Transition should be published as an initial approach procedure, either on the Final Approach chart or on a separate chart designated as "Initial Approach"

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