Joint Authorities for Rulemaking of Unmanned Systems

JARUS

RECOMMENDATIONS ON THE USE OF CONTROLLER PILOT DATA LINK COMMUNICATIONS (CPDLC) IN THE RPAS COMMUNICATIONS CONTEXT

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Contact Person(s)	**Tel**	**WG**
Dominique Colin	+32 272 93182	Leader WG5

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JARUS WG 5

Dominique Colin

Tel: +32 (0) 2729 9826

Fax: +32 (0) 2729 9078

E-mail: contact@jarus-rpas.org

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1.1 Background

1.1.1 The CPDLC application provides a means of communication between the controller and pilot, using data link for ATC communication. CPDLC is a mature technology supported by the appropriate spectrum and an increasing number of aircraft capable of using it.

1.1.2 CPDLC has been developed and regulated for non-RPAS aviation. It is appropriate to observe how CPDLC is defined and operated today, look at the impact of RPAS on this technology and find the best way to accommodate RPAS in the CPDLC environment.

1.1.3 CPDLC is accepted and standardized at the ICAO and regional levels, therefore, it is recommended that any proposed changes to CPDLC be initiated by the ICAO RPAS panel.

1.1.4 RPAS drives a need for a careful look at operational safety within the context of available capability of commercial C2 service provider. Since the critical command-control link of the aircraft system depends on RF performance of RPS-UA radio link, it is bound to impact RPIL-ATC communication and hence the CPDLC messages.

1.2 Purpose of this document

1.2.1 The purpose of this document is to summarize the most relevant information about CPDLC and the supported ATS services, and to associate them with RPAS operations.

1.2.2 This document will propose a set of recommendations to review and change EUROCAE standard ED-228 / RTCA standard DO-350 to cope with the specifics of RPAS. It is recommended by WG 5 that this document be made available to EUROCAE and RTCA.

1.3 Explanation of terms

1.3.1 Acronyms

ATC	Air traffic control
ATS	Ait traffic services
ATSP	Air traffic services provider
ATSU	Air traffic service unit
CPDLC	Controller-pilot data link communications
C2	Command and control
ET	Expiration time
RCP	Required communication performance
RCTP	Required communications technical performance
RPA	Remotely piloted aircraft
RPAS	Remotely piloted aircraft system
RPIL	Remote pilot
RPS	Remote pilot station
TRN	Transaction

TSD Time sequence diagram

TT Transaction time

1.3.2 Definitions

Term	Definition (from ED-228/DO-350)
End System	A system that contains the human-machine interface, application processing, and is distinct from system components interfacing the communication services. Note: This definition is modified from RTCA DO-264 / EUROCAE ED-78A to remove technological dependencies.
Initiator	The human and/or machine that initiates a transaction. NOTE: In some cases a human and a machine may both contribute to the initiation of a message. For example, a human may create a route clearance message and a machine may conduct a conflict probe check on that message and/or append an altimeter setting before it is released
Required communication performance (RCP)	Required Communication Performance is a statement of the performance requirements for operational communication in support of specific ATS functions.
Required communication technical performance (RCTP)	Required Communication Technical Performance is the set of performance requirements bearing on the technical communication ATM/CNS elements within RCP. NOTE: RCTP is a statement of the performance requirements for operational communication limited to the technical communication portions of the communication process. (ICAO)
Responder	A human and/or machine party that is the target of a transaction and is required to provide an operational response.
TRN	Symbol used to designate monitored operational performance.

1.4 Reference documents

The references in this document are listed below:

a. ICAO Doc 4444

b. ICAO Doc 9869

c. ICAO Doc 10019

d. JARUS RPAS C2 Link RCP concept V1.0

e. EUROCAE ED 228 / RTCA DO-350

f. EUROCAE C3 CONOPS

2 Chapter 2 – Overview of CPDLC FROM ED-228/DO-350

2.1 General

2.1.1 Description

2.1.1.1 The data link services provide communication and surveillance capabilities for the ATSU to perform the following ATS services:

a) provide supplemental means to the controller to obtain information on the current position, actual progress, and intended movement of each aircraft for performing separation management;
b) provide supplemental means to the controller to issue clearances and information for performing separation management;
c) provide supplemental means to the flight crew to obtain clearances and instructions; and
d) provide primary or supplemental means to the flight crew to obtain flight information.

