NLR-CR-2025-560 | February 2026

KDC Air-Ground Datalink Operational Validations

Controller-Pilot Data Link Communications (CPDLC)

CUSTOMER: KDC

Royal NLR - Netherlands Aerospace Centre

EXECUTIVE SUMMARY

UNCLASSIFIED

Accelerating the future of aerospace

KDC Air-Ground Datalink Operational Validations

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REPORT NUMBER
NLR-CR-2025-560

AUTHOR(S)
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KNOWLEDGE AREA(S)
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Problem area

Communication between air and ground is still often done using RT contact. RT has been used for decades in aviation and has proven to be a reliable means of communication. However, with the ever increase of traffic, the limits of RT communication will be encountered within the foreseeable future. Frequency congestion at busy airports/airspace, miscommunication or bad quality of transferred messages are known problem areas. Datalink is the apparent technology to complement and potentially replace RT in the future, answering to these known problems with RT.

Description of work

The study that has been done has performed a step towards the implementation of Controller-Pilot Data Link Communications (CPDLC) capabilities at LVNL, in particular for Area Control. The focus has been on (a) development of a first message set, (b) design and evaluation of the Human Machine Interface for the ACC controllers, and (c) technical assessment of the readiness of and potential changes to the iCAS system as it will initially be in operation at LVNL.

Results and conclusions

The development and evaluation of a prototype for the integration of the use of a selected CPDLC uplink message set has established the feasibility and controller acceptability, based on a limited number of participating controllers. Necessary software changes (to be implemented by the system supplier) and configuration changes (to be implemented by LVNL) have been identified.

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Summary

Since a number of years, various ANSPs, such as Maastricht Upper Area Control Centre (MUAC) and Deutsche Flugsicherung (DFS), are operating air-ground data link in upper airspace. This is mainly the result of an European mandate for Data Links Services above FL285 (approx. 8.7 km). The Dutch civil Air Navigation Service Provider LVNL (Luchtverkeersleiding Nederland) sees benefits and therefore has shown an interest in the use of air-ground data link below FL245 (approx. 7.5 km). This involves both Controller-Pilot Data Link Communications (CPDLC) and Automatic Dependent Surveillance – Contract (ADS-C). CPDLC is ultimately a means of communication between air traffic controllers and pilots, whereas ADS-C is means of communications between aircraft systems and ATC systems. The information obtained by ADS-C will be used by the ATC systems and may impact the display of information to controllers and their working methods. CPDLC and ADS-C are also main enablers for the transition to Trajectory Based Operations, ultimately enabling ATC to share complex trajectory clearances (2D positions, altitude, speed and time constraints) with the aircraft so that they can be loaded and executed safely and predictably by the aircraft FMS.

The benefits of air-ground data communications as seen by LVNL are:

- Conformance monitoring, e.g. to reduce number of SID blunders (ADS-C)
- Prevent double transmission (CPDLC)
- Prevent clearance being taken over (CPDLC), i.e. clearance intended for others (e.g. SID blunders, DCT clearances, FL confusion)
- General reduction of R/T load (CPDLC), resulting in more calmness and more overview
- Above benefits also result in greater success rate for candidate ATCOs, with more attention to critical conflicts instead of R/T

A consortium of To70, Royal Netherlands Aerospace Centre (NLR) and FerWay, has investigated the stepped introduction of air-ground communications for LVNL, including design and evaluation of operational prototypes. This report focusses on the CPDLC part; the ADS-C part of this study will be reported separately. The main objective of the CPDLC part is to show the feasibility of a first message set, both operationally and technically. In the end the LVNL engineers should be able, based on the results of this study, to write requirements for the new ATC system (iCAS) supporting the implementation and thereafter operation of this initial CPDLC message set. Service contracts with Communication Service Providers (e.g. ARINC, SITA, INMARSAT), a Ground-Ground ATN Router and a Data Link Front End Processor (DLFEP) converting the ATN protocol are also needed. The Router and DLFEP are more generic and not dependent on the selected message set, though the supported standards (e.g. B1, B2 RevA, B2 RevB) impact the DLFEP. However, the Flight Data Processing (FDP) and integrated Controller Working Position (iCWP) of iCAS are the systems mainly affected by the selected message set.

For CPDLC, an initial message set has been discussed and selected for use by LVNL in ACC airspace (which is the scope of the CPDLC study) in close collaboration with LVNL air traffic controllers. Also feedback on this message set has been obtained from members of the Operational Focus Group (OFG) including MUAC and Transavia. The OFG, a subgroup of the European Datalink Support Group, addresses items with primarily an operational dimension and helps to progress the resolution of the operational problems and harmonise the datalink usage across Europe.

After establishing the set of (19) CPDLC uplink messages of interest, the Human Machine Interface to operate the messages of this message set has been discussed, developed and evaluated with ACC air traffic controllers. Finally, a technical assessment has been performed of the readiness of and potential changes to the iCAS system as it will initially be in operation at LVNL.

The development and evaluation of a prototype for the integration of the use of a selected CPDLC uplink message set has established the feasibility and controller acceptability, based on a limited number of participating controllers. Necessary software changes (to be implemented by the system supplier) and configuration changes (to be implemented by LVNL) have been identified.

Based on the relative priorities indicated by the participating controllers for the individual messages in the selected message set, and the estimated effort involved in the required technical implementation development, it is recommended to start implementation with a subset of uplink messages, containing at least CLIMB/DESCEND, FLY HEADING, PROCEED DIRECT and CONTACT. However, in the corresponding system design care should already be taken for the future inclusion of other messages from the message set, especially those messages that require the controller to provide multiple user parameters. A consistent design for the TID menus should be developed that supports both single and multiple user parameter uplink messages.

Contents

Abbreviations

ACRONYM	DESCRIPTION
AAA	Amsterdam Advanced ATC (system)
ACC	Area Control
ACID	Aircraft Identification
ACL	ATC Clearances
ACM	ATC Communication Management
ADS-B	Automatic Dependent Surveillance – Broadcast
AGDL	Air Ground Data Link
AMA	Arrival Management Message
AMC	ATC Microphone Check
ANSP	Air Navigation Service Provider
APP	Approach Control
ASD	Air Situation Display
ASW	Air Situation Window
ATC	Air Traffic Control
ATM	Air Traffic Management
CCIS	Closed Circuit Information System
CD	Commands Dictionary
CFL	Cleared Flight Level
CPDLC	Controller-Pilot Data Link Communications
CWP	Controller Working Position
DD	Data Dictionary
DLFEP	Data Link Front End Processor
DFS	Deutsche Flugsicherung
D/L	Data Link
dM	Downlink Message
FDP	Flight Data Processing
FIM	Flight Information Message
GRM	Graphical Route Modification
HMI	Human Machine Interface
ICAO	International Civil Aviation Organisation
iCAS	iTEC-based Centre Automation System
iCWP	Integrated Controller Working Position
LAM	Logical Acknowledge Message
LVNL	Luchtverkeersleiding Nederland (Air Traffic Control The Netherlands)
MUAC	Maastricht Upper Area Control Centre

ACRONYM	DESCRIPTION
NARSIM	NLR ATM Real-time Simulation
NM	Nautical Mile
ODS	Operational Display System
OPS	Operations
PSL	Pilot Selected Level
PSR	Primary Surveillance Radar
R/T	Radio Telephony
RVR	Runway Visual Range
SESAR	Single European Sky ATM Research
SSR	Secondary Surveillance Radar
STAR	Standard Arrival Route
STCA	Short Term Conflict Alert
TID	Touch Input Device
UCO	Under Control
uM	Uplink Message

1 Introduction

Since a number of years, various ANSPs, such as Maastricht Upper Area Control Centre (MUAC) and Deutsche Flugsicherung (DFS), are operating air-ground data link in upper airspace. This is mainly the result of an European mandate for Data Links Services above FL285 (approx. 8.7 km). The Dutch civil Air Navigation Service Provider LVNL (Luchtverkeersleiding Nederland) sees benefits and therefore has shown an interest in the use of air-ground data link below FL245 (approx. 7.5 km). This involves both Controller-Pilot Data Link Communications (CPDLC) and Automatic Dependent Surveillance – Contract (ADS-C). CPDLC is ultimately a means of communication between air traffic controllers and pilots, whereas ADS-C is means of communications between aircraft systems and ATC systems. The information obtained by ADS-C will be used by the ATC systems and may impact the display of information to controllers and their working methods. CPDLC and ADS-C are also main enablers for the transition to Trajectory Based Operations, ultimately enabling ATC to share complex trajectory clearances (2D positions, altitude, speed and time constraints) with the aircraft so that they can be loaded and executed safely and predictably by the aircraft FMS. By digitally uploading the clearance and automatically loading it into the FMS, the loop in trajectory management (clearance uplink, execution, downlink of trajectory and confirmation) can be closed (1). A number of messages in the initial message set, such as “Cleared to position via” and “Cross position at/at or above/at or below”, are a first step of the CPDLC enabler for Trajectory Based Operations.

The benefits of air-ground data communications as seen by LVNL are:

- Conformance monitoring, e.g. to reduce number of SID blunders (ADS-C)
- Prevent double transmission (CPDLC)
- Prevent clearance being taken over (CPDLC), i.e. clearance intended for others (e.g. SID blunders, DCT clearances, FL confusion)
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For CPDLC, an initial message set has been discussed and selected for use by LVNL in ACC airspace (which is the scope of the study) in close collaboration with LVNL air traffic controllers. Also feedback on this message set has been obtained from members of the Operational Focus Group (OFG), including MUAC and Transavia. The OFG, a subgroup of the European Datalink Support Group, addresses items with primarily an operational dimension and helps to progress the resolution of the operational problems and harmonise the datalink usage across Europe.

After establishing the set of (19) CPDLC uplink messages of interest, the Human Machine Interface to operate the messages of this message set has been discussed, developed and evaluated with ACC air traffic controllers. Finally, a technical assessment has been performed of the readiness of and potential changes to the iCAS system as it will initially be in operation at LVNL.

2 Message set selection

2.1 Introduction

Communication between air and ground is still often done using RT contact. RT has been used for decades in aviation and has proven to be a reliable means of communication. However, with the ever increase of traffic, the limits of RT communication will be encountered within the foreseeable future. Frequency congestion at busy airports/airspace, miscommunication or bad quality of transferred messages are known problem areas. Datalink is the apparent technology to complement and potentially replace RT in the future, answering to these known problems with RT.

A previous KDC study (2) has analysed the current datalink capabilities on ground and airside within the Dutch FIR. The intention has been to develop an implementation strategy for LVNL to start implementing and benefitting from datalink applications. This implementation strategy has been developed in close collaboration with the involved stakeholders, as well as looking at implementation examples of neighbouring countries.

Concerning CPDLC the study made a number of recommendations that are addressed in this document:

Recommendation 1: It is recommended that one of the first steps of an implementation project is to perform a final review of operational use cases (with reviews from DEL, SUC, GND, RC, APP and ACC controllers, and adjacent centres such as MUAC and NATS) and then to decide on a good message set that will at least support these operational use cases.

Recommendation 3: Start operations with a defined set of CPDLC message set, make all available messages available to the controller. Message usage (what, when and where) is up to the individual air traffic controller, however it should be transparent for the controller whether a flight is B1 or B2 capable. Operationally there could be a quiet introduction if deemed necessary, e.g. by initially using a limited set of messages.

Recommendation 11: It is also recommended to work together with airspace users to define a harmonized message set and lowest altitude for CPDLC operations, for example the HMI of the Boeing 737 was mentioned as a potential concern to use CPDLC at lower altitudes.

While addressing these recommendations, the main objective is to capture requirements (mainly on HMI) at a sufficient level to feed LVNL requirements specification of design changes to iCAS, see next chapters.

At the outset of this study the scope was limited to:

- Implementation based on iCAS (the new ATC system currently being developed by LVNL, in cooperation with DFS and Indra).
- Implementation for ACC.
    - Note: in a next step the scope should be extended to also include Delivery (DEL) and Start- Up Control (SUC), and possibly Approach (APP).
- Implementation based on B1 and B2 standards (CPDLC message sets).
    - Currently approx. 93% of the Schiphol flights is equipped with B1, and in 2028 approx. 95% of the flights will be equipped with B1 and 40% with B2 (2)
    - The tentative message sets for ACC is supported by the datalink standards as follows:

        - 17 out of 29 uplink messages, as defined in (2), are supported by B1
        - 29 out of 29 uplink messages , as defined in (2) are supported by B2
- The implementation based on FANS 1/A standard will be investigated during the project, in particular (a) the extent to which iCAS does support FANS 1/A messages and (b) the transparency and uniformity of operations of B1, B2 and FANS 1/A messages will be considered.
    - A significant part of the flights are equipped with FANS 1/A (53% in 2023, 91% in 2028) (2)
    - However, FANS 1/A is limited in guaranteeing the delivery of a CPDLC message in a given time.
    - The tentative message sets for ACC is supported by the datalink standards as follows:
        - 24 out of 29 uplink messages, as defined in (2), are supported by FANS 1/A

2.2 Use cases

A number of use cases for CPDLC have been identified and have been discussed with a number of ACC controllers, and informally with two APP controllers.

