OPERATIONAL DATA LINK PANEL (OPLINKP)

WORKING GROUP C MEETING

Rio de Janeiro, Brazil, 16 to 21 March 2000

SUMMARY OF DISCUSSIONS AND CONCLUSIONS

(Presented by the Rapporteur)

1. INTRODUCTION

1.1 The meeting was chaired by Mr. Roy Oishi, and the Secretary of the OPLINKP, Mr. Chris Dalton provided advice and coordination support for the meeting.

1.2 Working Group C (WG/C) was established at the fifth meeting of the Automatic Dependent Surveillance Panel (ADSP/5, Montreal, 18 to 29 October 1999), and had progressed its work through correspondence, this being the first meeting since that time. The meeting noted that the Air Navigation Commission had supported the need (ADSP/5, Recommendation 5/2) to change the name of the panel to the Operational Data Link Panel (OPLINKP).

2. WORKING ARRANGEMENTS

2.1 The meeting was held in Rio de Janeiro, Brazil, and was attended by 11 panel members, and 9 advisors. A list of participants is at **Appendix A**.

2.2 A list of working papers is at **Appendix B**.

3. AGENDA

3.1 The meeting opened with a review of the draft agenda, which had been circulated by the Secretary. The meeting approved the following agenda:

Agenda Item 1 Development of the concept of required communication performance (RCP) with specific regard to Human Factors issues

Agenda Item 2 Additional sections for the RCP document and the development of those sections of the RCP concept that require increased detail

Agenda Item 3 Any other business

4. **Agenda Item 1: Development of the concept of required communication performance (RCP) with specific regard to Human Factors issues**

Note.— Amendments to the operational concept of RCP (version 1.0 presented at ADSP/5), consequential to discussions held on Agenda Items 1 and 2, can be found at ***Appendix C****.*

4.1 WP/53 presented the case for careful consideration of the perceptual, cognitive, and physical capabilities and limitations of the human in the design and evaluation of systems. Such consideration was seen to assist in minimising the probability of human error, mitigate the effects of the inevitable human errors, reduce the system's technical and safety risks, and minimise the implementation and life-cycle costs. Furthermore, when human factors were ignored or only minimally considered, there was a risk that the system would be cumbersome or operationally unacceptable. Projections of risk and benefits of a system often unwittingly assumed a good human factors design. This assumption was seen only to be prudent when the design had been shown to be sound, from a human factors standpoint. The projected benefits of a given system, whether stated as such or not, are totally dependent upon the equipment being designed to fit the user and the task.

4.1.1 The purpose in measuring the human response time was to determine the time required by the task, with specific equipment in operationally representative conditions. It would be a test of the operational suitability of the equipment in that it tested whether the design of the equipment can support the human response time assumed in models of risk and benefits. System response time, on the other hand, was the time required for the users to perform the function that the system was designed to perform. It was system performance that is measured to determine whether or not the system is operationally suitable for specific uses.

4.1.2 The working paper also expressed the importance of distinguishing between measuring the performance of a component of a system and the performance of the total system. For example, in en route voice communications, this could be equivalent to comparing the error rate of the voice switching and control system to the operational communication error rate. In comparing the operational error rates of different communication systems e.g. voice versus data link, consideration should be given to the proportion of total communications that were successful i.e. a successful controller-pilot communication would be defined as a transmission by a controller to an aircraft that had been correctly acknowledged by the pilot. Controller-pilot communication error rate has been defined as the proportion of the total number of controller-pilot transmissions that need to be repeated by the controller for any reason e.g. due to a blocked transmission, lack of a response by a pilot when one is required or an error in the pilot's response (read back error).

4.1.3 It would not be operationally useful to measure communication error rate solely as the failure of the radio devices to successfully transmit the message e.g. due to a blocked communication or radio failure. Clearly, the communication of a clearance would not be considered successful, if there was no indication that the pilot for whom the transmission was intended, received it. For example, when a transmission was acknowledged by an aircraft other than for the one for which it was intended, the equipment had successfully performed its intended function, but operationally, there was a serious communication error that must be corrected. Similarly, when the system response time is considered, the time required for the system to complete its intended function has to be taken into account. The working paper contended that this could be defined in two ways:

a) the time required for the sender to receive an acknowledgement that the transmission is available on the other end (e.g., a logical acknowledgement); or

b) the time required for the sender of the message to receive an indication that the message has been received by the person for whom it was intended (e.g., a correct pilot read back).

4.1.3.1 The first represents the time required for a transmission to be successfully sent. The latter represents the *round trip* time required for a transmission to be successfully sent and received.

4.1.4 The working paper also noted that the time required by the human to perform a specified task represented a test of the system interface (and to some extent, the training), not of the person. The system would need to be designed to allow the user to be *able* to respond within a certain amount of time, but in no way should it *require* the user to respond within a specified time. Task management would always be left to the discretion of the operator.

4.1.5 Consequently, the working paper proposed that the RCP operational concept should include appropriate text to make this distinction clear and to state what human performance was included within RCP and what was excluded.

4.1.6 In discussing the working paper, the point was made that the author of the working paper had attempted to gain some consensus on human factors issues by separating the user interface to the communication system from the reaction of the user to the message. One method that human factors professionals have used in this regard, was the determination of nominal values for human performance times under representative conditions. It was pointed out that this method alleviates concerns about the wide variability of actual human performance.

4.1.6.1 Some of the concerns which have been previously raised were expressed during the discussion:

a) whether the RCP covers one-way or two-way communications;

b) whether the human is or is not included in the RCP concept; and

c) whether RCP is a stated requirement or whether it is a measure of one system's performance.

While there was some objection to what appeared to be "covering old ground", it was determined that the discussion was valuable in that new insights might be gained and that the resultant improvements to the operational concept document would convey those insights to those not privy to the discussions of the group.

4.1.6.2 An opinion was expressed that decision making should not be included, whether it be by human or machine. The assertion was made that there was either a need to consider ADS communication requirements or to decide that RCP deals only with the Communications (C) of Communications, Navigation, Surveillance (CNS). It was suggested that the group needed to clarify the meaning of *end-user of the communications*. If it were a surveillance system, it may not necessarily include the human element. Considerable discussion ensued on these points. It was suggested that a diagram illustrating the relationships among the communication, navigation, and surveillance elements of air traffic management (ATM) needed to be created to clarify these points.

4.2 WP/53 also made the following points with respect to the measurement of system response times. In order to determine whether a specific air-ground communication system would be able to support specific types of operations e.g. to relay time-critical messages, critical measures of system performance must be assessed. Such measures would include:

a) probability of system failure;

b) probability of human error induced by the system e.g. sending a message to the wrong aircraft, relaying the wrong information, etc; and

c) the time required to relay a message (from the controller to the pilot or vice versa) using the system.

4.2.1 The time required for a controller to select or construct a message and relay it to the pilot and for the pilot to notice the message was available, select it (if necessary) and read it were necessary components of the time required to successfully relay a message.

4.2.2 Following on from this, if the purpose of a system was to transmit data from one port to the other, then the response time would simply be the time required for this transmission to be completed. If however, the purpose of the system was to transmit a message from one person to another, then the human response time would necessarily have to be included. Any projection of benefits to be derived by a communication system e.g. to reduce frequency congestion; or models that would include measures of system performance, must include the human component of the system response time. If it did not, the projection would be seriously flawed.

4.2.2.1 During the discussion it was pointed out that the recommendation in the paper challenged the group to determine whether RCP actually measured what a specific human could do or whether RCP specified a target or goal. To answer that question, the opinion was expressed that RCP should not propose the measurement of a given human but what was possible to be achieved.

4.2.2.2 It was noted that ADSP/5 (Report on Agenda Item 3) had accepted that the figure contained in the draft RCP concept (appendix to the Report on Agenda Item 3), showing the overall communication process (now referred to as the Lafferton Model) represented the extent of RCP with the caveat that partial pathways in the communication system could be specified in some instances. That, if the human response time component was not included for a specific use of RCP, that the definition must then clearly specify what was and what was not included in the RCP model. There was general agreement that the Lafferton Model remained the overall representation of the extent of RCP but that draft material was needed to more clearly illustrate the context of the *communication process*. It was also recommended that a definition of *communication process* be drafted.