2.1.1.2 Data link services for ATS applications are characterized as follows:

a) used in situations where the delay or loss in operational data communications is not significant to the safety of operations. Delay or loss in operational data communications may be significant to operational usefulness of the system.
b) procedures are established to revert to ATC voice communications, as required by operating rules, and within acceptable time limits when data link service can no longer be provided.
c) required ATC communication, e.g., VHF voice, has the functionality and performance to satisfy the operational capability provided by the data link services in the event of loss of those data link services.
d) provides sufficient integrity of operational communications to avoid the need for procedural mitigation of anomalous

2.1.1.3 The CPDLC application provides a means of communication between the controller and the pilot, using data link for ATC communication. This application includes a set of clearance / information / request message elements which correspond to the phraseologies used in the radiotelephony environment.

a) The controller is provided with the capability to respond to messages, including emergencies, to issue clearances, instructions and advisories, and to request and provide information, as appropriate.

b) The pilot is provided with the capability to respond to messages, to request clearances and information, to report information, and to declare or cancel an emergency.

c) The pilot and the controller are provided with the capability to exchange messages which do not conform to defined formats (i.e. free text messages).

2.1.1.4 Ground and airborne systems allow for messages to be appropriately displayed, printed when required and stored in a manner that permits timely and convenient retrieval should such action be necessary.

2.1.1.5 The high level description of the systems and services involved in support of the CPDLC application is provided by figure 1.

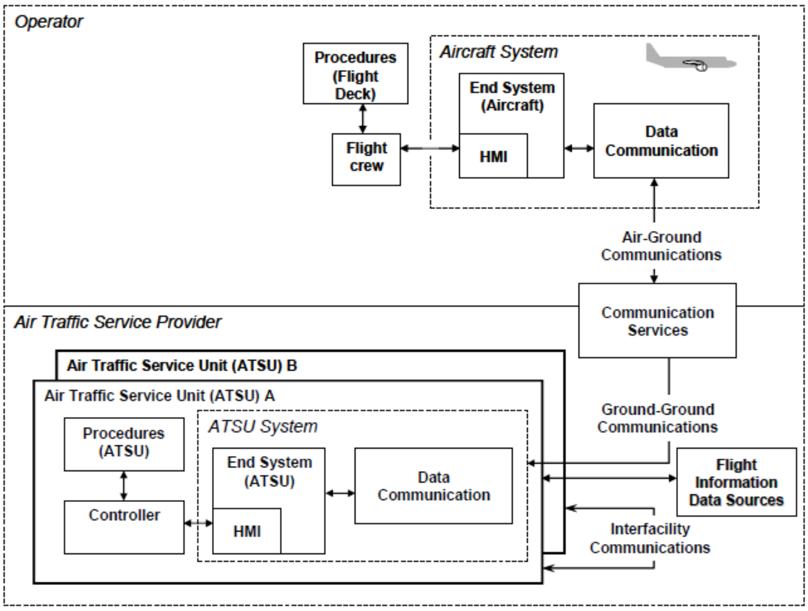

Figure 1 Overview of the CNS/ATM system (ED-228)

2.1.1.6 Stakeholders roles and responsibilities and their interrelationships to ensure the compatibility and interoperability of the system elements are described in ED-228/DO-350.

2.1.2 Apportionment of CPDLC

2.1.2.1 Annex D / page D-10 of ED-228 describes the allocation for CPDLC. The performance requirements are provided against human and ATM/CNS elements of the data communication transaction.

- The ATM/CNS elements are:
- Aircraft system
- Aircraft operator
- ATS provider
- Communication service provider

2.1.2.2 A CPDLC transaction is apportioned into ATM/CNS components for

- Composition and recognition processing (initiator)
- Monitor transaction (TRN)
- Reaction (responder)
- Technical communication (Technical system)

2.1.2.3 The technical system is further broken down into 3 technical sub-systems:

- Aircraft system
- Air traffic service unit (ATSU)
- Communication service provider (CSP)

Each portion has to comply with performance requirements defined by the supported Air Traffic Service (ATS) function and desired operational environment.