The use cases are:

1. Use Case ACC#1 "Outbounds – after initial handover from APP"
2. Use Case ACC#2 "Inbounds – after initial handover from MUAC/NATS/skeyes/DFS"
3. Use Case ACC#3 "Transfer of Communications"
4. Use Case ACC#4 "Specific conditions"
5. Use Case APP#1 "APP outbounds"
6. Use Case APP#2 "APP inbounds"

Hereafter a short description of each use case will be given.

2.2.1 Use Case ACC#1

It concerns clearances (immediately) after the initial call (e.g. direct to, continue climb to FLxxx) for outbound traffic. Also conditional clearances such as "When passing FL120 direct KAROF" could benefit from CPDLC (the example is an inbound example, but it is also relevant for outbounds).

Considerations:

- In general these clearances are very suitable for data link, also with high traffic demands ("*lucht op de frequentie*")
- In case of conflicts, use data link after the conflict is over
- Benefits of the use of CPDLC are also related to safety cases at LVNL
    - Prevent USiT (double transmissions)
    - Prevent clearances being taken over, i.e. clearances intended for others (DCT clearances, FL confusion)
    - General reduction of R/T load, resulting in more calmness and more overview (*"meer rust en overzicht"*)
    - Above benefits also result in a greater success rate for candidate ATCOs, with more attention to critical conflicts instead of R/T

Some typical examples of RT messages that may be done with CPDLC are:

- ATCO: KLM123, Fly direct KOLAG
- ATCO: KLM123, Climb to FL240, Cross KOLAG FL180 or above

The initially agreed-upon message elements to implement these clearances via CPDLC at ACC consist of:

- uM20 Climb to
- uM46/47 Cross position at/at or above
- uM74 Proceed direct to
- ~~uM78 At level proceed direct to~~
- uM79 Cleared to position via

It should be noted that the identifiers in this list, e.g. uM20, refers to the B1 standard. The related message identifiers for B2 and FANS 1/A can be found in Table 1 in section 2.3. In the remainder of this document the B1 message identifiers are used unless indicated otherwise.

Feedback from MUAC and Transavia (both members of the datalink Operational Focus Group, OFG) indicates that regarding the uM78, there are several safety concerns as it is a "conditional clearance", which tends to often go wrong on CPDLC. So MUAC does not use it and also the ICAO GOLD manual (3) states that the controller should only use conditional clearances after determining that the operational efficiency needed outweighs the risk of a missed condition on the clearance. Conditional clearances have been associated with a large number of operational errors. The problem with these uplinks is that pilots don't get a reminder so they either tend to forget to do it or they do it before the condition is met. Neither case is ideal.

For these reasons it is proposed not to include uM78 as long as not all avionic equipment can handle these messages. Furthermore, uM78 is not supported by the B1 standard, which is currently the standard widely implemented on aircraft.

MUAC also indicated that message uM79 has caused a lot of troubles due to its display being not very intuitive. The Operational Focus Group has issued a recommendation, which helped driving down incident rates considerably at MUAC and is now being implemented across Europe.

OFG-ANSP-REC7: In order to avoid further incidents through the use of the UM79 CLEARED TO – VIA message, it is recommended to use the message in the following format: UM183 “ROUTE CHANGE ---”+ UM79 CLEARED TO [position] VIA [routeClearance] + UM183 “REST OF ROUTE UNCHANGED”. UM183 is technically a free text message as indicated by the quotes.
For example, ROUTE CHANGE --- CLEARED TO ALINA VIA ARTIP [REST OF ROUTE UNCHANGED]
The last part of the message (REST OF ROUTE UNCHANGED) may depend on local implementation as it was concluded that there is no real need to have it on board the aircraft.

2.2.2 Use Case ACC#2

It concerns clearances (immediately) after the initial call for inbound traffic; i.e. arrival clearance. The arrival clearance contains STAR or direct route, landing runway for inbounds EHAM, level instructions, other instructions or information (as needed). Not only the landing runway is relevant but also the approach type (ILS or RNP APCH) would be good to know as the FMS needs to be (re)programmed as early as possible. A working method could be to omit the approach type in case of standard ILS operations, but to include it otherwise.

Considerations:

- In general the STAR, direct route and/or headings with level instructions are very suitable for data link, also with high traffic demands
- Also the confirmation of a crossing conditions at the IAF (FL100 or below) and expected landing runway could well be communicated via CPDLC as well as heading instructions for delay vectoring and route clearance beyond the TMA entry point
- Give ATCOs the option to choose between voice (in case of urgency) or CPDLC (with less urgency)
- Same benefits related to safety cases as before

Some typical examples of RT messages that may be done with CPDLC are:

- NORKU 2A arrival, landing runway 18C or RNP approach [runway] 18C
- Maintain 270 knots
- Descend when ready FL070, cross ARTIP FL100 or below
- Proceed after ARTIP to SPL/KAROF/ALINA

The initially agreed-upon message elements to implement these clearances via CPDLC at ACC consist of:

- uM23 Descend to
- uM46/48 Cross position at/at or below
- uM74 Proceed direct to
- ~~uM78 At level proceed direct to~~
- uM79 Cleared to position via
- ~~uM215 Turn left/right degrees (not to be confused with Turn left/right heading)~~
- uM96 Continu present heading
- uM106 Maintain speed
- uM190 Fly heading
- uM183 When ready (technically as free text)
- uM203 Landing runway and approach type (technically as free text)
- uM81 Cleared procedure name
- ~~uM80 Cleared route clearance~~

The same rationale as before to exclude uM78.

Feedback from MUAC indicates that uM80 is not used, it completely replaces the existing route so whatever you uplink there you need to be sure that it is correct. It also takes much longer time to get a response to this, especially early in the flight as pilots need to make sure that it works properly before executing it.

MUAC indicated that they stopped TURN LEFT/RIGHT instructions on CPDLC, they just use FLY HEADING where the new heading is calculated by the FDPS, based on the Mode-S downlinked heading. So the ATCO just clicks L05 for turn left 5 degrees and the FDPS checks, calculates the new heading and uplinks it. It is much more foolproof.

Finally MUAC indicated that EXPECT instructions have also caused a lot of issues in the past over the North Atlantic. Should one wish to use them, use them with caution (see ICAO GOLD manual (3)). Transavia indicated that in cases where the expected approach is not clear it would be useful to know so pilots can brief each other accordingly and make the right set-up in a period with less workload.

For above-mentioned reasons it is proposed to exclude uM215 and uM80 from the selected message set. Note that turn left/right degrees still should be accommodated from an ATCO perspective, but with the (underlying) use of uM190.

2.2.3 Use Case ACC#3

It concerns transfer of communications for both outbound and inbound traffic. For the moment silent transfers are not included, they are considered for the long term. Silent transfers via CPDLC also need ADS-C B2 Rev B (and only the B2 Rev B standard includes the transmission of VHF frequencies to enable notification to the controller that the flight crew is monitoring the correct frequency). B2 Rev B is however not mandatory through the European CP1 implementing regulation which mandates ADS-C capability for new aircraft; B2 Rev A systems comply with this regulation and have actually been implemented in aircraft such as the A320neo family. Besides the technical issues there are also procedural/legal issues.

Considerations:

- APP also needs to be involved to develop a harmonized implementation of the transfer of communications at ACC and APP

A typical example of RT messages that may be done with CPDLC is:

- Contact London 121.325

The initially agreed-upon message element to implement transfer of communication via CPDLC at ACC consist of:

- uM117 Contact

2.2.4 Use Case ACC#4

A number of operational cases have been identified where data link could be beneficial in reducing ATCO task load in specific conditions.

- ACC providing Runway Visual Range (RVR) information well ahead of the TMA entry point, the IAF. Based on the actual RVR and minimum allowable RVR for an aircraft it is decided, amongst others, whether an aircraft has to hold or not.
- ACC providing Expected Approach Times (EAT) in case there is a need to hold. This happens well before the IAF. Often accompanied by a speed and holding instruction.
- In case of a sticky mike the controller can now, via CPDLC, inform the flight crew that there is a stuck microphone.

The initially agreed-upon message elements to implement this information via CPDLC at ACC consist of:

- uM92 Hold at position as published and maintain level
- uM157 Check stuck microphone
- uM203 Expected approach time (technically as free text)
- uM214R RVR

2.2.5 Use Cases APP#1 and APP#2

Informal discussions with two APP controllers indicated potential benefits of the possibility to use CPDLC in the following cases.

- Transfer of communication for departing aircraft only, not for landing aircraft.
- ATIS information after transfer from ACC.

The initially proposed message elements for potential implementation at APP consist of:

- uM117 Contact
- uM158 ATIS code

2.3 Initial set of CPDLC uplink messages

Table 1 below summarizes the CPDLC uplink messages as identified in collaboration with ACC controllers and as discussed in the previous section. The strikethrough part of the messages in the table indicates that these optional features of the datalink standards are not needed (e.g. use of block levels) and therefore do not need to be supported by the controller Human Machine Interface (HMI).

The table also indicates which data link standard (B1, B2 Rev A, B2 Rev B, FANS 1/A) do support the selected messages. For more information about these standards see (2). Note that there is a need to implement B2 Revision B ground system in order to be able to communicate with both B2 RevA and B2 RevB (and B1) aircraft. The caveat is that RevB aircraft can't communicate with RevA ground systems, but RevB ground systems can communicate to both RevA and RevB aircraft. This was done to simplify the airborne requirements.

The table further indicates which messages are already supported, at least to a certain extent, by the iCAS system currently in development at LVNL. Although the iCAS system, which is already in use by DFS, supports those messages they will not be directly available at LVNL, because LVNL has not (yet) planned the inclusion of this capability in their system configuration targeted for operational introduction. Dashes in the iCAS column indicate that a message or group of messages are not yet supported by iCAS, e.g. all B2 messages are not supported as the B2 standard is not yet supported by iCAS.

It should be noted that the iCAS system currently only supports messages from the B1 and FANS 1/A standard, the new global baseline for data link (B2) is not supported. Whenever LVNL will be discussing CPDLC with INDRA, the plans in support of B2, preferably B2 RevB (or later revision), should be part of this discussion as B2 is considered by SESAR and internationally as the future standard to be globally implemented. Note that Airbus is already delivering aircraft complying with the B2 standard, though B2 RevA.

The table also provides some insight in how the messages are treated on-board aircraft, in particular whether FMS loading (reducing pilot errors) is mandatory or is recommended to be available. FMS loading is an important feature that enables the flight crew to insert the uplinked message and its data content into the FMS with a single button push. Without FMS loading of often more complex messages, the flight crew needs to manually insert the uplinked message into the FMS, which requires valuable time of the crew and is prone to entry errors.

Table 1: Initial set of CPDLC uplink messages

	Standard	Message ID	CPDLC uplink message	iCAS	Potential FMS Loading	Additional info
1	B1 B2 Rev A+B FANS 1/A	uM20 uM20 uM20	CLIMB TO [level] CLIMB TO (~~BLOCK [level single] TO~~) [level single] CLIMB TO AND MAINTAIN [altitude]	YES --- YES		No use of block levels During the evaluation (see paragraph 3.5.5.3) it was suggested to also support vertical rate clearances via CPDLC (uM171, uM172, uM173 and uM174), i.e. climb/descend at [vertical rate] minimum/maximum. These four messages are part of the European ATN B1 mandate.
2	B1 B2 Rev A+B FANS 1/A	uM23 uM23 uM23	DESCEND TO [level] DESCEND TO (~~BLOCK [level single] TO~~) [level single] DESCEND TO AND MAINTAIN [altitude]	YES --- YES		No use of block levels
3	B1 B2 Rev A+B FANS 1/A	uM46 uM46R uM46	CROSS [position] AT [level] CROSS [positionATW] (AT) (~~BETWEEN) [level single] AND~~) [level single] CROSS [position] AT [altitude]	---	YES	No use of block levels Linked to uM20 or uM23
4	B1 B2 Rev A+B FANS 1/A	uM47 uM47R uM47	CROSS [position] AT OR ABOVE [level] CROSS [positionATW] AT OR ABOVE [level single] CROSS [position] AT OR ABOVE [altitude]	---	YES	Linked to uM20 or uM23
5	B1 B2 Rev A+B FANS 1/A	uM48 uM48R uM48	CROSS [position] AT OR BELOW [level] CROSS [positionATW] AT OR BELOW [level single] CROSS [position] AT OR BELOW [altitude]	---	YES	Linked to uM20 or uM23
6	B1 B2 Rev A+B FANS 1/A	uM74 uM74R uM74	PROCEED DIRECT TO [position] PROCEED DIRECT TO [positionR] PROCEED DIRECT TO [position]	YES --- YES	uM74R is mandatory loadable	

	Standard	Message ID	CPDLC uplink message	iCAS	Potential FMS Loading	Additional info
7	B1 B2 Rev A+B FANS 1/A	uM79 uM79R uM79	CLEARED TO [position] VIA [routeClearance] CLEARED TO [positionR] VIA ([departure data]) [route clearanceR] CLEARED TO [position] VIA [routeclearance]	---	uM79R is mandatory loadable	uM79 is an alternative for uM81(R), which is not defined in B1. Route clearance could be a procedure name. Examples: CLEARED TO KAROF VIA ARTIP / CLEARED TO ARTIP VIA NORKU 2A ARRIVAL / CLEARED TO NIRSI VIA ARTIP 1C TRANSITION The OFG recommends to use uM79 in combination with a standard text using uM183.
8	B2 Rev A+B FANS 1/A FANS 1/A	uM81R uM81	CLEARED [procedure nameR] CLEARED [procedurename] Or CLEARED [procedureName] + uM169 ‘<procedure>’	---	YES	B2 and FANS 1/A only Procedures includes STARs and (Night) Transitions FANS 1/A message depends on whether the procedure name has 6 or less characters.
9	B1 B2 Rev A+B FANS 1/A	uM92 uM92R uM92	HOLD AT [position] AS PUBLISHED MAINTAIN [level] AT [positionR] HOLD ~~([direction compass])~~ AS PUBLISHED HOLD AT [position] AS PUBLISHED MAINTAIN [altitude]	---	YES	Do not uplink the direction compass (= N/E/S/W/NE/SE/SW/ NW)
10	B1 B2 Rev A+B FANS 1/A	uM96 uM96 uM96	CONTINUE PRESENT HEADING CONTINUE PRESENT HEADING FLY PRESENT HEADING	---		
11	B1 B2 Rev A+B FANS 1/A	uM203 uM99R uM99	“EXPECT <named instruction>” EXPECT [named instruction] EXPECT [procedurename] Of EXPECT [procedurename] + uM169 ‘<procedure>’ Of uM169 ‘EXPECT <clearance name>’	---		Landing runway or landing runway + approach type in case of RNP approach. Feedback pilots: keep possibility open to always (transparent to ATCO?) uplink the approach type, also for ILS approaches.