4.2.3 It was suggested that it was necessary to consider an entire service in order to establish the full scenario for communication and that sometimes one-way communication would be appropriate. It was pointed out that in many cases the same communication system would be used for surveillance and communications e.g. automatic dependent surveillance (ADS) and controller-pilot data link communications (CPDLC) using the aeronautical mobile-satellite service (AMSS). The question was asked whether or not there would be a need for many different RCP types. The point was extended to say that there may be a need to define *required pilot performance* or *required controller performance* or *required air traffic service performance*. While these were clearly out of the scope of WG/C it was agreed that some of these considerations had an effect upon RCP.

4.2.3.1 Support was expressed for the RCP to cover the two-way communications with the human performance included, as currently shown in the Lafferton Model, with the caveat that flexibility be included to cover partial communication paths in the concept. The group agreed that trying to refine the operational concept for all possible communications scenarios was not a reasonable goal for presentation to the Air Navigation Commission. It was decided that the group would develop the operational concept for controller-pilot communications while keeping the flexibility in the concept to support other scenarios.

4.2.3.2 It was pointed out that the time to respond for each CPDLC message would depend on traffic complexity, controller workload, and many other factors. If there were to be a different RCP type for each of these, the RCP concept would be very complex, difficult to realize and, consequently, of no benefit. It was generally agreed that such a plethora of RCP types should not be included in, or implied by the operational concept.

4.2.3.3 The group confirmed that RCP must include the human reaction time but that it must be clear that groups like the Review of the General Concept of Separation Panel (RGCSP) should set the values for particular RCP types, considering both intervention time and interface time.

4.2.3.4 The opinion was expressed that RCP should be in terms of *the ability of the system* to allow intervention. Also, it was acknowledged that there were other factors, such as air traffic considerations, task priorities, etc, which were external to communication performance.

4.2.3.5 The information from the working paper was considered valuable, bringing forth the confirmation that for controller-pilot communications, the human reaction time must be included within the RCP concept.

5. **Agenda Item 2: Additional sections for the RCP document and the development of those sections of the RCP concept that require increased detail**

5.1 WP/59 consisted of four diagrams which illustrated the idea of *service time*. Five scenarios were presented:

a) Separation;

b) Separation — Radar/very high frequency (VHF);

c) Separation — Radar/VHF (voice communications error);

d) Separation — Pilot Report/high frequency (HF) via a third party operator; and

e) Separation — ADS/CPDLC/aeronautical telecommunication network (ATN).

5.1.1 Each diagram showed the *service time* being composed of a sequence of alternating *RCP time* and *user information processing time* elements. Each service consisted of a sequence of communications between aircraft/pilot and controller with *communication of information* arrows shown, going between the two participants.

5.1.2 The *communication of information* arrows were annotated to illustrate the various components of the communication between the pilot and controller. It was noted that sometimes there was an overlap between *RCP time* and *user processing time*, such as when a pilot initiated an activity e.g. the processing of a clearance received, while simultaneously initiating a communication response.

5.1.3 In reviewing the working paper, the suggestion was raised that the “Separation — Radar/VHF” diagram made an inappropriate application of RCP in a surveillance situation. The paper was written from the point of view that RCP was to cover the communication of information. Whether that information was radar target information or clearances made no difference. It was noted that the Air Traffic Management Operational Concept Panel (ATMCP) was developing the concept of required total system performance (RTSP). One possible approach envisaged encapsulating all system capability aspects such as RNP, RCP and required surveillance performance (RSP). This would require further elaboration of RSP. The suggestion was made that these diagrams in the working paper may be appropriate to their work.

5.1.3.1 In attempting to categorize the interrelationship between the communications, navigation and surveillance, their relationship to the provision of air traffic management and the limits by which the RCP concept would support a total system performance the working group produced three figures:

a) Figure 1 (page C-4 refers) showed that air traffic management as being comprised of air traffic services and other components. Air traffic services consisted of air traffic control services, flight information services and alerting Services. Each of these services could be broken down into specific services, such as separation services or monitoring services. Communications, navigation, and surveillance supported these services. RCP would be used to specify communications performance necessary to support these services within a designated environment considering, for example, traffic density, separation standard, message volume, etc;

b) Figure 2 (page C-5 refers) showed that communications, navigation, and surveillance may have areas where their characteristics overlap. For the case of communications, this would mean that there were applications wherein communications supported:

   1) navigation, such as differential corrections for global navigation satellite system (GNSS); or

   2) surveillance, such as the communication of position information by data link; or

   3) both, such as in ADS, where the navigation system provides position information to the communication system which carries the information to the surveillance system for display.

c) Figure 3 (page C-6 refers) showed a pie chart which illustrated that there were several aspects of communications including, controller-pilot, human-machine, machine-machine, and controller-controller. To illustrate the idea that the initial RCP concept would address the controller-pilot aspect, the appropriate section of the pie chart was separated from the remainder.

5.1.3.2 It should be noted that the relative sizes of the various components of the diagrams should not be interpreted as a representation of the relative importance of the various components.

5.1.3.3 In discussing WP/59 further, it was noted that ADSP/5-WP/9 included tasks associated with operational issues concerned with communications only. Furthermore, the RCP concept needed to be a framework which allowed an allocation process to be developed for the requirements of all elements of the system. It was generally agreed that the RCP concept should take into consideration issues such as how verification of compliance with a specified RCP type might be accomplished. The view was taken that if the operational concept for RCP could not be promulgated and communication systems could not be qualified, then the concept would not be useful.

5.2 IP/51, whilst issued as an information paper, demanded discussion in recognition of its detailed critical review of the RCP concept. The meeting noted that the paper had been written as a technical review note to an April 1999 draft of the RCP concept, and consequently, it was recognized that several of the comments in the paper have already been addressed. The information paper was reviewed with the view that suggestions made by the paper would be considered, and either be endorsed or not. If endorsed, the action to be taken would be considered from the point of view of who was the appropriate group to take the action (WG/C or some other group). IP/51 was reviewed in some detail and comments by WG/C were recorded as appropriate. This annotated version, with WG/C comments in text boxes, is at **Appendix D**.

5.2.1 While the majority of the discussion items were summarized in the resultant comments included in the appendix, it was recognized that two points made in the paper needed to be highlighted:

a) a number of the points made in the paper referred to details of the implementation of a communication system. These details, whilst being important in the examination of a specific communication technology and a specific system to support that technology, were not relevant to the determination of the communication performance required in the context of an air traffic service. This point must be made clear and the drafting group was directed to attempt to address this issue; and

b) the authors were commended for a very thorough job, noting that they had presented several important ideas. However, details such as layout and position of transmitters and receivers, while important considerations, could be included within the availability, delay, and continuity parameters which were already a part of the RCP concept. Having made this point however, it was recognized that the greater the assurance that the performance was met, the higher the user confidence will be in the communication system. Furthermore, the orientation of the paper was toward data communications while the operational concept of RCP included both voice and data. There would be a need for an approval method to determine qualification for the most critical applications.

5.2.2 IP/51, as well as WP/58 (see below), suggested that the definitions of the RCP parameters could be improved and, consequently some changes were made to the definitions of the communication process time, availability and continuity of function parameters.

5.3 WP/58 proffered that if RCP was limited to cover only those uses of the communication channel which deal with person-to-person communications, i.e., pilot to controller and vice versa, then the issue of round-trip or one-way, was no longer in question. All person-to-person transactions needed some form of acknowledgement. It went on to suggest that the same data link could be used to support these communications, as well as supporting surveillance applications, e.g. ADS. Such a situation could be addressed by presuming that a surveillance performance requirement specification would include this kind of communications.

5.3.1 The paper also proposed refinements to the definitions of the RCP parameters.

5.3.2 An attachment to WP/58 included a description of work being progressed by the joint RTCA Special Committee – 189/EUROCAE Working Group 53 — Subgroup 3 (Air Traffic Services Safety and Interoperability Requirements) (Position Paper P/SG3/16). It described the work by the subgroup on extending the RCP concept down to the technical processes, something that would need to be accomplished in order to implement the RCP concept. The paper was not presented in any detail but was considered as information by the group. The working group recalled the recently made plans to hold a joint meeting between the WG/C and the RTCA SC–189/EUROCAE WG53 — SG3, 3 to 4 April 2000, in Seattle. The purpose of the meeting was to share thoughts on the operational concept for RCP being developed by WG/C and the communication performance determination, specification, measurement and analysis work being developed by SG3. The agenda would cover the following points:

a) overview of the C, N, and S elements relationship to generic performance requirements;

b) presentation from WG/C of the draft RCP operational concept;

c) presentation from SG3 of Operational Performance Analysis; and

d) discussion of communication performance requirements.