2.1.3 Required communication performance (RCP)

2.1.3.1 The Required communication performance (RCP) is composed of the requirements of each of these three portions.

For transaction time, the formula used is:

RCP = Initiator + (RCTP + Responder) = Initiator + TRN

2.1.3.2 The TRN (transaction)

- starts when the initiator portion ends
- ends when the initiator receives an indication of the operational reply.

2.2 CPDLC Performance requirements

2.2.1 The performance requirements are stated in terms of RCP parameters, RCP[1] allocations and TRN allocations.

The allocation table clarifies the sequence and the RCTP apportioned to each of the 3 technical sub-systems (ATSU, CSP and aircraft):

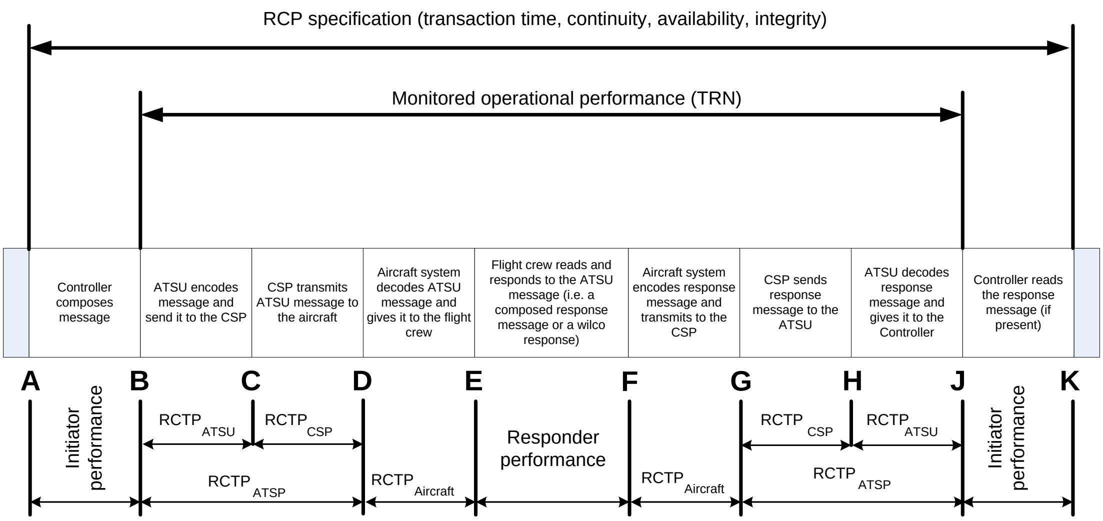

Figure 2 Performance and allocation model from ED-228 / DO-350

2.2.2 The RCP specification parameters described in the standard are:

- delay values for expiration time (ET),
- Transaction time for 95% of all transactions (TT(95%)),

  Note : Transaction time are apportioned per components and technical systems
- Continuity (ATSU, CSP and Aircraft),
- Availability (ATSU, CSP and Aircraft) and additional outage parameters for ATSU and CSP,
- Integrity (ATSU, CSP and Aircraft).

[1] as described in ICAO Doc 9869.

3 Chapter 3 – CPDLC in the RPAS context

3.1 RPAS communications architecture

3.1.1 RPAS communications are commonly broken down as depicted in figure 3. RPAS communication architecture regarding data communications with ATC is one of the following:

- The RPA receives information directly from the ATSP communication service provider and relays it to the remote pilot (architecture type 1, similar to manned aviation), or
- There is an additional network, separate from the ATSP communication service provider, that passes the information to the RPA before the RPA relays it to the remote pilot (architecture type 2) , or
- A direct communication line, which is not relayed by the RPA, is set between ATC and the remote pilot (architecture type 3).

3.1.2 Architecture type 1 has the most similarity with the current ATS data link communications architecture. Architecture types 2 and 3 are of a totally different nature and no standards have been developed yet to support them.

3.1.3 This document will focus on architecture type 1 only. Architecture types 2 and 3 will have to be considered in the future, when RPAS deployment will:

- be mature enough to justify investing into this new communications system architecture, or
- generate a saturation effect on available communications spectrum due to a dramatic increase of the overall traffic.