	Standard	Message ID	CPDLC uplink message	iCAS	Potential FMS Loading	Additional info
12	B1 B2 Rev A+B FANS 1/A	uM106 uM106 uM106	MAINTAIN [speed] MAINTAIN [speed] MAINTAIN [speed]	---		During the evaluation (see paragraph 3.5.5.3) it was suggested to also support uM108 and uM109, i.e. maintain [speed] or greater / less. Both are part of the European ATN B1 mandate.
13	B1 B2 Rev A+B FANS 1/A FANS 1/A	uM117 uM117R uM117	CONTACT [unit name] [frequency] CONTACT [unit nameR] ([frequencyR]) CONTACT [icaounitname] [frequency] Or uM169 'CONTACT <icaounitname>'	YES --- YES		
14	B2 Rev A+B FANS 1/A	uM158R uM158	([airport]) ATIS [atis code] (uM169 '<airport>' +) ATIS [atis code]			B2 and FANS 1/A only
15	B1 B2 Rev A+B FANS 1/A	uM157 uM157R uM157	CHECK STUCK MICROPHONE [frequency] CHECK STUCK MICROPHONE ([frequencyR]) CHECK STUCK MICROPHONE [frequency] Or uM170 'CHECK STUCK MICROPHPNE'	YES --- YES		
16	B1 B2 Rev A+B FANS 1/A	uM183 uM164 uM164	"WHEN READY" WHEN READY WHEN READY	YES --- ---		Linked to uM23 uM183 is free text, its content may be preconfigured through the HMI
17	B1 B2 Rev A+B FANS 1/A	uM190 uM190 uM94	FLY HEADING [degrees] FLY HEADING [degrees] TURN [direction] HEADING [degrees]	YES --- ---		Including ATCO input 'turn left/right nn degrees' uM94 with direction automatically set to "either side"
18	B2 Rev A+B	uM214R	RVR ([airport]) ([runway]) [rvrData]	---		B2 only
19	B1 B2 Rev A+B FANS 1/A	uM203 uM226 uM169	"EXPECTED APPROACH TIME <time>" EXPECTED APPROACH TIME [time] 'EXPECTED APPROACH TIME <time>'	---		Frequently linked to uM92/uM92R (HOLD AT position)

The B2 standards (both RevA and RevB) support all 19 messages, the FANS 1/A standard supports 18 of these messages, and the B1 standard supports 16 of these messages.

The RVR message is not supported by FANS 1/A. The ATIS, RVR and CLEARED [procedure name] messages are not supported by B1. B1 message uM79 (CLEARED TO [position] VIA [routeClearance[) could mitigate the missing of the CLEARED [procedure name] message.

iCAS currently only supports 7 of these 19 CPDLC uplink messages.

3 Prototyping and feasibility

This chapter describes the prototype of the air traffic controller HMI used to evaluate the feasibility of incorporating the selected initial Controller-Pilot Data Link Communications (CPDLC) messages in the application(s) of the LVNL controller working position. The working methods involved and the main design decisions are outlined, with controller feedback and suggestions for improvements and refinements.

The prototype is based on the iCAS iCWP, as it is currently being developed by LVNL, in cooperation with DFS and Indra. The objective of this part of the project is the demonstration of the feasibility of integrating the necessary HMI changes in this existing framework. Evaluations performed with controller participation are used to determine this feasibility, within the limits of the prototype and simulated environment.

3.1 Overview of selected CPDLC services

The prototype development for and the evaluation of the use of the CPDLC services described in the use cases in the previous chapter, has been based on the initial set of message elements, selected by LVNL, summarised in Table 1 in section 2.3. The table below provides a summary of these message elements and message element combinations; optional parts are indicated with parentheses, while square brackets delimit user parameters, as specified in ED-110B (4). (Parameter identifiers from the B1 standard are used as reference, in line with the choice to use the B1 message identifiers, as mentioned in section 2.2.1. For message elements not supported in B1, double quotes are used to indicate the use of a free text message. If message elements were selected for use in certain message element combinations, these combinations are listed as one entry.

CLIMB TO [level] (CROSS [position] AT (OR ABOVE) [level])
(“WHEN READY”) DESCEND TO [level] (CROSS [position] AT (OR BELOW) [level])
PROCEED DIRECT TO [position]
FLY HEADING [degrees]
CONTINUE PRESENT HEADING
MAINTAIN [speed]
CLEARED TO [position] VIA [routeClearance]
“EXPECT <named instruction>”
HOLD AT [position] AS PUBLISHED MAINTAIN [level]
“EXPECTED APPROACH TIME <time>”
CONTACT [unit name] [frequency]
CHECK STUCK MICROPHONE [frequency]

The uM79 “CLEARED TO [position] via [routeClearance]” message, although listed in the table above, has not been included in the prototype of the controller HMI. The decision to not include this message in the scope of this project was partially based on the potential misunderstanding and regular confusion MUAC has reported on (5).

The uM81R “CLEARED [procedure nameR]” and uM158R “([airport]) ATIS [atis code]” message elements, listed in Table 1, are not supported by B1 and have not been included in the prototype.

3.2 The prototyping platform

The NLR ATM Real-time Simulation platform (NARSIM) is used as platform to prototype and evaluate the integration of CPDLC services. One of the recommendations presented in section 8.3.11.1 of EUROCONTROL's Operational Guidance document (6) requires the display of e.g. data-link equipage status to be associated to the radar label or position symbol. This implies that the presentation of information related to CPDLC connection status and messages dialogues has to be integrated in the air situation display of the controller working position.

Another important part of the prototype evaluation is to determine the feasibility of not only triggering the uplink of relatively 'simple' CDPLC messages (e.g. a single message element with a single user parameters, like "CLIMB TO [level]"), but also of completing complex message element combinations (e.g. with multiple user parameters), without unacceptable workload for the controller. The prototype therefore necessarily needs to integrate the HMI functionality to interact with the CPDLC functionality in the existing HMI.

NARSIM is a real-time, human in the loop ATC simulator capable of simulating the full working environment and working conditions of air traffic controllers in detail. As such, it provides a platform for training, validation and conducting research in a controlled environment on all aspects of air traffic control and the air traffic controller. These facilities are used for research and development of new user-interfaces, user-interaction, ATC system support, new and revised concepts of operation and development and assessment of ATC training and its effectiveness.

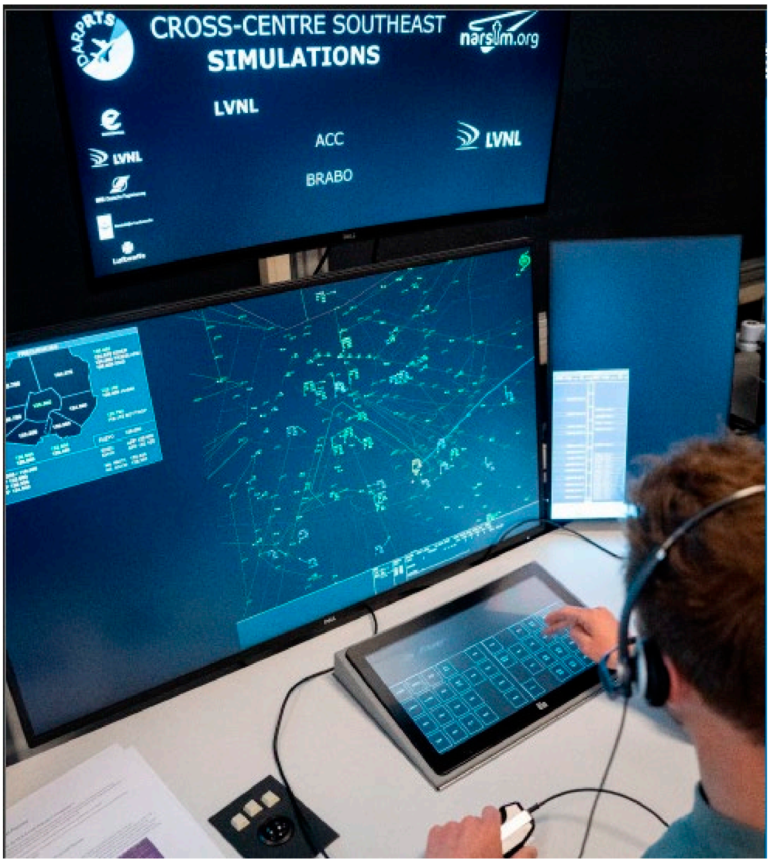

Figure 1: Controller Working Position in NARSIM with trackballs and touch input display

NARSIM is developed in-house by NLR and has been used in many projects for LVNL simulating the AAA controller working positions and AAA system behaviour to a high degree of exactness. Some of the recent projects have already introduced HMI and system features from iCAS in NARSIM. CPDLC functionality is also available in NARSIM, having been introduced in the scope of SESAR projects.

The experimentation facilities at NLR are equipped with realistic Air Traffic Controller Working Positions (CWP), simulator (pseudo) pilot and supervision positions and support more than 50 actors to participate simultaneously in one large simulation spanning multiple centres. The prototyping sessions presented in this document were organised as small-scale activities with one or two working positions and the participation of active LVNL controllers.

3.3 CPDLC integration in the prototype controller HMI

The prototype controller HMI is based on the Controller Working Position of LVNL's ACC controllers. Each CWP contains many components, but the modifications for CPDLC focus on the main air situation display and the connected touch input devices.

The main air situation display shows surveillance and flight plan data, maps, measuring tools, operational data windows and meteorological information. Surveillance and flight plan data is presented as tracks (position symbol, with optional: track label, history dots, speed vector, SSR-label, microlabel), as lists (e.g. containing flight plans and conflict alerts) and as part of the so-called interaction area.

The prototype CPDLC integration involves five of these HMI elements: modifications of four existing elements and the addition of one new element (the CPDLC list). These elements are:

- Track symbol
- On-request line
- Track label
- CPDLC list
- Touch-input menu pages and input template

3.4 Organisation of the pre-operational prototype evaluation

The evaluation sessions consisted of:

- one initial session with one LVNL ACC controller using NARSIM (May 1, 2025),
- one follow up session with two LVNL ACC controllers using NARSIM (June 19, 2025).

Both sessions started with a short presentation on the purpose and scope of the prototyping activity, followed by a demonstration of and hands-on interaction with the prototype CPDLC HMI in the NARSIM facility. Representative traffic samples (validated as part of a different project with LVNL participation) were used; pilot inputs were simulated by using the system's pilot HMI to e.g. acknowledge CPDLC uplink messages. The version of the prototype used in the initial session was prepared based on the input from the participating controllers obtained during a preceding meeting and email correspondence. Feedback from the first session was used to further develop the prototype in the time between the initial and follow up sessions.

Feedback was captured during and after the hands-on part of the session, the latter as part of a concluding debrief.

In addition, two other LVNL ACC controllers were included in the evaluation process using screenshots of the protype presented as a power point presentation, discussed in meetings and via email.

All the participating LVNL controllers are active controllers.

3.5 Prototype development and evaluation summary

The pre-operational HMI prototype (Figure 2) has been developed based on information obtained from the participating LVNL controllers, on information obtained about the CPDLC HMI of MUAC and DFS and on information from the iCAS system supplier Indra. Recommend practices, regulations and guidelines from EUROCONTROL (6), ICAO (7), EUROCAE, EASA and other parties (8) have been consulted as part of this development.

Figure 2: HMI prototype running on a Controller Working Position at the NARSIM facility

Two general design decisions, supplied by LVNL, were applied in the prototype.

- CPDLC information is displayed to both executive and planner controller.
- Block-levels are not allowed as parameter (e.g. as in “CLIMB TO BLOCK [level] TO [level]”).