The meeting also noted that WG/C participants were welcome to stay for the three day SG3 meeting that would follow immediately after the joint meeting (5 to 7 April 2000).

5.3.2.1 The working group agreed that it was important to distinguish between system-independent and application-independent. RNP and RCP should be system-independent but each should be specified for a particular air traffic control service, in a particular context.

5.3.2.2 The suggestions in the paper with respect to parameter definitions were dealt with and were reflected in the new draft version 1.1 of the RCP operational concept draft document in Appendix C. It should be noted that the definition of communication process time was changed to refer to the maximum time for the completion of a two-way dialogue.

5.3.2.3 It was pointed out that the attachment to the working paper suggested that the human performance would be measured with the same parameters as RCP as a whole. This was in contradiction to the action taken at ADSP/5 where it was agreed that the human performance would only contribute to the time parameter. This point would have to be made to SG3 in order to maintain consistency between the RCP operational concept and the detailed implementation documents. It was noted that there was considerable commonality between the joint RTCA SC–189/EUROCAE WG53 — SG3 Position Paper P/SG3/16 and the RCP operational concept as it was evolving in WG/C.

5.4 It was suggested that it was necessary to make clear that the RCP type needed for a particular service was derived from the operational requirements of that service. This would necessitate an analysis of the operational environment and level of service to be provided. Consequently, new material was added to the concept (paragraphs 2.2.2 and 2.2.3) asserting that RCP types would be imposed by States. However, often the RCP type needed for a specific service would be determined by a group such as the RGCSP for communications performance needed to support a separation service for a particular separation minimum.

5.4.1 Once an RCP type had been determined, and a state had imposed that requirement, then it would be necessary to qualify particular communications systems. This process might begin with a detailed examination of the proposed communication system and an analysis which determined whether it did, or did not meet the required RCP type. Other than making it clear that this sort of qualification was necessary, and that some consideration had been given to making this qualification process possible, it was agreed that the operational concept of RCP should not attempt to describe this process.

5.5 A further proposal supported by the working group included the need to highlight the fact that where a particular communication system was qualified to meet an RCP type, it could not be assumed that the system would automatically comply with an apparently less rigorous RCP type (paragraph 2.2.5 of Appendix C).

5.6 The group then engaged in a discussion of the consequences of some of the modifications made to the introductory material. By introducing definitions for such concepts as communication process and communication system, there is an opportunity to reduce the ambiguities present in the draft with respect to things like references to “transactions”, “dialogues”, etc. It was recommended that WG/C members review the terminology contained in the current draft RCP concept in Appendix C and present material as appropriate, at the next meeting in berlin, that would effectively reduce any ambiguity still prevailing in the document.

5.7 WP/57 presented a number of editorial corrections to the draft. The results of WG/C’s discussions on these corrections are reflected in Appendix C.

6. **Agenda Item 3: Any other business**

6.1 WP/54 contained the latest version of the OPLINK Panel Lexicon of ATS Data Link Applications. The custodian of the document, Mr. Heribert Lafferton, summarized the changes from the previous version noting that additional or revised definitions had been included from:

a) the draft RCP concept (as proposed at ADSP/5). The modifications to the Lexicon derived from the RCP Concept were the definitions of Communication process time, integrity, availability, and continuity of function. It was noted that the Lexicon kept any definitions which were superseded to retain the historical record. At some point it would be necessary to remove all but the current definition of each term. It was also noted that there was no current definition for *required communication performance (RCP)* itself. That task was taken as an action item for the Berlin meeting;

b) the Air Traffic Management Operational Concept Panel (ATMCP) (as progressed at their second working group meeting of the whole, held in Cape Town, South Africa in 13 to 17 September 1999);

c) the draft definitions, as proposed in the framework of the EUROCONTROL ADS programme.

6.1.1 The working paper showed the value of the work carried out by Mr. Lafferton; both as a suitable reference document and as a means to find and evaluate those terms that may need to be amended. Additionally, further evidence was provided on the use of the documentation by other panels in reviewing the ADS panel’s progress on a variety of issues.

6.2 WP/55 introduced the arrangements for the next WG/B, WG/C and WG/A meetings which would be held from 25 September to 6 October 2000, in Berlin, Germany. The meeting would be held at the Best Western Euro Hotel, also referred to as the Best Western Hotel Euro-Consul (Sonnenallee 6/Ecke Hermannplatz 12047 Berlin; ph +49 30 61 38 20; fax +49 30 61 38 22 22; email <euro-consul@t-online.de>; web site www.bestwestern.com). Members could expect additional information, including the formal invitation in the near future. Of critical importance though, was the need to have room reservations made by 22 August 2000. Reservations are to be made directly with the hotel. A preliminary guide concerning the order of business is as follows:

a) WG/B: 25, 26 and the morning of 27 September (2½ days, plus DP to be reviewed on morning of 2 October);

b) WG/C: afternoon of 27 September, 28, 29 September, 2 October (3½ days, plus weekend as required, plus DP to be reviewed morning of 6 October); and

c) WG/A: 3, 4, 5 October (3 days, plus DP to be reviewed morning of 6 October).

6.3 In concluding the meeting, it was recognized that significant progress had been made, gaining consensus for a way forward. The suggestions made in both WP/53 and IP/51 permitted the group to gain further insight into how the RCP operational concept should be progressed. The idea of concentrating on the initial controller-pilot communications, while maintaining the flexibility to later address other forms of communications has gained broad acceptance within the group.

6.3.1 The group agreed that for Berlin, all working papers would be required to address specific document sections for modification or specify the position of any new text i.e. redline and strikeout method. All members of the Working Group were encouraged to take the electronic copy of the revised operational concept document and develop proposals for improvement.

6.3.1.1 It was suggested that one useful working paper would be one that performed a complete sweep of the draft document to make all references to RCP, RCP type, communications process, etc consistent.

6.3.2 It was recognized that progressing the work via correspondence might not be sufficient with respect to some of the material that needed to be advanced. Consequently, members were encouraged to meet, as appropriate, to progress working papers for presentation in Berlin.

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APPENDIX A

LIST OF PARTICIPANTS

Name	M/A/O*	Nominated by
Dollman, W.	M	Australia
Pearce, S.	A	
Cirilo, C.	M	Brazil
Silva, S.	A	
MacLean, D.F.	M	Canada
Grout, J-F.	M	France
Teissier, L	A	
Lafferton, H.	M	Germany
Zacchei, M.	A	Italy
Ohishi, T.	A	Japan
Diez, D.	M	Spain
Hietala, A.	M	Sweden
Asbury, M.	M	United Kingdom
Anderson, G.	A	United States
Kraft, T.	A	
Oishi, R.	A	
Béhier, P.	M	Eurocontrol
Roca, J.M.	A	
Desmarais, L.	M	IATA
Robin, C.	M	IFATCA
Dalton, C.M. (ICAO)	Secretary	

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*M = Member, A = Advisor, O = Observer.

APPENDIX B

LIST OF WORKING PAPERS

Working Paper No.	Agenda Item	Presented by	Title
51	-	Secretary	Administrative Arrangements, Agendas and proposed Timetable
52	1	Secretary	ADSP Task List
53	1	D. Cherry	The Role of Human Factors in System Specification and Evaluation
54	3	H. Lafferton	Lexicon of ATS Data Link Applications
55	3	H. Lafferton	ADSP Working group meetings in Berlin
56	1, 2	D. Cherry	Current Draft RCP Document
57	2	D. Cherry	Proposed amendments of an Editorial Nature
58	2	D. Cherry	Proposed amendments of a Substantive Nature
59	1	S. Pearce	Proposed Application Use of the Concept of RCP
60	-	Rapporteur	Summary of Discussions and Conclusions

Information Paper

IP/51	3	J-F. Grout	RCP Paper presented to AMCP

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APPENDIX C

CONCEPT OF REQUIRED COMMUNICATION PERFORMANCE (RCP)

Version 1.01

Table of Contents

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FOREWORD

1. BACKGROUND

1.1 General

1.1.1 The International Civil Aviation Organization (ICAO) has recognized a need for major improvements to the existing air navigation system. First addressed by the ICAO Special Committee on Future Air Navigation Systems (FANS), this need was expressed in terms of communications, navigation, surveillance and air traffic management (CNS/ATM) enhancement.