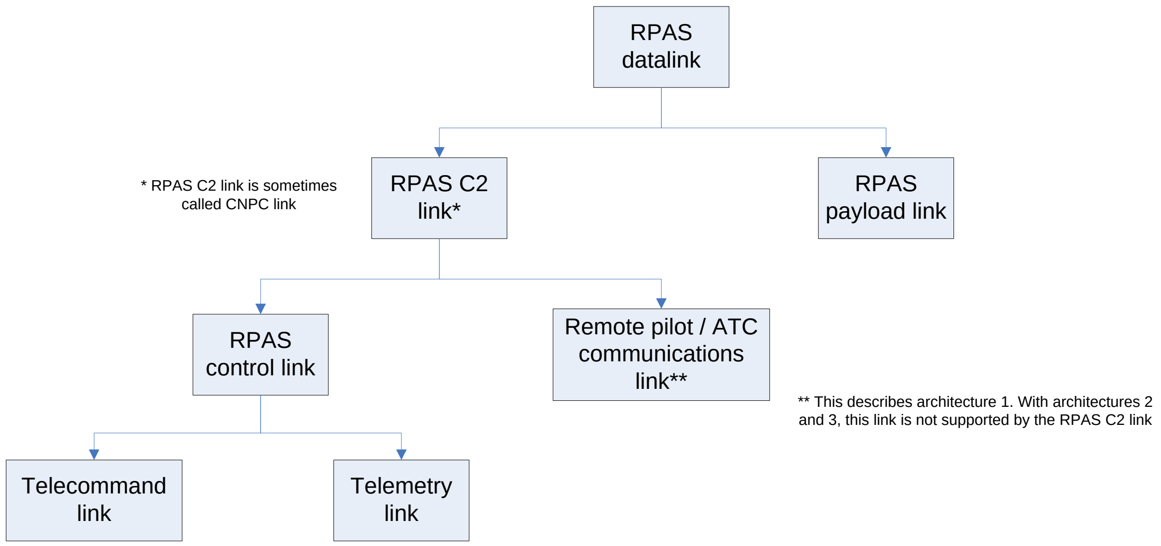

Figure 3 RPAS communications

3.1.4 The ED-228/DO-350 time sequence diagram describing the CPDLC transaction should be modified to be compatible with the RPAS communication system architecture.

3.1.5 It is assumed that an RPAS will have to meet the same CPDLC RCP than manned aviation in the same operational context (e.g. RCP 240, RCP 400…).

3.2 Transposition of CPDLC typology to RPAS

3.2.1 Description of the elements

3.2.1.1 According to ICAO Document 10019, RPA is the aircraft. But substituting “aircraft” by “RPA” in ED/228/DO350 would be functionally inoperative because the ATM data could not reach the remote pilot.

3.2.1.2 To meet the functionalities of the CPDLC operational capability, and to be in line with ICAO Doc 10019, the aircraft system element from figure 1 must be replaced by a RPA element, a command and control link (C2 link) and a RPS element. Those substituting elements must meet the same performance requirements as the former “aircraft”. All the other elements remain the same as components of the current service (figure 4).

3.2.1.3 The main differences to address in the RPAS context are:

- There is another communications service (RPAS C2 datalink) between the aircraft communications system and the remote pilot/HMI. This communication service is of the responsibility (contracted or directly provided) of the RPAS operator; it is not the same communication service provider described in ED-228 / DO-350.
- There are communication systems, data processing and interfaces on board the RPA and in the RPS.