In addition, the following general design decision was applied, based on pilot feedback:

- Only Fix Name, Navaid and Airport are allowed as position parameter (i.e. not the Latitude and Longitude, and Place Bearing Distance alternatives supported by ED-110B).

Each of the subsections below presents a general description of the discussed HMI element, a summary of the design decisions, the feedback provided by the participating controllers and a comparison with the corresponding feature in the MUAC HMI. MUAC has been operating CPDLC since 2003: the resulting user interface has been selected as an exemplary reference case.

3.5.1 Track symbol

3.5.1.1 General

The position of a track symbol indicates the current position of an aircraft; the shape of the symbol additionally displays information about either the surveillance source or of the controller who has assumed control of the flight. iCAS (and AAA) use over 50 different track symbols, a few of these are shown below:

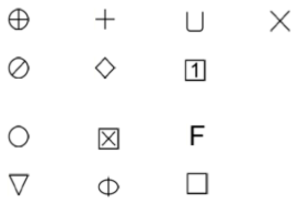

Figure 3: A few of the symbols used as LVNL track symbol

The MUAC HMI implements the use of the track symbol to present CDPLC related information, as described in section 3.5.1.4. This is in compliance with data link operational guidance recommendations. It was decided to use the track symbol in a similar way in the prototype.
A new under control (UCO) track symbol was designed for display in the prototype, replacing in specific situations the currently used symbols, to indicate CPDLC connection (and message) status. The logic of displaying a specific track position symbol is determined in the configuration of the iCWP: no changes of the iCWP software itself are required.

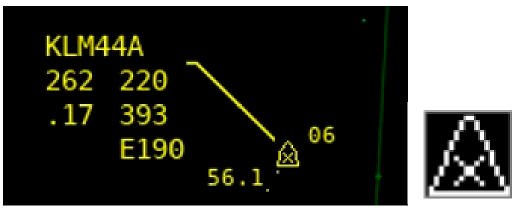

Figure 4: The track symbol used in the prototype for UCO flights with CPDLC connection

The logic rules in the configuration were made such that only in conditions where the PSR+SSR (basic) track symbol is currently displayed in AAA, the symbol may be used instead to display CPDLC status related information. Only for flights relevant to the controller (e.g. flights under control or when the controller is next in the control sequence), the symbol may be used for CPDLC status presentation. For exceptional cases, for example if SSR radar detection is lost, the corresponding (blinking) track symbol will have priority over de CPDLC status indication.

The example from MUAC shows that the shape of the new symbol can be used to display, in an easily distinguishable way, information about CPDLC equipage, data link log-on and CPDLC connection status. The figure below illustrates how in the prototype this was implemented.

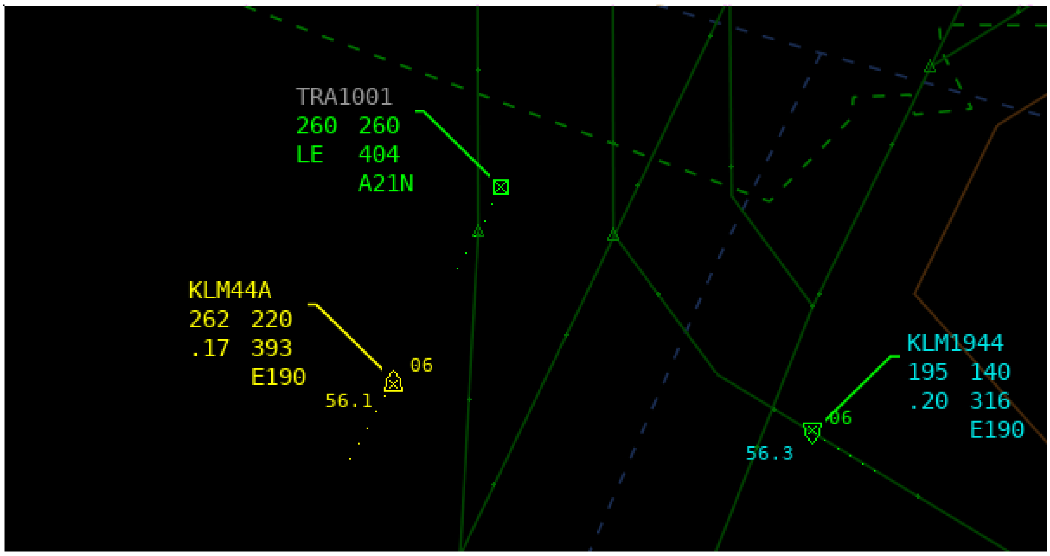

Figure 5: KLM44A with track symbol indicating established CPDLC connection, and KLM1944 with symbol showing the flight is not logged on

Care has to be taken, however, to ensure sufficient differentiation with the other track symbols already in use. The prototyped track symbol was only designed to demonstrate this can be achieved. Alternative symbols may be designed instead. During the prototyping workshops a pentagon shape (⌂) was proposed, with a cross in the middle. Such a pentagon shape can be turned 90 degrees to indicate CPDLC capability and logon status.

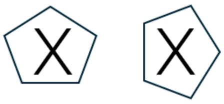

Figure 6: Impression of proposed pentagon shaped track symbol

3.5.1.2 Design decisions

- Use the track symbol, under specific, configured conditions to display CPDLC status information.
- Only display the established CPDLC status. (Other CPDLC status information will be displayed in the On-request line).
- Existing alerts and warnings that are presented using the track symbol, have priority over the CPDLC status presentation. (E.g. STCA.)

3.5.1.3 Feedback

- The CPDLC UCO track symbol should only represent whether the flight has an active CPDLC connection: other information should be displayed on the On-request line.
- LKP labels (indicating a Last Known Position) shall not display a CPDLC status track symbol.

- A track symbol has to be designed sufficiently different from the already used ones. (The symbol used in the prototype can be improved.)
- Some operational procedures (either existing or in development) need to be verified for compatibility: procedures for test flights, and for application of 3 NM separation.
- Colour of the track symbol may be used to display e.g. a CPDLC time-out on message acknowledgement, but only in the absence of other colour use, like during STCA presentation.

3.5.1.4 MUAC reference

The design principle of using a polygon shape with 90 degrees turning capabilities is the same logic as applied by MUAC for a CPDLC track symbol. The image below provides details on the meaning of the different datalink related shapes concerning datalink. As can be seen, MUAC has chosen for a triangle as main symbol, with different meanings when the triangle is facing up, down or to the right. Feedback from MUAC indicated that this logic has been widely accepted and has proved to function for a couple of years already. It is expected that the same logic with the prototyped or the pentagon shape for LVNL will therefore be acceptable.

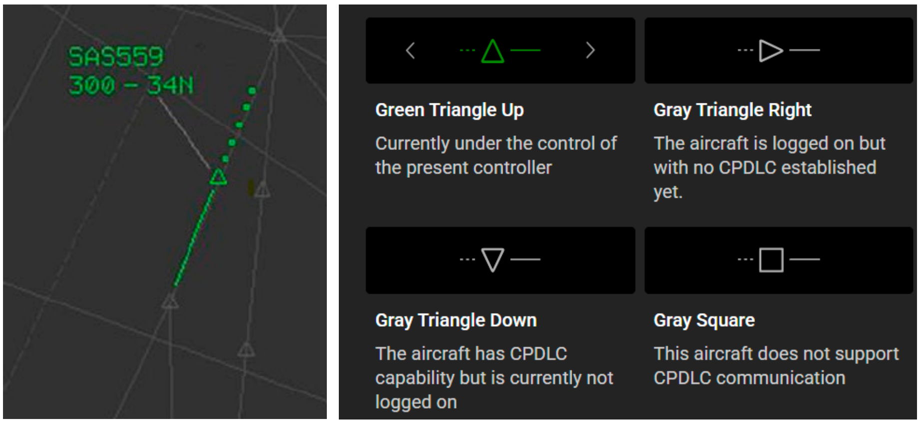

Figure 7: MUAC track symbol with CPDLC status information (9)

3.5.2 On-request line

3.5.2.1 General

The On-request line is part of the interaction area at the bottom of the main air traffic situation window of AAA and iCAS. This interaction area also contains an input template. The On-request line displays up to four lines of system flight plan information of the selected flight. The specific information depends on availability.

Figure 8: AAA On-request line and input template

Presentation of the On-request line (and corresponding input template) will be moderately different in iCAS, but functionally identical. Based on controller feedback, the On-request line is for LVNL the most suitable area on screen to display additional CPDLC information, like a flight's CPDLC equipage and status. More detailed information about log-on and CPDLC status can be displayed here, in addition to the basic information displayed in the track symbol. Also the PSR/SSR/ADS-B information normally provided by the basic track symbol can be displayed here. The colour of the background of the CPDLC status presentation could be used as a visual indication, e.g. to draw attention to an equipped flight not logged-on.

3.5.2.2 Design decisions

- The CPDLC status shall be part of a flight's information presented on the On-request line.
- Any attention getter used as part of the presentation of the CPDLC status in the On-request line shall be acknowledgeable to remove the highlighting, e.g. with a REV input.

3.5.2.3 Feedback

- For ACC, it may be useful to be notified of an equipped inbound flight that is not logged on, in order to request the pilot to initiate the necessary actions, such that APP can benefit from an established CPDLC connection.

3.5.2.4 MUAC reference

The HMI of MUAC's ATC system features the Flight Information Message Window (FIM), which includes (almost all of) the functionality of the On-request line of AAA and iCAS. It provides sub-windows (which can be selected using a mouse) which offer access to a larger set of data than is available as part of the On-request line.

Figure 9: MUAC's Flight Information Message (FIM) window with 'CPDLC' sub-window button (10).

The CPDLC sub-window displays the CPDLC history of the flight in context, if the flight is assumed by the sector. Each line in the sub-window corresponds to a separate dialogue type (level, route, etc.).

3.5.3 Track label

3.5.3.1 General

Colour coding is used in the prototype to indicate in the track label open CPDLC dialogues. A light blue colour is used to display an uplinked value that has not yet been replied to. In the figure below, the controller has made an input for

a new flight level (240), which the system has uplinked using a “CLIMB TO 240” message. The new value ‘240’ is displayed in a light blue colour in the label on the screen of the controller(s) of the sector where the flight is assumed. The colour has been selected to be identical to the colour used in the AAA and iCAS system for an AMA-speed value displayed in the track label. An AMA-speed is a request to a neighbouring ANSP for a speed change e.g. to fit a flight in the inbound arrival stream for Schiphol. The requested value is displayed in the track label in light blue (cyan) until the AMA messages has been acknowledged (with a LAM message) by the receiving ANSP. The same colour blue is selected for the prototype for values related to open CPDLC dialogs started with uplink messages because of the similarity of the communication process.
The selected colour is also sufficiently discernible from the regular green used for track labels. The colour has also been selected to fit in with LVNL’s rules for colour use (11): it matches with the expectation that no further action of the controller is currently expected to complete the instruction, but that the situation requires to be monitored until its completion.

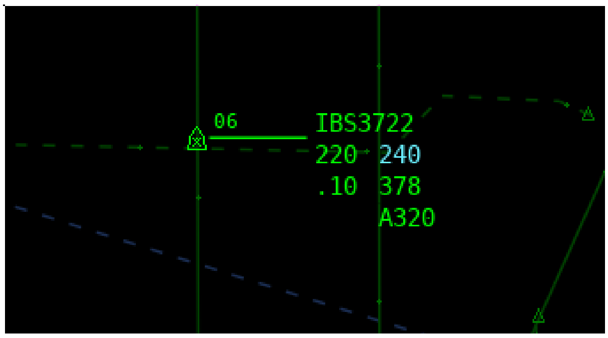

Figure 10: Track label in prototype indicating a CPDLC uplink of a climb to level 240

The colour white is reserved to indicate downlinked pilot requests: the presentation includes the use of this colour for both the position symbol and the label field involved. As a further enhancement, the white part of the position symbol can be presented blinking (e.g. alternating in colour between white and green).

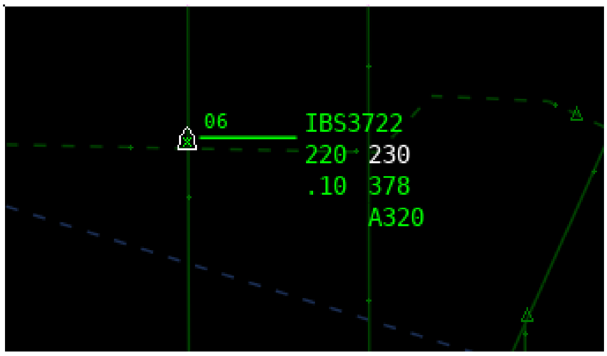

Figure 11: Track label in prototype indicating a CPDLC downlink request to climb to level 230

An amber warning colour is used in the prototype to indicate that either a time-out parameter has been exceeded, an UNABLE downlink reply has been received or an error has occurred. As with the downlink requests, the amber part of the position symbol can be presented blinking (e.g. alternating in colour between amber and green). The amber colour used should be the same as the amber colour already used in the system for the PSL alert in the track label.