1.1.2 Before the advent of data link, the capability of existing communications systems for ATS was assessed on the basis of actual performance, as it usually was readily evident when performance became degraded or was unavailable. There was no identified need to quantify performance because the perceived performance of voice communications is an ingrained human characteristic. For instance, the delay between the “press-to-talk” and radio transmitter keying, if too long, was readily apparent and would be reported for corrective action.

1.1.3 By using voice conversations for ATC communications, the most stringent requirements for the highest priority messages were met. All lesser priority messages also used voice and, therefore, had their less stringent requirements met. There was no need to provide a secondary mode of communications, (e.g. Morse code) so all communications shared the same mode, i.e. voice. However, the acceptance of data link as an allowable medium of communication for ATS means that there is now a choice of modes.

1.1.4 At the fourth meeting of the Aeronautical Mobile Communications Panel (AMCP/4) (Montreal, April 1996), the urgent need for objective criteria to evaluate the performance requirements for communication systems was recognized. It was noted that the concept of required communication performance (RCP) was already under consideration in ICAO. Recommendation 2/2 was prepared which invited ICAO to arrange that an appropriate ICAO body progress, with urgency, the development of the concept of RCP by 1999.

1.1.5 When reviewing the report of AMCP/4, the Air Navigation Commission (ANC) approved Recommendation 2/2 and requested the Automatic Dependent Surveillance Panel (ADSP) to develop the operational concept of RCP in time for ADSP/5 in 1999. At the fourth meeting of ADSP (ADSP/4) (Montreal, September 1996), the panel accepted a work programme to develop the concept, but not the types, of RCP by the desired completion date. The ANC emphasized the need for the ADSP to cooperate closely with other panels as appropriate and, in particular, with AMCP with regard to the activities on the comparative analysis of the various data links.

1.1.6 The development of the RCP concept by ADSP has been progressed in coordination with other groups both within ICAO and outside of ICAO (e.g. RTCA, EUROCAE). AMCP had made the following recommendations which have been taken into consideration by the ADSP in its development of the RCP concept:

a) all groups (e.g. RGCSP, AMCP, ADSP, RTCA, EUROCAE, etc.) use the same set of parameters;

b) all groups should have the same understanding of the meaning of the parameters; and

c) all parameter values used for a particular airspace or function are consistent, justified, and the least stringent to meet the operational need.

1.1.7 In addition, aspects of the work on RNP were reviewed during the development of the RCP concept.

1.2 Communications, Navigation, Surveillance/Air Traffic Management (CNS/ATM)

1.2.1 Air Traffic Management is comprised of air traffic services and other services. Air traffic services consists of air traffic control services, flight information services and alerting services. Each of these services can be broken down into specific services, such as separation services or monitoring services, etc. Communications, navigation, and surveillance support these services. Figure 1 shows this interrelationship between air traffic management and communications, navigation, and surveillance. RCP would be used to specify communications performance necessary to support these services within a designated environment, e.g., traffic density, separation standard, message volume, etc. For example, a separation service would have an RCP specified which will depend upon the operational environment within which that separation service will be provided and will also depend upon the level of service provided, e.g., the separation minimum.

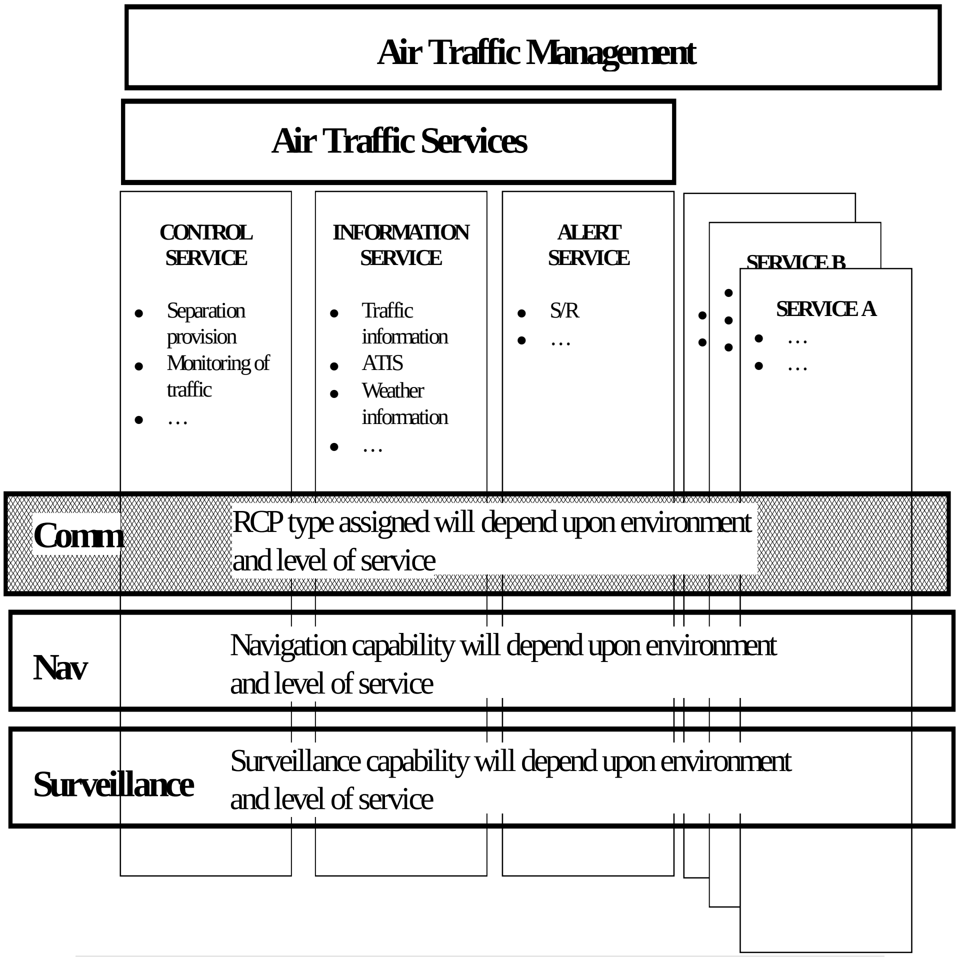

Figure 1. Interrelationship between air traffic management and communications, navigation and surveillance

1.2.2 The elements of the CNS/ATM system overlap. There are areas wherein communications, for example, may be needed to support a navigation or surveillance system or both at the same time. For example, communication elements are needed for certain forms of surveillance, such as when ADS is used. It can also be pointed out that the navigation system also contributes to ADS. To try to develop an RCP concept which immediately covers all of these possible interactions was determined to be too difficult a task. Figure 2 shows the overlap between the elements of communications, navigation, and surveillance within the context of air traffic management, noting that room exists within ATM, for other aspects of total system performance.

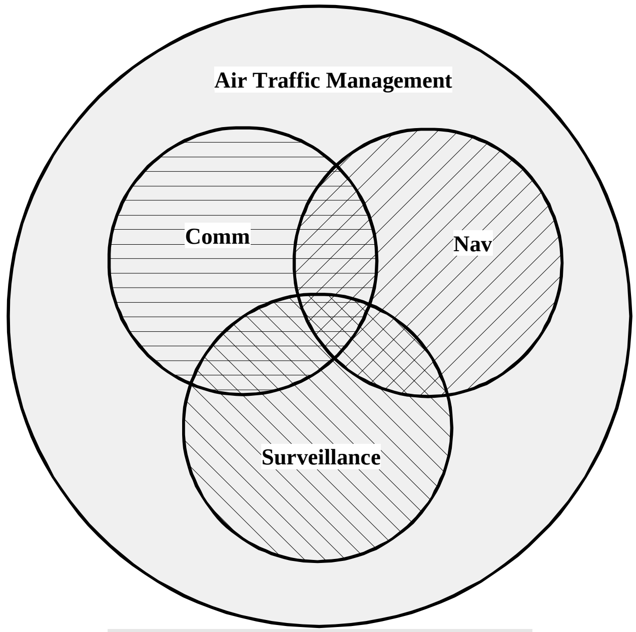

Figure 2. The intrinsic overlap of communications, navigation and surveillance requirements.