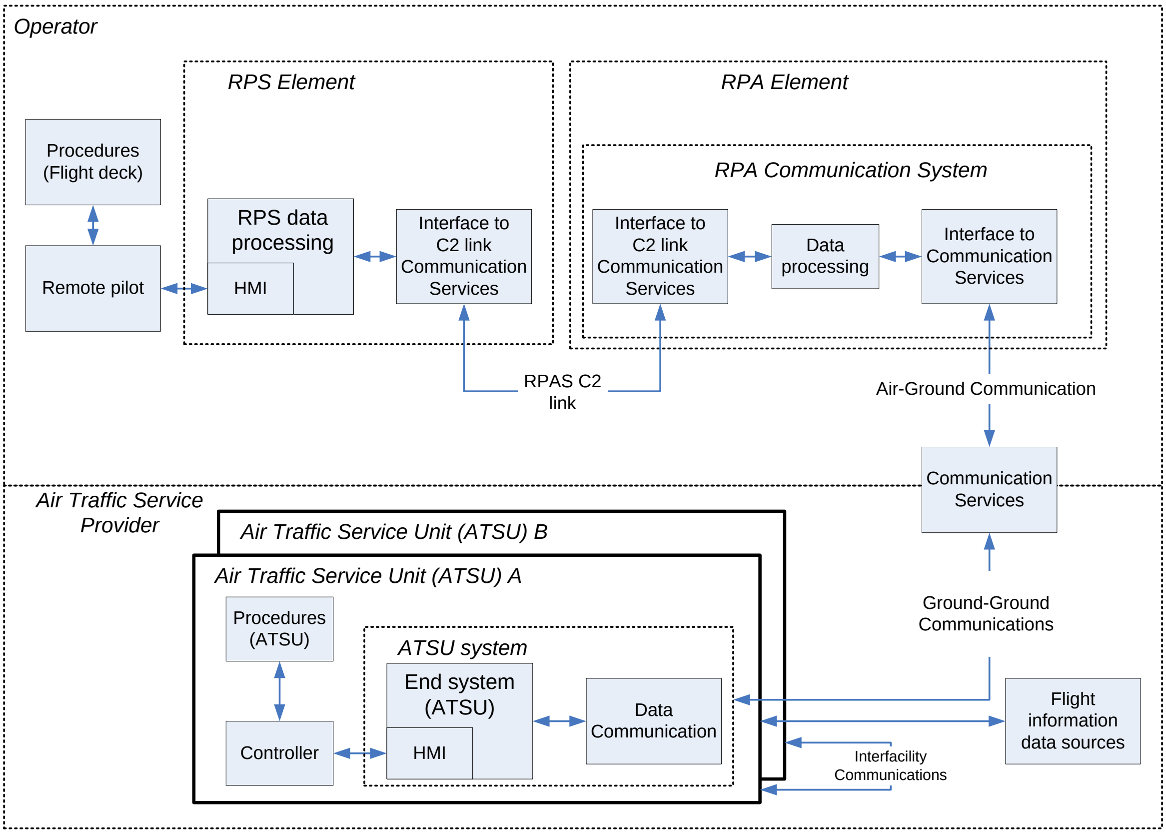

Figure 4 CPDLC application systems and services in the RPAS context (architecture 1)

3.2.2 Description of the portions of the CPDLC RCP model

3.2.2.1 The current apportionment of RCTP in ED-228 / DO-350 to the aircraft implies that the RPA, the RPAS C2 link and the RPS are composing the aircraft allocation, each of them being allocated with a RCTP. It leads to an updated architecture model (figure 5).