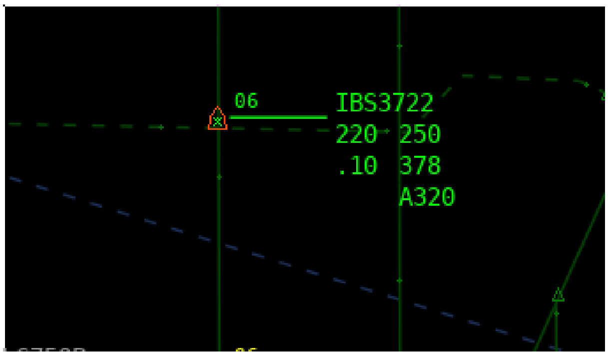

Figure 12: Track symbol in prototype indicating a CPDLC time-out warning

The track label field presentation in iCAS is configured using rules: the changes described above require access to the relevant information about open CPDLC dialogues, like the status and the uplinked or downlinked value or values. This requirement is described in more detail in section 4.3.3.1.
Similarly, the presentation of a track's position symbol is configured via rules. Currently it can only be configured as a shape with a single colour. I.e. the 'x' inside the triangular border would have to be the same colour as the border itself. This presentation was selected in the second prototype session.

3.5.3.2 Design decisions

- Present information about open CPDLC messages in the track label.
- Display the uplinked/downlinked value in the track label, using agreed colours to indicate the dialogue status.

3.5.3.3 Feedback

- The controllers indicated that the track label is the preferred HMI element to present information about open CPDLC dialogues (as it ensures awareness of any open CPDLC dialog as part of their scanning pattern).
- The use of colour for CPDLC information in the track label must be aligned with LVNL's existing rules for the use of colour, especially for AMA-speed (blue after AMA message transmission, until receipt of LAM).
- There shall be a visible presentation after sending a "CONTACT" (or "MONITOR") message, until the receipt of the "WILCO" response, e.g. via the colour of the ACID in the label. It was suggested to also display a warning (e.g. change the colour of the ACID to a warning colour) after a grace period.

3.5.3.4 MUAC reference

The use of track label fields to present information about open CPDLC dialogs is very similar to the design used in the MUAC HMI. However, MUAC uses a light green colour for uplinked values of open dialogs. If applied in iCAS, the result may be as shown in the figure below on the left. The colour used in the prototype (as seen below on the right) is selected to match LVNL's rules for colour use.

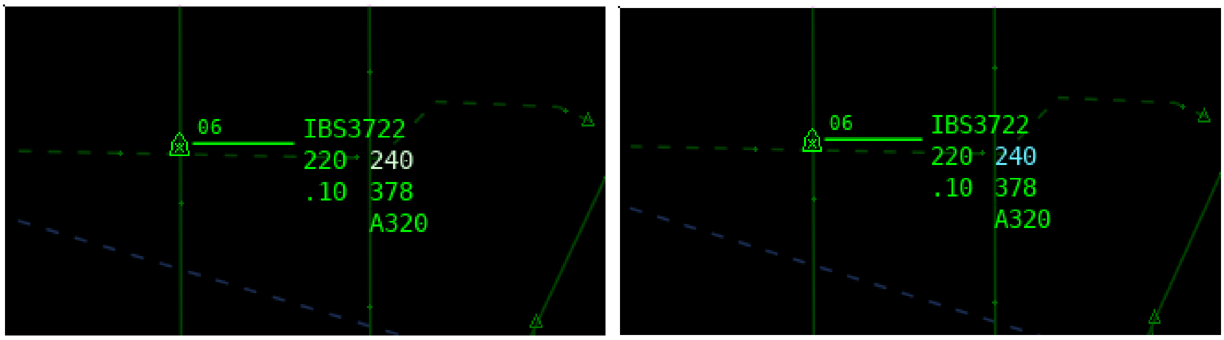

Figure 13: Colour coding for CPDLC uplink: light green as used by MUAC (left), light blue as proposed for LVNL (right)

The colour selected in the prototype for warnings related to CPDLC communications (e.g. time-outs) also differs from the colour used in the MUAC HMI, for a similar reason. While MUAC uses yellow in this situation as a warning colour, amber is selected for the prototype to align with LVNL's rules for colour use.

3.5.4 CPDLC list

3.5.4.1 General

Not all information concerning open CPDLC dialogs can be efficiently presented in a track data label. Additionally, controllers should also be able to access information about (recently) closed dialogs. A new list, displaying CPDLC dialogs of flights under control at the sector has been introduced in the prototype to serve these two purposes. This list also provides an instant overview of all on-going CPDLC communications.

Figure 14: CPDLC list displaying open dialogs used in the prototype

Information presented in the CPDLC list includes: the time of the last message in the dialog, the callsign of the flight and a summary of the dialog. Such a summary contains e.g. the request with its user parameters and any reply already received. For example 'CLIMB 240' until a positive reply is received, which may be indicated with the summary 'WCO/CLIMB 250'. Especially messages with multiple user parameters can efficiently be displayed in the CPDLC list: for example:

WHEN READY DESC 70 X ATP AT 100/BLW

as a summary of the complex message combining uM23, uM48 and uM183: "DESCEND TO 70", "CROSS ARTIP AT OR BELOW 100", and "WHEN READY", respectively.

The time that is displayed for the last message in a dialog should be the time that the message was sent by the controller for an uplink message, and the time that the message was sent from the pilot for a downlink message, as recommended by (8).

The iCAS iCWP software supports the configuration by LVNL of tabular lists, presented on the air situation display. Each row of a tabular list displays information corresponding to a single data object. Currently the supported data objects include instances of data classes such as flight plans, tracks and STCA conflicts. These are called driver keys. A new driver key for data link dialogs ('Agdl data') needs to be introduced in the iCWP software. This will enable LVNL to configure a CPDLC list as described above.

The primary source for information concerning open CPDLC dialogs is the track data label; the CPDLC list functions as a supplementary source for more detailed information, to be accessed when needed. For this reason, controllers should be able to place the list on a suitable position on the screen. The iCAS iCWP provides, in addition to the main air situation window (ASW1), also a secondary window (ASW2). The availability of ASW2 depends on the unit: it is, for example, not available on the CWPs of the APP controllers.

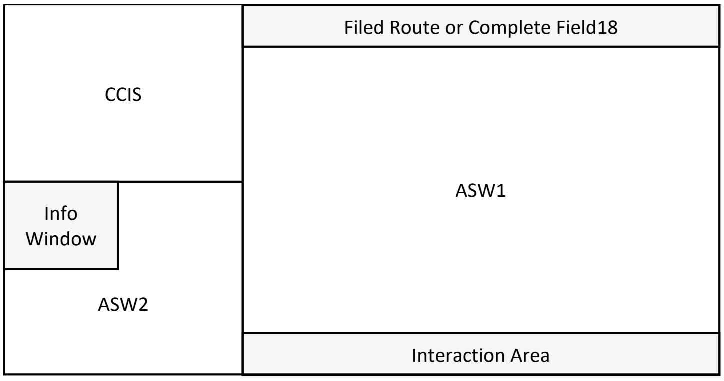

Figure 15: Diagram showing the relative positions of ASW1 and ASW2 on an ACC working position.

The iCWP should support a controller to position the CPDLC list on the ASW2 window, if this window is available on the working position, in order to avoid too large an overlap of information on ASW1.

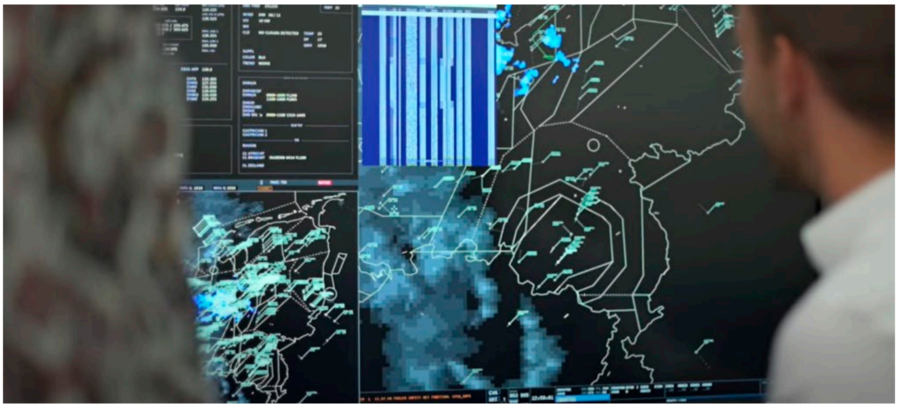

Figure 16: Users behind an iCAS CWP, with on the left CCIS (top) and ASW2 (bottom), on the right ASW1 (12)

3.5.4.2 Design decisions

- The CPDLC list is not the primary HMI element to display CPDLC information, but provides access to the details of CPDLC dialogues, especially for multi-element messages.
- CPDLC related inputs shall be recorded in the list of 25 most recent flight related inputs (see Figure 17). This provides the controllers access to information about closed dialogues, which can be displayed on demand in the input history window.

KLM25W	EFL	200	(140)
KLM25W	HDG		( )
BAW941	EFL	170	( )
KLM433	EFL		(230)
BAW941	EFL	190	(170)
KLM433	TOC		
DLH4ER	EFL		(100)
DLH4ER	HDG	3	(ATP)
KLM25W	EFL	210	(200)
BAW941	EFL	210	(190)
DGDTP	TOC		
SAS827	EFL	150	( )
BAW941	EFL	220	(210)
KLM1159	EFL	190	(140)
BAW941	EFL	240	(220)
CSA9374	REL	RA4	
SAS827	EFL	100	(150)
SAS827	HDG	3	(ATP)
KLM1159	EFL		(190)
BAW941	EFL		(240)
BAW941	TOC		
KLM23Y	EFL		(140)
BEE7CF	HDG	3	( )
KLM23Y	HDG	VAL	( )
KLM891	EFL	190	(140)

Figure 17: Screenshot of the list of 25 most recent flight related inputs displayed on demand in the current AAA system

3.5.4.3 Feedback

- The controller shall be able to select between display of the CPDLC list on either ASW1 or on ASW2.
- The CPLDLC list shall be sorted on the time of the most recent message within each dialogue.
- It should be possible to filter the CPDLC list on ACID.
- It should be possible (i.e. via user input) to display the most recently closed dialog of each dialog type (see section 4.2.2) for a flight.

3.5.4.4 MUAC reference

The CPDLC Dialogues window of the MUAC HMI is shown in the figure below. It also contains the history of uplink and downlink messages. Callsigns are displayed in the second column of each row, but these have been blanked due to the operational reasons. It offers filters to enable/disable the display of uplink messages, downlink messages, and closed dialogs.

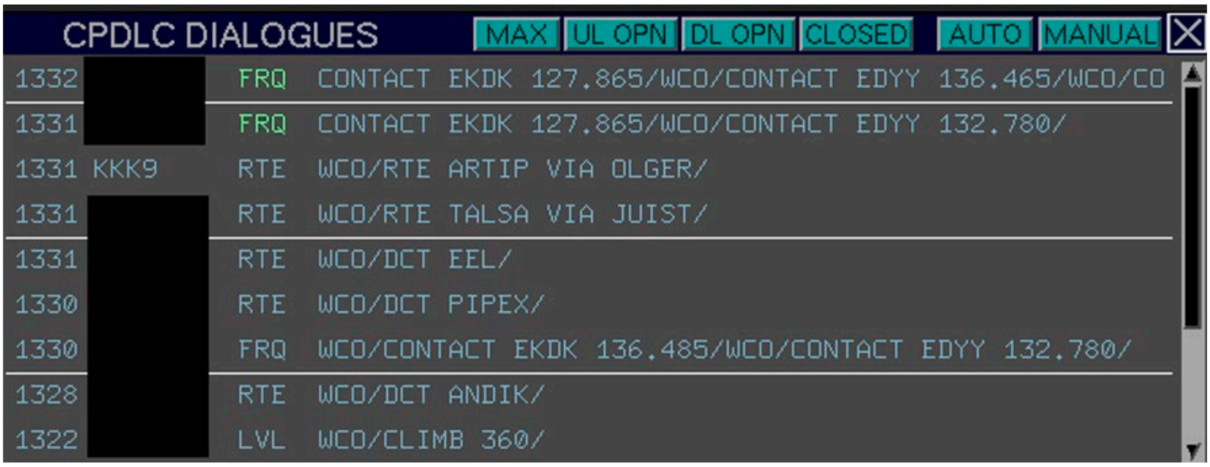

Figure 18: MUAC's CPDLC Dialogues Window (with blanked out callsigns in the second column) (5)

3.5.5 Touch input menu and input template

3.5.5.1 General

User interaction with the iCAS iCWP uses the same input devices as LVNL's currently operational AAA system. The figures below show the roll balls and touch input device (TID) and their relative position to the main screen.