1.2.3 Communications is made up of several sub-types which can be used for various purposes, including supporting the navigation and surveillance elements of CNS/ATM. The RCP concept must ultimately cover all of these sub-types of communications. However, because of the complexity of the issues involved in creating an operational concept which can be applied to all of the possible types of communications, the OPLINK Panel has decided on two strategies:

a) develop a flexible framework which can be expanded to cover all of communications; and

b) work out the issues associated with controller-pilot communications as an initial goal.

1.2.3.1 Figure 3 shows the various sub-types of communications intrinsic to air traffic services and that the initial goal of the concept will be to support controller-pilot communication requirements.

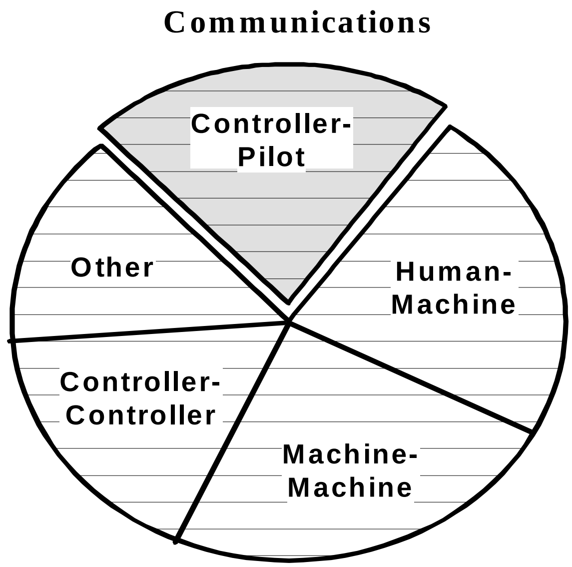

Figure 3. Sub-types of communications intrinsic to air traffic services

1.~~2~~3 Purpose/scope of this document

1.~~2~~3.1 The purpose of this document is to provide guidance material to explain the operational concept of required communication performance (RCP), identify how RCP affects the airspace managers and the airspace users, and provide regional planning groups with a basis for the development of documents, procedures, and programmes to introduce the use of RCP in airspace planning methodology.

1.~~2~~3.2 This document will ultimately enable airspace managers, certifying authorities, and aircraft operators to formalize performance aspects of the communication portion of the CNS/ATM concept taking into account local circumstances as well as global interoperability requirements for civil aviation operations.

2. OPERATIONAL CONCEPT OF RCP

2.1 General

2.1.1 The RCP concept is a framework for the expression of the operational performance requirements for ATS communications in support of specific services, operations, or procedures within defined homogeneous airspaces.

2.2 Overview of the RCP

2.2.1 The RCP concept will provide a basis for increased flexibility of application of communication technologies. It will permit an evaluation of their suitability to deliver required communication performance in support of ATS. It may be possible, for instance, to consider the establishment of a global RCP for a specific service, e.g. ATIS.

2.2.2 An RCP type is a statement of the performance required of a communication process to support a particular air traffic service. Typically the RCP type needed for a specific service will be determined by a group such as the RGCSP. For example, the communication performance needed to support a particular separation minimum may have an associated RCP type determined. When a State provides a particular service for which an RCP type has been determined, the associated RCP type will be mandated.

Note. —It should be noted that not every service will have an associated RCP type.

2.2.3 Once an RCP type has been determined, and a state has imposed that requirement, then it will be necessary to ensure that communication systems comply with the RCP type. It is beyond the scope of this Operational Concept to describe the compliance process. The need for compliance has influenced some of the characteristics of this Operational Concept.

2.2.24 In order to be operationally acceptable, and to obtain the benefits envisioned by the CNS/ATM conceptfor a particular service, it is necessary for aircraft, communications networks, and ground systems to achieve an appropriate level of performance related to communications, navigation, and surveillance. For RCP to have value to ATS, it needs to be able to verify that the message – not just the data – was in fact received. The level of performance to be achieved must be stated clearly and unambiguously. It should also be specified in a technology-independent manner so that it may cover all existing and emerging systems that support CNS/ATM.

2.2.35 The use of an RCP type will define the required performance for the most stringent use of communications, such as the application of separation standards. A different RCP may be used to define communications performance for the less stringent services, such as flight information services. While there are several more applications in use for ATS, only the aforementioned applications were selected in order to indicate the range of RCP types required. The principle reason for this approach is to illustrate that once RCP types were developed for these applications, then most, if not all, other communications requirements would fall somewhere within the performance requirement. However, a communication system capable of compliance with a given RCP type (however quantified) would not necessarily mean that the same communication system automatically would comply with an apparently less rigorous RCP type.

2.2.46 An RCP is a statement of the communication performance necessary to achieve a defined level of service. RCP seeks to quantify the communications element of the ICAO CNS/ATM concept. In the development of the RCP concept the work completed in the development of required navigation performance (RNP) was taken into account. Included in the RNP measurements is the "goodness of the position estimation" function and the ability of the aircraft to be steered to the intended track – otherwise known as flight technical error (FTE). FTE allows for human and equipment variability in defining RNP and subsequently in the design of the aerospace environment. The human element in RNP, whilst a small contributor to the calculation of RNP, is nevertheless a critical component.

2.2.46.1 The contribution of the human element is significant to the definition of RCP.In contrast, the contribution of the human element to the calculation of RCP is of much greater significance. In this context, communication between humans is more than the transmission of a set of words, characters, tones, or electronic data bytes; it is the accurate transfer of meaning between the humans operating within a specific environment. This transfer of meaning must be completed within the appropriate period of time specified for the designated environment.

2.2.57 RCP quantifies the transfer of meaning between systems or the human elements of the communication system. The intrinsic value of RCP relates to the ability to transfer the intelligence within the specified performance parameters whilst not being specific about the technology used to achieve this. RCP is highly dependent on the performance of the system and/or humans in the loop.

2.2.68 In order to complete the transfer of information, communications may not always be limited to a round-trip dialogue. However, the RCP concept demands a unique beginning and ending point. The following are two examples of such unique beginning and ending points:

a) when RCP relates to communications between systems, the beginning is when the sending system initiates the communication and the end is when the receiving system receives and is capable of using the information; or

b) when RCP relates to communications between humans, it begins when the sender initiates the communication, e.g. by activation of the "press to talk" switch or an initial movement of a mouse, and ends when the sender understands the reply.

Note. —For both voice and data a "standby" message may be appropriate to end the communication process. This may happen when the traffic situation requires a human processing time incompatible with the specified RCP type. There may be a separate communication process which will begin with the appropriate response.

2.2.79 The Lafferton Model (Figure 14), shows four levels of increasing detail of the overall communication process. Each point between separate elements of the process at whatever level is identified by a letter within a triangle. The complete communication process is symbolically flanked by the letters A and Z. Level 1 shows the first major breakdown of the process into three components; the sending of information to the recipient, the processing of the information by the recipient, and the return of an operational reply to the originator. At level 2 and 3 there are increasing levels of detail displayed. It is envisioned that further levels of detailed decomposition will be prepared by other specialist bodies.

2.2.810 The concept, presented in Figure 1the Lafferton Model, has the flexibility to address either two-way or one-way communications scenarios as appropriate to the service or procedure for which RCP is being specified. An RCP type will be defined by an appropriate combination of the values calculated for each appropriate decomposed element. Furthermore, various methods of communication may have differing decompositions at a given level. Some of the elements at a given level may not apply and may have their parameters set to null.

2.2.911 Airspace planners will establish RCP types as necessary to achieve a defined level of service within their designated airspace. In addition, they must develop procedures to cover the variations of human/system performance observed in actual communication performance. This would allow for evaluation of both the installed and proposed communication systems while minimizing the impact of the human performance variability. In this manner technical systems could be certified leaving ATS capability/capacity (and daily human performance) to operational procedures, rules, and performance thresholds.