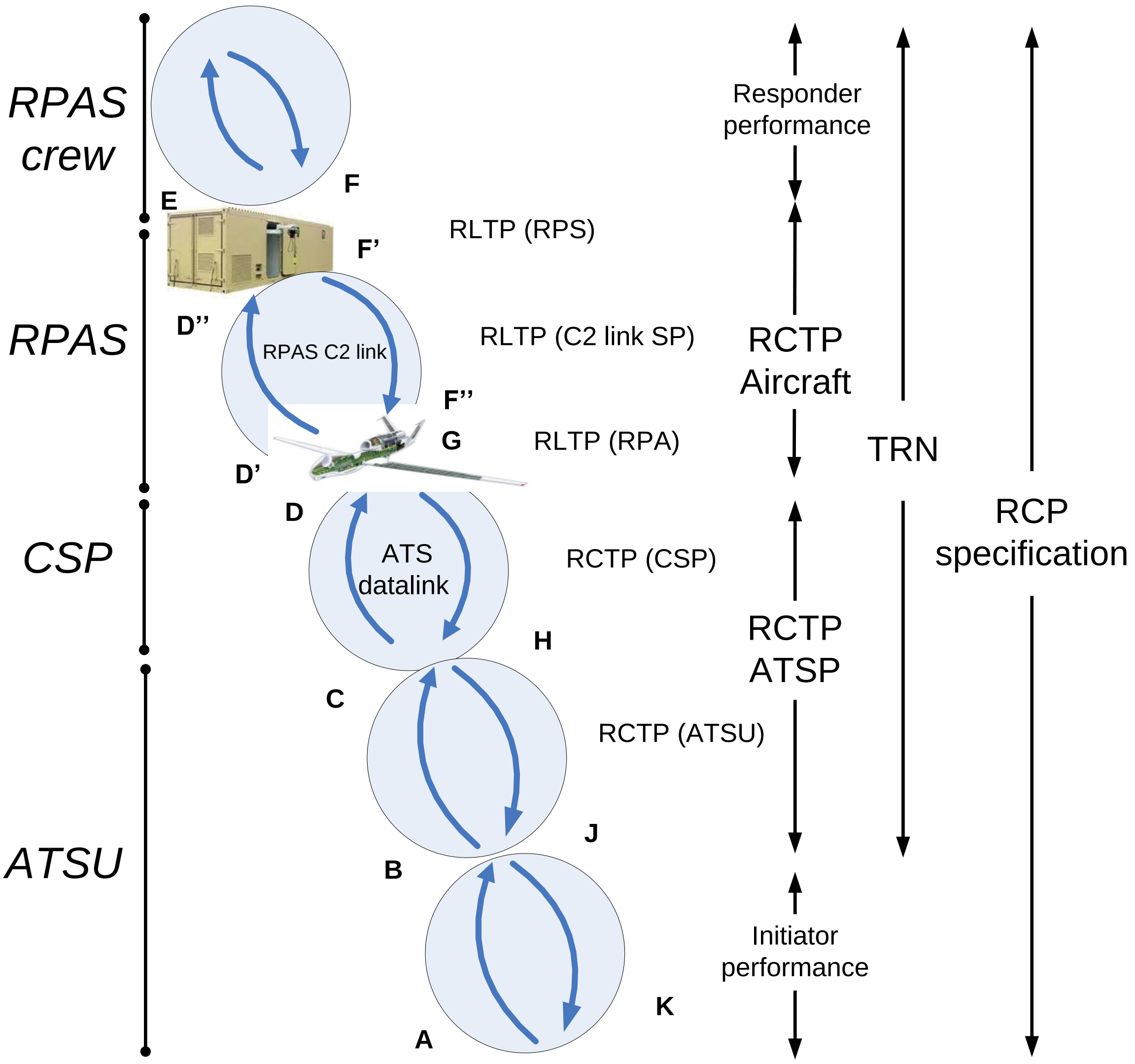

Figure 5 RPAS CPDLC architecture

The C2 Link RCP parts are being changed into RLP to be consistent with the approved JARUS terminology on the "RCP" concept applicable to the C2 Link.

3.2.2.2 The apportionment has to be refined as there are additional sub-systems contributing to the performance at the aircraft level. The [D,E] and the [F,G] portions have to be broken down in 3 sub-portions. The letters D' and D'' (respectively F' and F'') are introduced to take into account the RPA, the C2 link and the RPS sub-systems (figure 6). Figure 4 describes the RPA, the C2 link and the RPS parts as the "RPA communication system", the "RPAS C2 link" and the "RPS element".