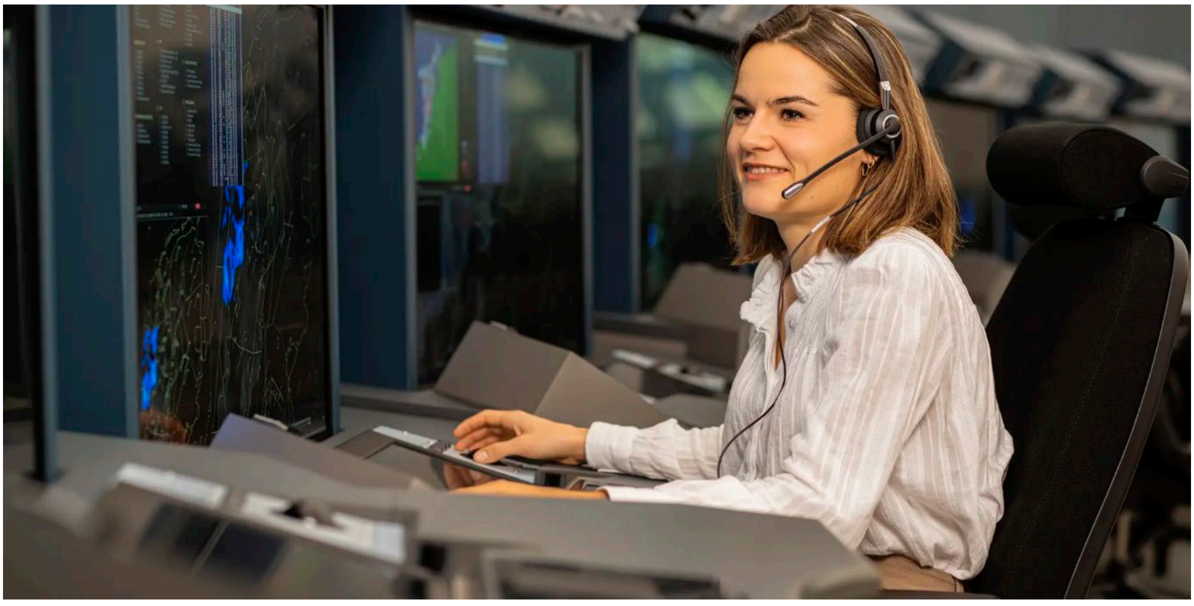

Figure 19: Air Traffic Controller operating the iCAS iCWP in LVNL's new OPS-room (13)

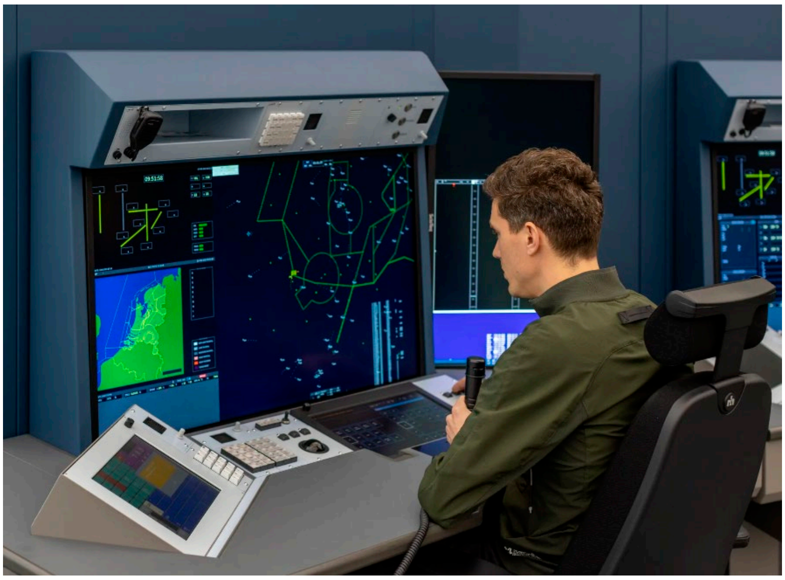

Figure 20: New LVNL Controller Working Position (during system development), including a roll ball at the left hand side and one at the right hand side of the touch input device, both integrated in the desk, and the air situation display with ASW1, ASW2 and CCIS window, and a control panel for communication equipment in the left hand corner of the image (15)

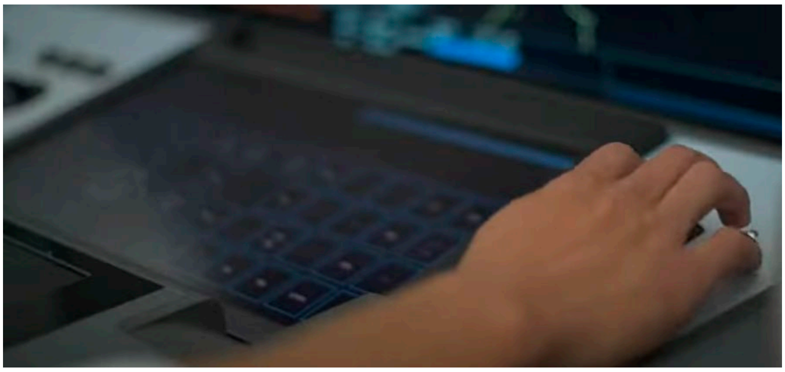

Figure 21: iCAS iCWP TID with input template (blue bar just left of the hand using the roll ball) (12)

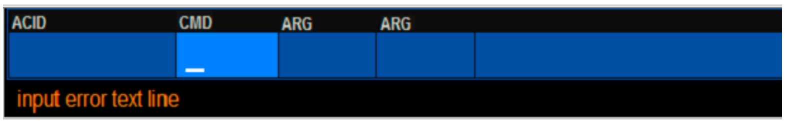

Figure 22: The input template located at the top of the touch input device.

The roll balls allow control over one cursor (or sometimes over two separate cursors) on the main display. They are equipped with buttons to trigger track or flight selection, track label repositioning and other functions.
The touch input device displays buttons organised in hierarchical menus; each button supports user interactions, like press and release, press and hold, double click, and similar actions. The menus are typically organised in menus for control over display settings (on the left hand side of the device) and menus for flight related inputs (on the right hand side). (The roll ball functions and menus can be swapped for left handed users.) Support for CPDLC has been introduced in the prototype by modifying the configuration of the flight related input menus, in a way that lets the controller decide between using R/T or CPDLC in situations where the system provides support for both options.

The main menu page for flight related inputs used in the prototype is shown in the figure below. It is similar to the same menu page configured in the iCAS iCWP: the latter is however still in development. The structure of both versions of this menu is the same. The prototype version includes the following changes:

- new buttons for transfer of control, turn, and rate of climb/descend instructions via CPDLC;
- new button for check stuck microphone CPDLC service;
- new button opening a CPDLC sub menu.

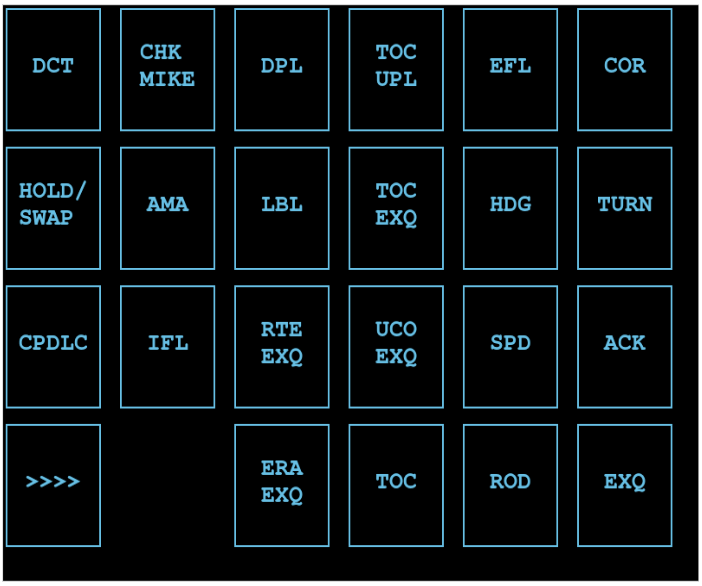

Figure 23: Main input menu for flight related inputs used in the prototype

The main design principle for the menus, however, is to integrate the option to use CPDLC in the existing menus for level, heading and speed inputs. The design of all menus in iCAS and AAA always places an execute ('EXQ') button in the bottom right corner, to complete and confirm an input. As shown in the figure below for the speed menu, use of CPDLC is integrated by providing an "uplink" ('UPL') button, always positioned just above the EXQ-button, but only available if the selected flight is under control at the sector and has an established CPDLC connection. In these situations, the controller decides either to use R/T and tap the EXQ-button, or to use CPDLC and tap the UPL-button.

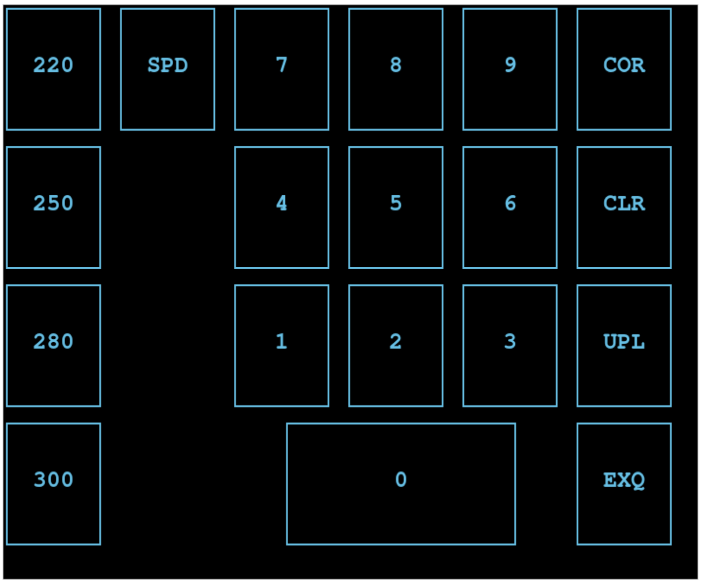

Figure 24: Speed menu with uplink button ('UPL') in the prototype

The design choice to always place the uplink button in the same location implies that some menus have to be adapted. For example, in the Heading menu, the button to open a virtual keyboard ('ANKB') has to be moved to a new location.

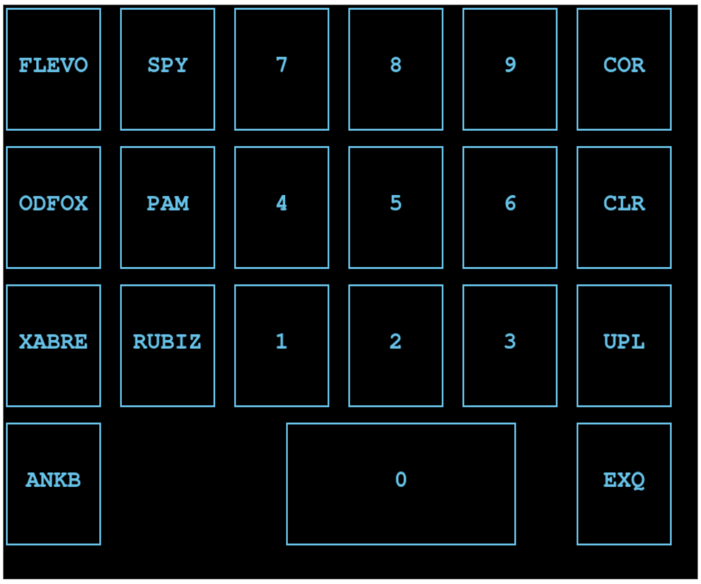

Figure 25: Heading menu in the prototype: the 'ANKB' button has been moved to always place the Uplink button in the same location

The Level menu in the prototype has been modified to use CPDLC including support for complex uplink messages (e.g. combinations with uM47, uM48 and/or uM183). For example, when tapping the 'WHEN READY' button, this text is added to the displayed input template; the controller can then complete the input by tapping the uplink-button. The 'CROSS' and 'WHEN READY' buttons are only enabled after a valid level value has been entered; the system also checks if the use of 'WHEN READY' is supported based on the actual and (to be) instructed level.

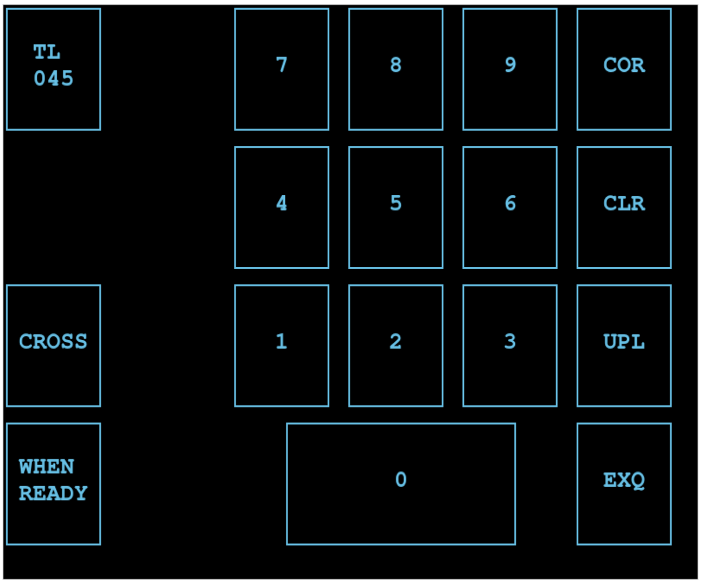

Figure 26: Level menu in the prototype with support for complex CPDLC uplink messages

Tapping the 'CROSS' button in the Level menu in the prototype opens a submenu to input the crossing condition. This submenu contains buttons corresponding to the flight's not yet overflown route points, and a selection of either the 'AT' or 'AT OR BELOW' / 'AT OR ABOVE' condition. The system automatically decides the correct condition based on the actual and to be instructed level.