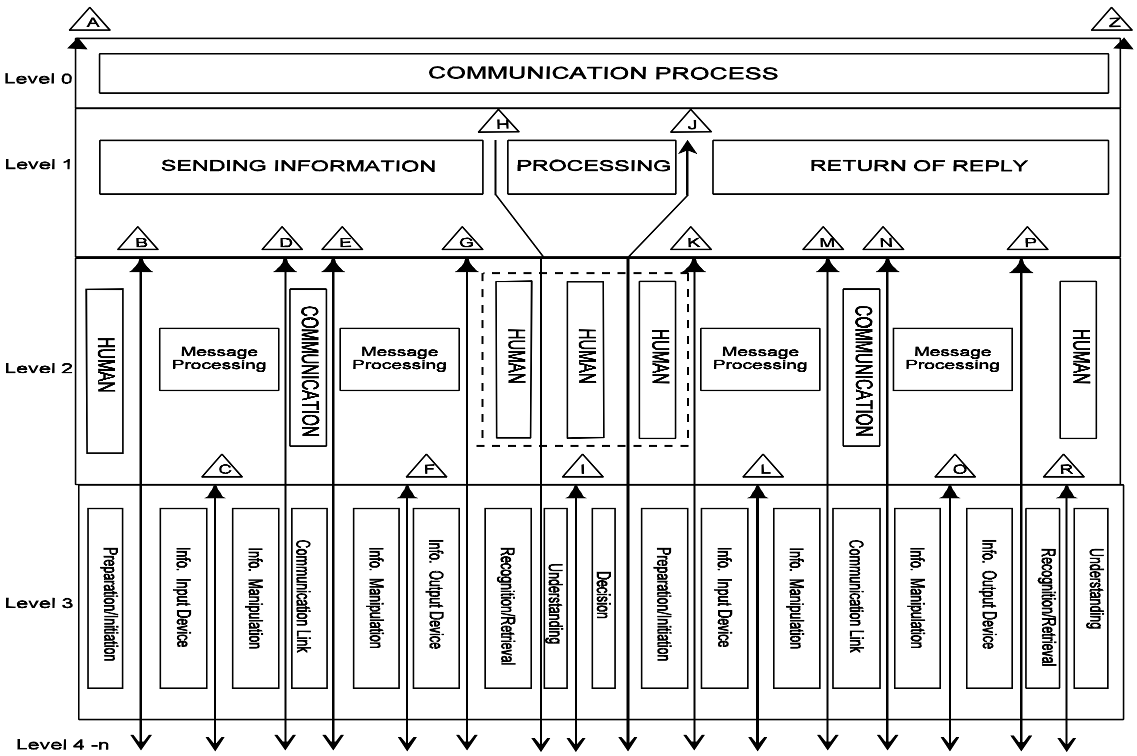

Figure 4 - The Lafferton Model expressing the overall communication process

2.2.~~10~~12 Both the human and system elements should be included within the RCP by:

a) assigning a prospective RCP for the entire communication system;

b) determining network technical performance;

c) determining representative human perception and psychomotor times through manufacturer/implementer/operator usability testing;

d) determining representative human processing times through high fidelity, environmentally specific simulation and assign a "protected time" value for the communication process;

e) assessing the assigned RCP to determine network and human processing parameter values for suitability of operation in the specified airspace; and

f) subsequently, having assessed the RCP type as being appropriate, the airspace planners should develop operational procedures to cater for those occasions when actual communication performance does not meet the specified RCP.

2.2.~~11~~13 It is essential that the ATS authority monitors conformance to the applicable RCP type and takes the necessary action should the level of performance be deemed unsatisfactory.

2.3 Assumptions

2.3.1 The RCP concept is completely general, in that it allows airspace managers to establish performance requirements for data, voice, or combined voice and data capabilities in a particular airspace, for particular routes, or for particular operations.

2.3.2 Voice and data are conceptually similar in the communications process. Both voice and data are capable of transferring information for ATS purposes. RCP will be capable of describing communications performance requirements for either method of communication.

2.3.3 Communications begin when the controller or pilot interact with the communications system, e.g. keying the microphone, moving the mouse/trackball, typing on the keyboard.

2.3.4 A system capable of meeting a given communications requirement in a given airspace is deemed to be capable of meeting any less stringent communications requirement in a comparable airspace, provided the aircraft has access to the system. For example, very high frequency (VHF) communications will provide high performance but limited coverage in oceanic and remote airspace.

2.4 Applicability

Basis of application of RCP

2.4.1 The RCP concept is intended for use by airspace managers responsible for the definition or specification of ATS services or procedures that require communications.

2.4.2 Once RCP has been specified for a given airspace, any single communication system or combination of systems meeting the set parameters and supported by appropriate ground infrastructure can be considered operationally acceptable.

2.4.3 RCP specifies the operational characteristics of the communications means used to support a service or procedure. For example, an airspace manager may set an RCP type to be met by all aircraft wishing to use a particular service or procedure. Therefore, RCP will permit operators to determine whether competing communications technologies satisfy those requirements.

2.4.4 RCP is to be applied operationally on a per service or per procedure basis. That is, for each service or operational procedure that requires communication of information, there may be an RCP type specified. This RCP type will constrain the performance of the communication means for the complete communications path.

Note.— The term "completed communications" may be either one-way or two way as appropriate to the particular service or procedure.

2.4.5 In the case of data link flight information service (DFIS) only one RCP type could be defined globally. Generally speaking, the information provided to the pilot has the same level of urgency whether the pilot is in an oceanic airspace or a dense continental airspace. The RCP type specified for DFIS would then apply to all airspaces.

2.4.6 In an airspace where several services are provided via data link, the characteristics of the communication infrastructure must accommodate the RCP type of the most stringent service. This could mean, for example, that if one airspace planner only foresees the provision of DFIS, a communication infrastructure limited to this specific requirement could be implemented. Later on, if more demanding services are implemented, it could result in a complete upgrade of the communication infrastructure to meet the new RCP type.

Examples of the application of RCP

2.4.7 Specification of RCP for the provision of a separation service

2.4.7.1 Communication requirements are only one of many considerations in developing a separation minimum. The ATS communication capability has heretofore been expressed as an intervention capability, i.e. the ability to intervene to prevent a collision. An increase in traffic in particular airspace can result in airspace planners considering a change in airspace utilization (e.g. separation minima, route configuration) while maintaining an acceptable level of risk. In collision risk analysis, this acceptable level of risk is most frequently referred to as the target level of safety (TLS).

2.4.7.2 Once the separation minimum and the TLS are determined, a minimum level of performance can be set for the air navigation system parameters of navigation and communication. In the case of a remote oceanic environment for 50 nautical mile lateral separation, the airspace requirements may be stated as:

a) RNP-10

b) Surveillance comprised of position reports every y minutes, i.e. via voice or ADS; and

c) RCP x for communication system performance.

2.4.7.3 RCP x for that airspace (i.e. remote, oceanic/50 lateral separation) indicates that the minimum combined performance of all the elements will be x seconds. This figure was determined in order to meet the most stringent situation, e.g. intervention to avoid collision. Routine messages using that medium will also arrive in the specified communication process time.

2.4.7.4 In this example, human processing time for controllers and pilots, (as indicated in Figure 1, letters H to letter J) will be determined by provider States or regions. Cockpit processing/response time has not traditionally been a value considered in the development of requirements for separation minima. However, similar human factors measurement processes must be used to determine cockpit processing/response time.

3. RCP PARAMETERS

3.1 Number of parameters

3.1.1 The RCP concept ~~should~~ includes the minimum number of parameter values consistent with the proper characterization of the operational requirements of the various applications.

3.2 Communication process time

3.2.1 The communication process time specifies the maximum time for the completion of a two-way dialogue between the originating user and the receiving user, i.e. from sending the information to the receipt of the reply after which an alternative procedure must be applied.

Note. —The definition also caters for one-way communications by setting to zero the reply time.

3.2.2 The communication process time is the primary RCP parameter. This parameter is an indication of the time criticality of the message transactions to which it is applied. It may be used to qualify a communications method for use in a particular procedure in a given airspace. It will immediately separate less time critical communications services such as FIS in oceanic airspace, from very time critical services such as controller-pilot data link communications (CPDLC) in the terminal area.

3.3 Integrity

3.3.1 RCP integrity is the probability that errors will be misdetected. This may be when a correct message is indicated as containing one or more errors or when a message containing one or more errors is indicated as being correct.

3.4 Availability

3.4.1 RCP availability is defined as the ability of the communication system to perform its required function at the initiation of a ~~dialogue~~communication process.

3.4.2 Availability is ~~quantified~~defined as the proportion of the time the system is available to the time the system is planned to be available. Availability is defined between end users. RCP availability includes all elements within the end systems, networks, intermediate systems and subsystems.