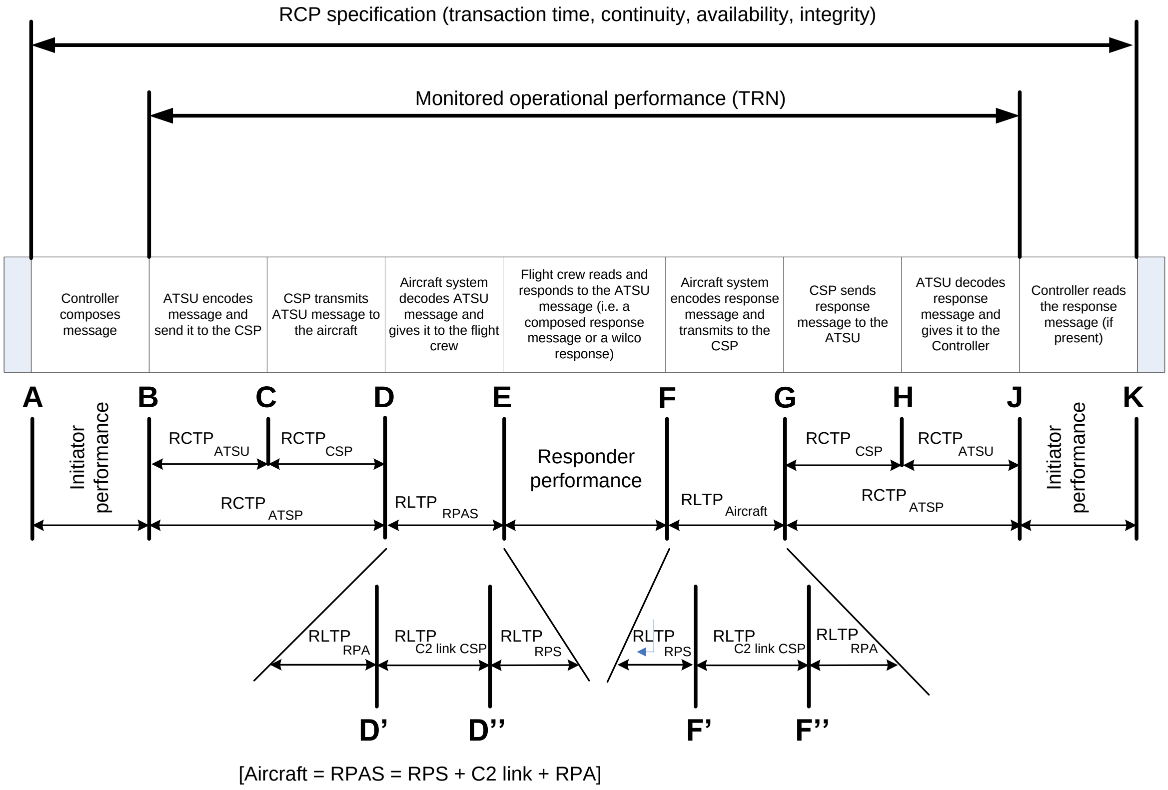

Figure 6 RPAS CPDLC performance and allocation model

The CPDLC time sequence diagram (TSD) is therefore refined as depicted in figure 7:

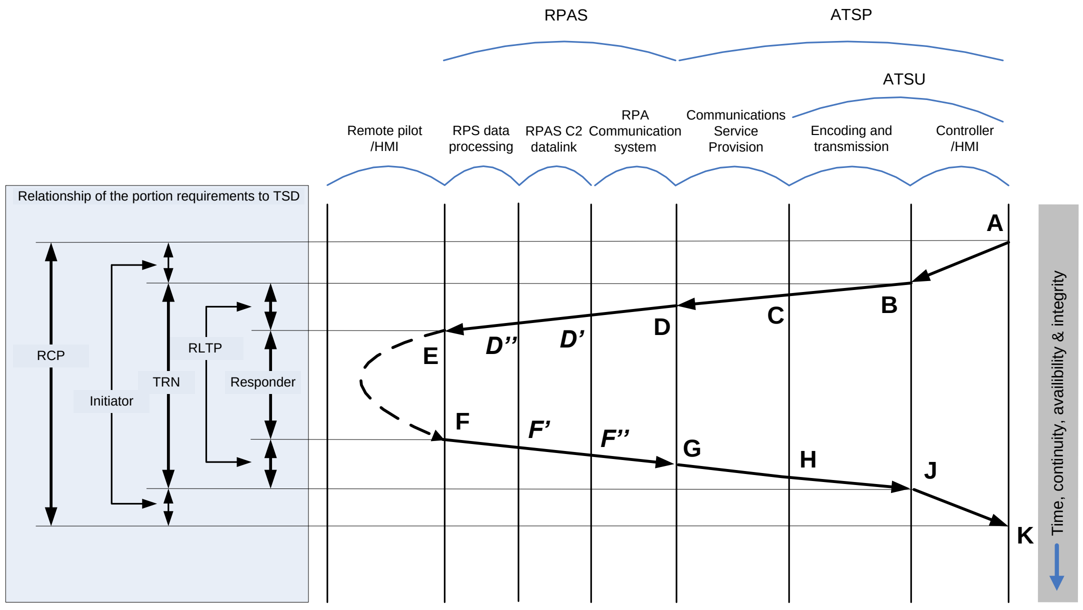

Figure 7 Time sequence diagram for CPDLC in RPAS context

3.2.2.3 In ED-228/DO-350, the performance parameters are set taking into account the safety levels and the operational environment. It is very unlikely that the values will be increased to accommodate the additional RPAS sub-systems and especially the C2 datalink performance, when used for CPDLC purposes.

3.2.2.4 This means that if the C2 link is used to support ATS/voice data services, the RPAS design (and C2 link service provision) will have to comply with the aircraft performance parameter from ED-228/DO350 ($RCTP_{aircraft}$) and its associated availability, continuity and integrity requirements, regardless of the specific design of an RPAS compared to a manned aircraft.

3.2.2.5 Future work plan for JARUS WG 5 could include a study on the relevance of setting availability, continuity and integrity parameters for the C2 link provision unplanned outage.

3.2.3 Demonstration of compliance

3.2.3.1 The aircraft installer should demonstrate compliance to RCP aircraft allocations, and necessary interoperability to provide assurance that the ground control station and UA are compatible with other components of the CPDLC system with which they interface with, as well as post implementation monitoring and corrective action of the RCP aircraft allocations.

3.2.3.2 In accordance with existing acceptable practices, when the operator establishes their contracts with the Communication Service Providers (CSP) it is imperative that they include the required RCP criteria allocated to CSP; and the operator’s responsibilities include operationally monitor, detect and resolve non-compliant performance for the RCP operator allocations.

4 Chapter 4 – Recommendations

4.1 General

4.1.1 Chapter 3 demonstrated that the application of ED-228 / DO-350 in the RPAS context includes additional sub-systems, internal to the RPAS. Those sub-systems have to comply with the aircraft performance parameters

4.1.2 This is a design constraint for the RPAS manufacturers. If the C2 link communication provision is contracted, the operator must demand the C2 Communication Service Provider to comply with the RCP.

4.1.3 JARUS recommends having a harmonized approach towards this issue in order to have a consistent C2 communications service provision contractual framework for all operations.

4.1.4 For the RPAS, the "aircraft system" is composed of three sub-systems. The design of the RPAS will need to consider criticality of the communication transaction time in the performance assessment.

4.2 Evolution of the reference documents

4.2.1 ED 228 / DO 350 standards

4.2.1.1 Some changes would be necessary in ED-228 / DO-350 to better take into account the RPAS operations.

4.2.1.2 It is recommended that ED-228 / DO-350 be amended to include a new section describing the sub-allocation of $RCTP_{aircraft}$ (becoming $RLTP_{RPAS}$).

4.2.1.3 It is recommended that when updating the standard performance metrics, the working groups take into account RPAS as new airspace user when apportioning the performance to the different sub-systems (especially the aircraft component).

4.2.1.4 It is recommended that the standardization working group discuss the relevance of setting availability, continuity and integrity parameters for the C2 link provision unplanned outage, creating a new set of parameters in a standard.

4.2.1.5 It is recommended that CPDLC message specifications in ED-228/DO-350 on phraseology and protocol are updated to accommodate CPDLC RPAS comm.

4.2.2 ICAO Documents

4.2.2.1 As a first assessment, nothing fundamental will be required. The documents mainly requires including RPAS terms and specifics.

4.2.2.2 For Example PANS ATM section 14.1.3 states "Ground and airborne systems shall allow for messages to be appropriately displayed, printed when required and stored in a manner that permits timely and convenient retrieval should such action be necessary". For RPAS, the notions of ground and airborne are blurred, especially because the remote pilot could be on the surface (ground, maritime), or airborne in another aircraft. Such sentences could either be modified or a note could be added to adapt to RPAS.

4.2.2.3 In general, any text referring to "airborne" or "pilot" (e.g. title of PANS ATM 14.2.2 section) has to checked and be adapted accordingly.