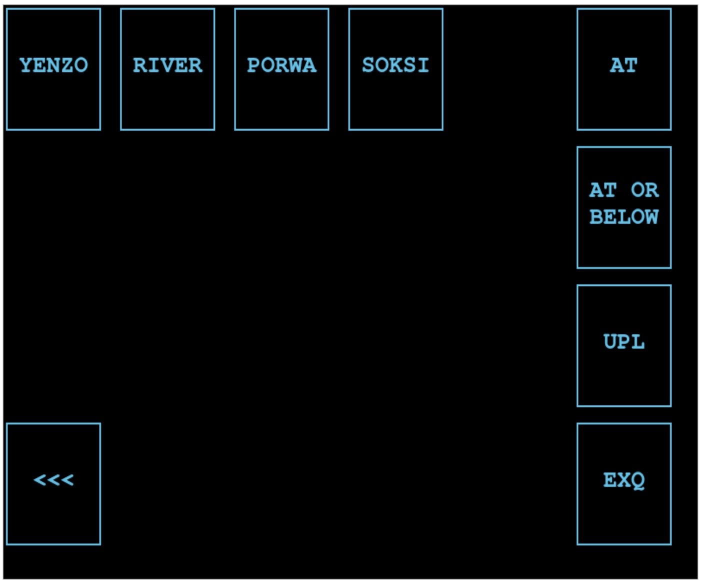

Figure 27: Sub menu in the prototype to input the crossing condition for the level input

After selecting the route point and At or AT OR BELOW condition, a new sub menu opens for the level input to complete the instruction.

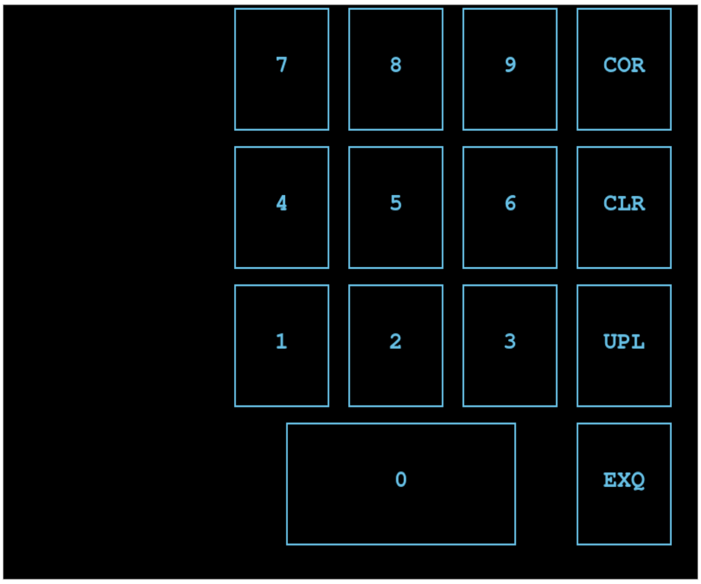

Figure 28: Sub menu in the prototype to complete the "CROSS [position] AT [level]" message

The design of the main menu in the prototype includes an alternative path for the controllers to use CPDLC. The button labelled 'CPDLC' opens the CPDLC sub menu, which provides access to all supported CPDLC services.

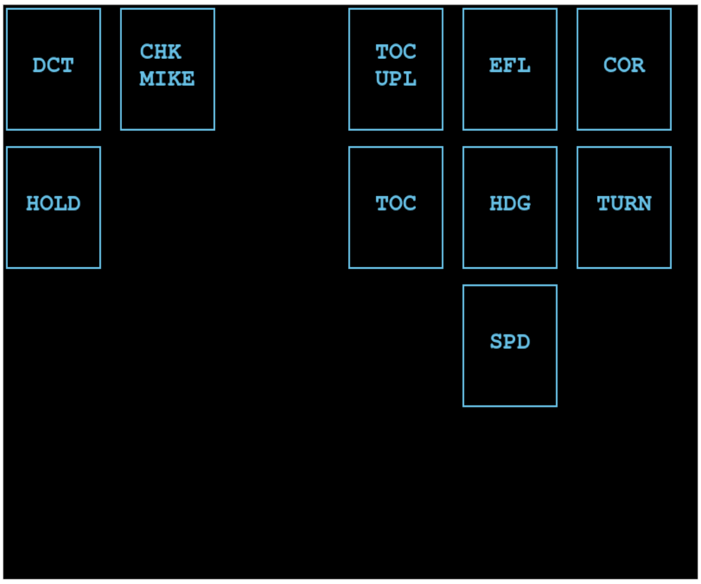

Figure 29: The CPDLC sub menu in the prototype offers an alternative way to use the CPDLC services

The 'CHK MIKE' button in the prototype opens a sub menu that allows the controller to select transmission of the uM157 message to either a selected flight or to all flights on the controller's frequency. If multiple frequencies are in use at the CWP, the menu can also display buttons to select a frequency.

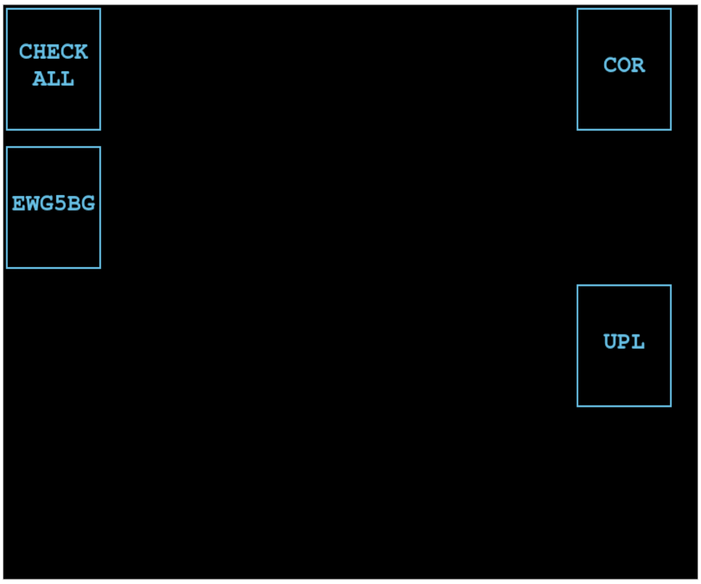

Figure 30: Sub menu in the prototype to complete the check microphone input

Several other menus have been changed to include the uplink button, or have been introduced in the prototype for new inputs. The menus for transfer of communications and for the “TURN” instruction are shown below. The “TURN” instruction is transmitted using the uM190 “FLY HEADING [degrees]” message: the system calculates the new heading based on the input and the heading downlinked via Mode S, before sending the message. The “TURN” input is not supported in the currently operational system, but is supported in the initial message set (section 2.3). Its implementation will require clear notification in the displayed input template of the required *relative* heading, with the appropriate input validation checks.

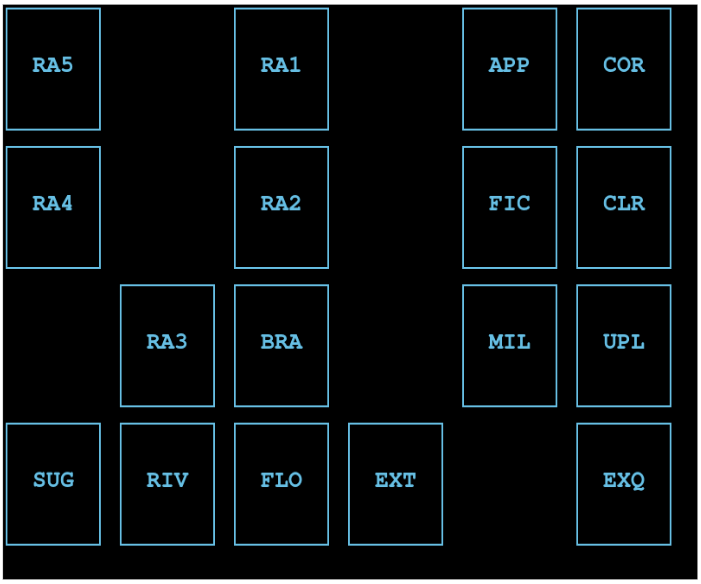

Figure 31: Transfer of communications sub menu with uplink button

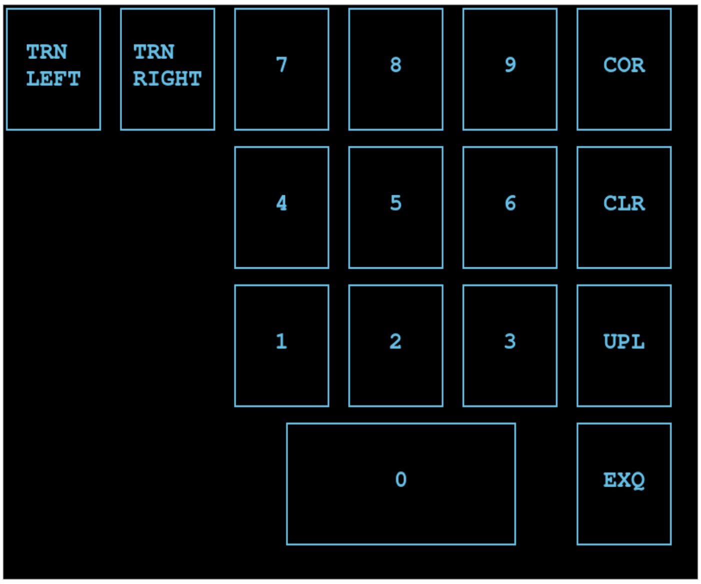

Figure 32: "TURN" instruction sub menu with uplink button

3.5.5.2 Design decisions

- Support for the use of CPDLC is integrated into existing TID menu pages (where applicable), to align with the controller's way of working to first consider the operational situation and then select a method to communicate the corresponding clearance(s) to the pilot.
- The system also provides access to all supported CPDLC communication organised in a separate 'CPDLC' submenu, accessible from the MAIN Menu. This offers an alternative path to access CPDLC services that are difficult to integrated in existing menus, like "CHECK STUCK MICROPHONE", "REPORT …" requests, and also CPDLC list related inputs, for example to close a CPDLC dialogue input, or to enable/disable the display of closed dialogs.
- The menus are organised to minimise the number of input actions that are required.
- Menus allow controllers to decide between the use of R/T ('EXQ') and CPDLC ('UPL') (if the system supports both these options).
- The button currently used (in AAA and iCAS) to complete and confirm an input (labelled 'EXQ') is still placed in its familiar position, and will still correspond to an instruction being communicated via R/T. If the controller can select between data link and R/T, an uplink button (labelled 'UPL') is also shown, placed just above the EXQ button. If a selected input can only be communicated via CPDLC, the EXQ button is replaced by the UPL button.
- The navigation through submenus is (as much as possible) the same for using datalink or R/T, with the exception of using (e.g.) the UPL button (instead of EXQ), and the optional use of submenu's for CPDLC specific message elements.
- Transfer of communication using CPDLC always requires more than a single button tap, in order to minimise involuntary triggering of this input. Instead, this action must require a second step, e.g. in the MAIN men, tapping 'TOC', then tapping 'UPL'.

3.5.5.3 Feedback

- The controllers preferred to have separate buttons for “AT OR ABOVE” and “AT OR BELOW” (see Figure 25), instead of having the system determine the appropriate option (based on actual level and clearance level). For example, if the system determines that a “CLIMB TO” message will be send, only the ‘AT OR ABOVE’ should be enabled, but the “AT OR BELOW” button should still be displayed, as greyed out to indicate it is disabled. This design ensures that the “AT OR ABOVE” and “AT OR BELOW” buttons are always displayed at the same position, to avoid confusion. The “AT OR ABOVE” button should be placed above the “AT OR BELOW” button.
- Although not part of the initial message set, the controllers suggested support in the SPD Menu to select values like ‘279’ and ‘281’: the system should transmit the corresponding CPDLC clearance e.g. “MAINTAIN 280 OR LESS” (uM109), or “MAINTAIN 280 OR GREATER” (uM108), instead of “MAINTAIN [speed]” (uM106).
- The HDG menu shall always include an ‘ANKB’ button (instead of this button only being available after selecting a second menu page).
- The “HOLD AT [position] AS PUBLISHED MAINTAIN [level]” (uM92) CPDLC message should be available via the existing heading menu: after entering (or selecting) a stack point (e.g. ARTIP, RIVER, SUGOL) the system should offer the option to send the “HOLD AT” (uM92) message, and to optionally add an expected approach time (e.g. to also send the uM203 message). Further enhancements could include appending the expected landing runway and optionally an approach type, e.g. using the uM203 message.
- Some of the controllers indicated a preference for also supporting vertical rate clearances via CPDLC, to be added in the Level menu (Figure 24). (This requires support for uplink messages uM171, uM172, uM173 and uM174, i.e. “CLIMB/DESCEND AT [vertical rate] OR GREATER/LESS”; these messages are not part of the selected message set, and are not yet supported by iCAS.)
- When tapping the ‘CHK MIKE’ button (ATC Microphone check service) the system should automatically fill in the callsign of the selected flight in the input template.
- The Transfer of Control Menu for CPDLC should contain an ‘ANKB’ button (which opens a virtual alphanumerical keyboard for frequency input).
- To support the Free Text uplink messages (uM183 or uM203), the corresponding TID menu should preferably support the selection of standardized, predefined texts.
- To support the “CLEARED [procedure name]” message (uM79 indirectly supports it), an appropriate submenu should be designed, which will open after tapping the ‘CPDLC’ button in the main menu, followed by tapping the ‘CLEAR’ button. The submenu supports e.g. the input of a STAR, runway or (night) transition.
- To support the “CLEARED TO [position] VIA [route clearance]” message (uM79), an additional submenu could be designed, which may be opened after tapping a (new) ‘VIA’ button in the heading menu. This submenu should allow the input of the route clearance, which is the route to fly prior to the named position. Selecting a number of waypoints for this purpose, is however a time-consuming activity for the controller. Different options to support the uM79 message should be investigated, like restricting its use to a combination with a graphical route modification (GRM) tool. Such a tool supports for example the direct selection of a sequence of waypoints by clicking on the corresponding positions on the ASW.
- iCAS and AAA support APP controllers in entering combined heading, level and speed instructions. iCAS may introduce similar support also for ACC controllers. The prototype developed in this study offered no support for combined clearances via CPDLC. ICAO prohibits the sending of two (or more) independent clearances in a single CPDLC message, because the flight crew has no way to individually respond to each clearance: see section 4.3.6.2, Note 2 on page 4-14 in (7).