3.5 Continuity of function

3.5.1 RCP continuity of function is defined as the probability of a system to perform its required function without unscheduled interruptions during the communication process presuming the communication system was available at the beginning of the communication process.~~RCP continuity of function is the probability of a system to perform its required function without unscheduled interruptions during the intended period of operations.~~

4. HUMAN FACTORS

4.1 Human performance

4.1.1 RCP includes human factors which reflect the human performance to complete a communication process by initiating and sending a response. Human performance should take into account the action to answer a message received by an appropriate return message. Task management should always be left to the discretion of the user, within the scope of defined task priorities.

4.1.2 It should be noted that the time required by the human to complete the communication process requires the HMI to be designed to allow the user to be able to react within an appropriate amount of time.

4.~~1~~2 Human-machine interface (HMI) considerations

4.~~1~~2.1 The overall philosophy of the HMI is one of the main issues allowing consistent measurement of RCP time values, taking into account human performance variability.

4.~~1~~2.1 Two of the main issues in the conceptual design of an HMI that interfaces to data link are:

a) how to implement more than one way of communication (e.g. VHF voice and data link) for a given user; and

b) how to reduce to the minimum the extra workload related to the manipulations on the HMI of the data link objects.

Note.— The transmission times are external to the HMI and are important elements of the overall communications process. Thus the time necessary for message composition and recognition, which is determined by the effectiveness of the HMI, is critical and all efforts must be made to reduce that time to a minimum.

4.~~1~~2.3 The introduction of data link has put more visual information on the HMI. This inflation of information, due to human limitations, needs particular efforts to structure what is displayed in order to enhance understandability. A categorization and hierarchical organization of the information can resolve this problem. To know what information is required for display, one must know the needs of the operators for each type of activity.

4.~~1~~2.4 Before any HMI conceptual design is developed that includes data link functionalities, there are many levels of constraints that must be taken into account:

a) technical constraints, for example constraints linked to the ATC system itself and constraints that are linked specifically to the use of data link;

b) constraints linked to the task; the main task that should always be done first (for example, to guarantee aircraft separation) and then subtasks more specific to the use of data link, (for example, the management of asynchronous data link dialogues); and

c) constraints that are purely human factors such as perception or memorization (for example, the increase in visual information as a result of introducing data link has an impact on human perceptive performance).

4.~~1~~2.5 The information displayed on the HMI for data link will be of a different nature than voice. In order to guarantee an acceptable level of consistency, the logic designed to perform the actions must be as common as possible.

4.~~1~~2.6 When many operators are working in cooperation (i.e. pilot-copilot or two controllers working on the same controlling position), the history of the most current dialogues must be available in order to guarantee a common representation of the situation.

4.~~1~~2.7 These constraints are situated at different levels and may need to be treated equally. Attention to the above principles will increase the consistency and therefore reduce the variability of the human response time contribution to the RCP.

4.~~2~~3 Human processing/reaction time

4.~~2~~3.1 The specification of human reaction time is more important in situations where the operator receives information that was not foreseen. The concept of reaction time must be placed in the context of the activity at a specific time. This point makes reaction time less relevant in a situation where the operator expects the information. Therefore, making an evaluation of the reaction time in a realistic environment is crucial (i.e. real operators, heavy traffic, etc.) and should take into account unexpected dialogues.

4.~~2~~3.2 A data link message, as compared to a voice radio message, gives less information. Implicit information such as tone of voice, rapid delivery of messages and explicit information such as qualifications to standard phraseology are lost. As a consequence, in order to get consistent time values for the RCP, the messages should not always be displayed in a generic format but more in a specific format that will minimize this loss of information. For example, the use of specific colours in the display of a message, or particular text formats are means to add more information than the raw message alone.

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APPENDIX D

TECHNICAL NOTE ENTITLED *A CRITICAL REVIEW OF THE RCP CONCEPT* (drafted by Mr. M. Delarche) AND SPECIFIC COMMENTS BY WORKING GROUP C

Note. —Comments made as a result of Working Group C discussions indicated by means of text boxes.

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1. PURPOSE OF THIS DOCUMENT

The objective of this document is to provide a critical analysis of the material presented in the RCP Manual prepared by the ADSP (Draft version 1.0 dated 30 April 1999.)

Our analysis is partly derived from various studies conducted in the three last years by Sofréavia for the STNA (E-TDMA concept study), for the DG7 of CEC (PROCTOR R&D study, CLAIM-GNSS study) and for EUROCONTROL (ASTOR).

This analysis is organised into 3 sections:

- In the first section, we identify a number of defects in the proposed RCP modelling approach, and we make some technical recommendations to improve the present framework;
- In the second section, we discuss some of the intrinsic limitations of the RCP concept with respect to a number of issues (infrastructure planning, system certification, service provider performance contract, performance monitoring);
- In the last section, we make a number of suggestions to address these limitations in future work related to RCP specifications.

2. PROBLEMS RAISED BY THE CURRENT RCP MODEL

2.1 Lack of a multi-dimensional vision

The current model is focused on the time delay performance, described as the "primary" characteristic in the RCP, in the same way as the accuracy is the main aspect of the RNP model.

Although the transfer time-related component is certainly a key aspect of operational communication performance, it would be an error to have the whole RCP concept organised along this single dimension.

Other performance characteristics may be equally or even more important from a system engineering and safety certification point of view: for example, the introduction of a loss-of-integrity alert delay in the RNP model is an essential feature of precision RNP.

In this respect, it is certainly an error to believe that an RCP-x capability where x is a certain delay-related characteristic should implicitly provide for any RCP-y capability where y > x.

As a matter of fact, the same problem exists in the context of the RNP model: a RNP 0.3 (NPA) capability does not necessarily implies a RNP 4 (high traffic density en route) capability, because, although the accuracy performance is met, the availability requirement set for RNP 4 is higher than the availability requirement set for RNP 0.3: when several aspects are involved in the specification of performance requirements, a single hierarchical ordering of performance is no longer guaranteed.

In the case of the RCP, there is a further incentive to take into account the multi-dimensional nature of the performance specification, because there is a need to optimise performance trade-offs (e.g. between time delay, throughput and integrity)

Therefore, to specify RCP requirements, we recommend to adopt a multi-dimensional representation of the specification.

WG/C comment: The RCP draft currently includes a multi-dimensional representation. Nevertheless, WG/C should explain the relationships among the various RCP types more clearly.

2.2 Need for successive layers of specifications

The ambition of the RCP model is to address the Total System (including such elements as the response times of pilots and controller to determine the total time spent in an operational transaction loop,) with the objective of supporting a safety assessment against a Target Level of Safety within a certain operational concept of operation.

Another salient objective is to provide a performance standard capable of supporting the related certification of telecommunication equipment on board aircraft.

To achieve this goal, an incremental certification process of end-to-end communication services and a model of the Total System architecture have to be established, and different layers of system integration should be defined, in order to provide for a two-way traceability between the operational performance requirements and the limitations set by technical components.

Such a layered approach is also necessary to create performance certification requirements in respect of various entities (equipment and aircraft manufacturers, telecom service providers, ATS providers etc.), so that the accumulation of partial certificates can provide truly compatible and combinable certification credits for facilitating the Total System certification.

For communication services, a hierarchy of embedded sub-systems should be defined so as to provide for system performance integration and requirement traceability.

A typical structure for communications could feature 3 distinct specification levels:

- The telecommunication services for carrying information across a certain “pipe” of limited capacity; performance requirements at this level would be telecom-focused and would have to be met by telecom equipment manufacturers and service providers;

- The end-to-end data transfer service between application systems; at this level, the performance requirements would be Data Processing application-focused and would have to be met by ATS DP system manufacturers and aircraft DP system manufacturers;

- The end-to-end information transfer service encompassing all the elements of the Total System ; at this level, the performance requirements would have to be met by the ATS service providers and airspace users (since these requirements include constraints on the information processing ability of pilots and controllers, they may include Human Factor qualification and certification activities such as the training and licensing of pilots and ATCO to a correct and efficient use of HMI and associated communication protocols)

Please note that the two first levels of the above hierarchy roughly correspond to the Intermediate Systems layers (network and below) and to the End System layers (transport and above) of the ISO-OSI model.