3.5.5.4 MUAC reference

MUAC, DFS and most other ANSPs do not use a touch input device in a similar way for input of clearances: the prototype is based completely on the AAA and iCAS systems of LVNL.

4 iCAS integration

4.1 Introduction

This chapter provides an overview of the software and configuration changes that will be necessary to implement the CPDLC functionality described in the previous chapters in LVNL's ATM system. The changes are based on the new air traffic control system currently being developed by LVNL, in cooperation with DFS and system supplier Indra. The transition by LVNL from the current system, AAA, to the new system, iCAS, is expected to take place in the next few years. An introduction of CPDLC functionality in the current AAA system is therefore not considered.

The basis of the new system consists of the Flight Data Processing (FDP) system component and the Controller Working Position (CWP) component. The sections below first describe the changes required of the FDP functionality to support the selected CPDLC message set. CWP changes required to support controller interaction with the CDPLC functionality as specified in the previous chapter is described next.

The development and configuration effort for the iCAS system is progressing towards the initial deployment: for the purpose of this document the status of the software implementation and configuration as currently predicted to be realised at the end of 2026 is considered as the basis for the description of the changes.

4.2 CPDLC message processing

The iCAS system depends on an Air Ground Data Link (AGDL) server for the actual exchange of CPDLC messages. The iCAS FDP interfaces with this AGDL server, controls the data link logon and CPDLC establishment, and processes CPDLC messages.

The current section first describes which CPDLC messages are already supported by the iCAS FDP, focussing on the messages that are relevant in the scope of the selected CPDLC message set described in chapter 1. This overview is followed by a presentation of those messages of the selected CPDLC message set which are not yet supported by the FDP.

4.2.1 Downlink messages

Shown in the table below are (some of the) supported CPDLC downlink messages, including (in bold) those relevant to the use of CPDLC described in this document.

DM	Message	Dialogue type
dM0	**WILCO**	
dM1	**UNABLE**	
dM2	**STANDBY**	
dM62	ERROR	
dM63	NOT CURRENT DATA AUTHORITY	
dM65	DUE TO WEATHER	

DM	Message	Dialogue type
dM66	DUE TO AIRCRAFT PERFORMANCE	
dM98	[free text]	Instruction
dM99	CURRENT DATA AUTHORITY	
dM100	LOGICAL ACKNOWLEDGEMENT	
dM107	NOT AUTHORIZED NEXT DATA AUTHORITY	

Note that downlink messages to request changes (e.g. a level change) have been omitted from the table. Message dM98 can be combined with dM62, messages dM65 and dM66 can be combined with dM1; but in general combination of messages is not supported.
Use of the selected CPDLC message set does not necessitate support for additional downlink messages by the iCAS FDP.

4.2.2 Uplink messages

The table below shows the supported CPDLC uplink messages, including (in bold) the ones relevant to the use of CPDLC described in this document. Where relevant, the dialogue type of each uplink message is indicated: the iCAS FDP imposes restrictions on the amount of open CPDLC dialogues, based on these types. Only one open dialogue per dialogue type per aircraft is supported.

UM	Message	Dialogue type
uM0	UNABLE	
uM1	STANDBY	
uM19	MAINTAIN [level]	
uM20	**CLIMB TO [level]**	**Level**
uM23	**DESCEND TO [level]**	**Level**
uM74	**PROCEED DIRECT TO [position]**	**Route**
uM117	**CONTACT [unit name][frequency]**	**Transfer**
uM123	SQUAWK [code]	Instruction
uM157	**CHECK STUCK MICROPHONE [frequency]**	**Instruction**
uM159	ERROR	
uM160	NEXT DATA AUTORITY [facility]	
uM162	MESSAGE NOT SUPPORTED BY THIS ATS UNIT	
uM183	**[free text]**	**Instruction**
uM190	**FLY HEADING [degrees]**	**Route**
uM227	LOGICAL AKNOWLEDGEMENT	

Note that, for the uplink message elements shown in the table above, the only currently supported combination is uM159 with uM183. A change of the iCAS FDP component is required in order to allow the combination of uM183 with uM23, to transmit ‘WHEN READY DESCEND …’ clearances to flights only supporting B1.
Compared to the selected CPDLC uplink message set, the uplink messages in the table below are not yet supported in iCAS. The iCAS FDP and CWP components will need to be enhanced with support for these uplink messages. The suggested additions to the initial message set (uM108, uM109, uM171 to uM174) are also included in the table below as they are not yet supported in iCAS.

UM	Message
uM46	CROSS [position] AT [level]
uM47	CROSS [position] AT OR ABOVE [level]
uM48	CROSS [position] AT OR BELOW [level]
uM79	CLEARED TO [position] VIA [routeClearance]
uM92	HOLD AT [position] AS PUBLISHED MAINTAIN [level]
uM96	CONTINUE PRESENT HEADING
uM106	MAINTAIN [speed]
uM108	MAINTAIN [speed] OR GREATER
uM109	MAINTAIN [speed] OR LESS
uM171	CLIMB AT [verticalRate] MINIMUM
uM172	CLIMB AT [verticalRate] MAXIMUM
uM173	DESCEND AT [verticalRate] MINIMUM
uM174	DESCEND AT [verticalRate] MAXIMUM
uM203	“EXPECT <named instruction>”
uM203	“EXPECTED APPROACH TIME <time>”

Note that messages uM46, uM47 and uM48 are introduced to be used in combination with uM20 and uM23. Their implementation should be aligned with Indra’s SkyNex implementation, which will support the same message combinations.

4.3 HMI

Controller interaction with CPDLC functionality is performed via the Human Machine Interface (HMI) provided by the CWP system component. The iCAS Integrated Controller Working Position (iCWP) implements the air traffic situation window displaying surveillance and flight plan information (e.g. as tracks, labels, and in tabular lists). The iCWP also presents additional information (e.g. weather, alerts, system status, information from external systems) and provides menus and (sub)windows to support controller interaction. Some of these menus and windows already include CPDLC related elements.

The iCAS iCWP supports the configuration (e.g. by the ANSP), by means of *rules and adaptation*, of the presentation of track and flight plan related information, and of the presentation of *panels*, which can support interaction with the system. These panels can, for example, be arranged to act as input menus on a touch input device. LVNL will, to a very large extent, use panels and rules and adaptation to implement the HMI for the controllers. This can only be realised if the iCWP offers sufficient ‘building blocks’ which can be used in the rules configuration. Rules are constructed using elements provided by the iCWP software: data from the Data Dictionary (DD) and commands from the Commands Dictionary (CD).

The current section first describes the CPDLC related HMI elements already available in the iCAS iCWP. This is followed by a description of the configurable rules functionality, presenting which functionality is currently not available using the Data and Command Dictionaries.

4.3.1 Menus

The iCWP provides several menus with integrated CDPLC functionality:

- Callsign menu with SEND D/L button and optional input of assuming sector;
- CFL menu with Execute D/L button (FDP determines maintain/climb/descend message);
- Waypoint menu (for DCT input, only from present position) with Execute D/L button;
- Assigned heading menu with Execute D/L button;
- SSR Code uplink (via click on coordination field).

These menus are not used by LVNL: because the controllers use (mounted) track balls the use of such pull-down menus on the radar display is not user friendly. Instead touch sensitive input devices are used; see section 3.5.5.

4.3.2 Windows

The iCWP provides a Data Link Window, displaying uplink and downlink messages, downlink responses and information about the status of uplinked messages and timeouts of expected downlink responses. It also allows the controller to trigger uplink responses and close dialogues.

The iCWP also provides a button to trigger the ‘Check stuck microphone’ message; allowing the controller to select a frequency from a submenu in case multiple frequencies are in use at the CWP. This button is part of the ODS Window button bar, situated at the top of the ASD.

The ODS Window is not used by LVNL: its functions are integrated in the menus of the touch input devices. The Data Link Window in its current form does not fit into the LVNL display philosophy; it would also require major modifications. This document therefore describes its replacement by a new, rules controlled, tabular list, configured using elements from the Data Dictionary.

4.3.3 Rules configuration

The iCWP allows configuration by means of ‘rules’ to control the display of track position symbols, track data label fields and flight plan related information in panels. Rules configuration can also be used to control the display of a CPDLC dialogues list. Finally, rules configuration can be used to define touch input device menus to support CPDLC related controller inputs.

All of the rules related to the display of CPDLC related information, and for the support of CPDLC related inputs, will need to be developed. This will typically involve adding new rules in the already configured rule sets, e.g. to show an uplinked flight level instead of the current CFL.

For the CPDLC dialogues list, the ‘Agdl’ data type needs to be supported as Driver Key for Rules Tabular Lists (as described in section 3.5.4.1.

4.3.3.1 Data Dictionary

The Data Dictionary offers access to information about datalink equipage, CPDLC connection status, CPDLC dialogues and CPDLC messages.

Currently, the frequency (uM117, uM157) item is missing in the AGDL Dialogue Message information.
For the combined messages (e.g. “CLIMB TO [level] (CROSS [position] AT (OR ABOVE) [level])”), the AGDL Dialogue Message type in the DD needs to be extended to contain all information of the combined message. For example, a field may be added to indicate that the level instruction is combined with CROSS AT, CROSS AT OR ABOVE or CROSS AT OR BELOW respectively. Also the AT (OR ABOVE/BELOW) level needs to be added, because currently the data can only contain a single level.

For all the not yet supported CPDLC messages, listed in the table in section 4.2.2, the message items that are not yet in the DD need to be added. For example, a procedure-name item, a direction item, a route clearance item, an altitude item, a speed item, a WHEN READY flag, and a time item.

4.3.3.2 Command Dictionary

The Command Dictionary offers access to the system functionality (implemented in the iCWP or FDP module) related to CPDLC.
Commands are missing for some of the supported CPDLC functions, including Uplink SSR, Uplink freetext, close dialogue, remove dialogue, send “UNABLE” response, send “STANDBY” response, send “CHECK STUCK MICROPHONE” message.
The existing level command needs to be enhanced in order to support the combined messages (like “WHEN READY …” and “… CROSS [position] AT [level]”).
For the selected messages set, new commands need to be added to trigger the transmission or inclusion of the following CPDLC message elements: uM46, uM47, uM48, uM79, uM92, uM96, uM99R (B2), uM106, uM164 (B2), uM203, uM226 (B2).

5 Recommendations

The development and evaluation of a prototype for the integration of the use of a selected CPDLC uplink message set has established the feasibility and controller acceptability, based on a limited number of participating controllers, as described in chapter 2.1. Necessary software changes (to be implemented by the system supplier) and configuration changes (to be implemented by LVNL) have been described in chapter 4.

Based on the relative priorities indicated by the participating controllers for the individual messages in the selected message set, and the estimated effort involved in the required technical implementation development, it is recommended to start implementation with a subset of uplink messages, containing at least CLIMB/DESCEND, FLY HEADING, PROCEED DIRECT and CONTACT. However, in the corresponding system design care should already be taken for the future inclusion of other messages from the message set, especially those messages that require the controller to provide multiple user parameters. A consistent design for the TID menus should be developed that supports both single and multiple user parameter uplink messages.

Experience from controllers working with the first implementation of CPDLC in iCAS (during development, training or operational use) can be used to extend the implementation with the remainder of the messages from the message set. This will involve more substantial effort from the system supplier, mainly focussed on providing access via the iCWP's Data Dictionary to all relevant information of complex or combined uplink messages, in order to present this information to the controller, typically as part of the CPDLC list. As part of this step in the development, more extensive prototyping of the input menus for the complex messages can be performed with the controllers, based on early experience and the feedback provided in section 3.5. The designs presented in this study have been used to establish the feasibility of the integration of the use of CPDLC in the existing HMI based on the iCAS iCWP software. These designs should, however, be further refined and evaluated with a larger group of controllers to optimise their efficiency and ease of use.

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