From the standpoint of end-to-end performance specification, the network layer is just a way of providing for the serial-parallel integration of various pipes into a single "virtual pipe" and need not be addressed separately from the notion of logical link layer, at the level of abstraction of an RCP model.

Similarly, distinguishing between the technical layers of end-to-end communication (transport, sessions, presentation, application) is of little relevance here.

DP engineers developing application software and related data exchange protocols should not have to concern themselves with operational environment issues such as track separation minima or collision avoidance procedures, even if these aspects are fundamental in the context of the Total System for defining the performance requirements of the software applications that the DP engineers develop.

In a similar way, telecom service providers and equipment manufacturers want to provide equipment certifiable for a wide range of use, and should not concern themselves with the application messages that the other layers define.

So, with these 3 levels, we can specify performance requirements at 3 distinct operational levels:

- telecommunication equipment and services (requirements bearing on telecom equipment, systems and services)

- application software (requirements bearing on CNS/ATM application protocols)

- total system (requirement bearing on ATM procedures)

What is important is to define a minimum set of layers identifying the respective responsibilities of different technical and operational actors and to define different types of performance standards and safety regulations. The three layer hierarchy proposed here seems sufficient for addressing correctly the separation of concerns between the different actors of ATM communications.

However, once this concept of a responsibility-driven hierarchy of specification layers is understood and accepted, it becomes important to define a methodology for consolidating both top-down operational requirements and bottom-up technical limitations across the different layers, whatever their exact number and related actors.

A further difficulty in telecommunications matters is that the low level components must carry various information flows, with an impact on their performance (in the GNSS context, things are much simpler because the quality of the signal-in-space is not sensitive to the number of simultaneously active end users, who are just "passive consumers" of the provided signal).

WG/C comment: The working group was of the view that the Lafferton Model illustrated the multi-level nature of communications and that improved text in the draft should clarify many of these issues. Furthermore, this analysis will be shared with the RTCA SC-189/EUROCAE WG53 SG3, the group dealing with some of the issues expressed, recognizing that they were somewhat out of the purview of OPLINKP WG/C.

2.3 **Poor definition of performance metrics**

At the current stage of the RCP definition process the relevant metrics are not clearly defined. The process consisting in defining mathematical functions (generally statistical ones) for specifying performance characteristics is termed "derivation" in ISO 13236 (a somewhat unfortunate choice since derivation has a well-defined yet different meaning in mathematics).

For example "mean transmission time" and "95% maximum transmission time" are two derivations of the more abstract "transmission time" characteristic.

Obviously, if the RCP model is to be used in a system engineering context, precise definitions are needed for derived QOS characteristics, in order to provide for quantitatively testable performance requirements.

In this respect, the introduction of such notions as "Installed Communication Performance" and "Actual Communication Performance" to try and cope with system performance fluctuations is hopelessly confusing.

WG/C comment: There is a technical communication portion and human communication portion that needs to be broken out. The descriptions of ICP and ACP have been removed as inappropriate at the level of the operational concept WG/C is progressing at this stage. Nevertheless, they (ICP and ACP) would ultimately need to be detailed.

Since the draft RCP manual makes it clear that RCP values should be defined as "the least stringent to meet the operational needs" the correct approach to deal with the issue of statistical fluctuations and/or system implementation variations is to define within the RCP model the "least stringent" testable derivations for each aspect of the performance requirements.

The word "testable" is quite important here: the generic notion of availability defined as a percentage of the total time is perfectly useless from a performance verification standpoint, unless it is explicitly qualified by a reference to an observation time interval: e.g. the average availability per year or per day.

The same notion holds for the reliability, that can be expressed by the MTBF and/or other metrics that need to be carefully qualified to be really testable.

In this context, the notion of "continuity of service" is merely a metric derived from reliability, expressed over a shorter yet operationally significant interval (cf. the 15 or 30 seconds intervals used as reference for of precision RNP categories).

It is important to realise that the purpose of adopting this or that time interval for specifying an ad hoc availability or reliability derivation is to provide a metric that can be easily related to operational objectives.

Specifying "continuity of service" metrics (i.e. a reliability measurement over a short interval of time) should be done with parsimony, and only when there is a compelling need to provide this type of information for some traceability purpose in respect of a well-defined operational scenario (like the final approach tunnel model in the case of the RNP, which is used to determine the most safety-critical time interval if a last resort failed approach manoeuvre must be started at a very low altitude).

A general heuristic rule here could be : the broader the intended field of application, the broader the observation time interval of the availability-reliability metrics.

For example, if we want to define at a general level the reliability and/or availability of the CPDLC service to a pilot, a probability of failure per flight hour is a simple natural metric.

Now, if we want to specify a performance constraint on the use of CPDLC to implement a data link-based transfer protocol at sector boundaries, then the performance assessment interval must be congruent with the operational scenario: the probability that the supporting CPDLC service fails over a 2 or 3 minutes interval (that is, the maximum nominal duration of a data link-based transfer) becomes significant, since it is also the probability that the voice-based back-up scenario is triggered.

The same problem of lack of clarity in the definition of the metrics can be raised for delay performance requirements: most of the time in emerging RCP-like requirements a 90 % or 95 % maximum transfer time is specified, but this is not necessarily sufficient for all types of application: for example, for future air-air collision avoidance protocols, it is likely that 99% (or more) maximum delays will have to be specified, so as to make the corresponding autonomous aircraft scenarios certifiable for a high traffic density environment.

To avoid creating dozens of had hoc metrics, a small set of rules connecting the format of the technical specifications with the operational context should be created so as to introduce a limited number of n-percentile metrics (e.g. defining 95 % max as the baseline metric for all applications, and adding a 99 % max delay as a supplementary metric for the most safety critical tactical applications).

WG/C comment: Text would be drawn from this document and the RTCA SC-189/EUROCAE WG53 SG3-WP16 to clarify the definitions of the RCP parameters.

3. INTRINSIC LIMITATIONS OF THE CONCEPT

The RCP concept is certainly of interest for Airspace Management, Aircraft equipment design and ATS planning, but, unless it is developed into a fuller performance and inter-operability specification framework, it is only of limited interest for designing, planning and certifying telecommunication equipment, systems and services.

The main limitation is that the RCP model says nothing about such things as the frequency inter-operability criteria, communication protocols, and message semantics. Yet all these aspects need to be agreed on in minute detail if aircraft and ATS providers are to communicate !

In this respect, the value of producing a RCP specification should not be overestimated: as long as an agreement has not been reached on all the other aspects of inter-operability, a RCP model is only an empty shell.

WG/C comment: There are aspects of these issues which must be flagged as future work for other groups. Any presentation of the concept to the ICAO Air Navigation Commission for review would need to indicate this fact. (para 2.2 ADSP/5-WP9)

Keeping in mind this important caveat, we can discuss other limitations of the current RCP concept which are well within its intended scope, that is the specification, verification and certification of communication performance.

Conducting an end-to-end verification of performance will require the following improvements:

- an integration of communication range requirements into the RCP model, so as to facilitate the mapping of operational requirements onto different types of systems and services ;

- a layered model of performance integration (as outlined in the preceding section) ;

- a performance categorisation scheme addressing not only the description of end-to-end user level exchange of information considered in isolation from each other, but also the grouping (multiplexing) of heterogeneous data flows over certain physical and logical communication "pipes", and

- a methodology for translating a set of individual RCP requirements into a macro-RCP requirement applicable to integrated service networks.

More generally, the individual then global (end-to-end) performance certification of the different links of the communication chain will require a number of improvements, essentially to make QOS commitments more explicit and more traceable, so that they become amenable to an orderly certification process.

What is needed for specifying, designing and operating certifiable communication systems and the service interfaces they offer is:

- a clearer definition of the contractual commitment made at any service interface along a communication chain. The ISO 13236 standards proposes a 3 level scale for describing the QOS management policy that can be offered by a service provider:

    - best effort (this is the level of commitment which the ATN and all its aeronautical sub-networks (Mode S, AMSS, VDL2, VDL4, HFDL) are currently designed for; the user is responsible for monitoring the QOS and for taking any corrective action when the QOS is not maintained, the service may be aborted to protect the QOS of more critical services)

    - mandatory : performance is monitored by the provider and non compliance is reported to the user ; the service may be degraded or aborted only to protect guaranteed services)

    - guaranteed (performance is monitored, and any non guaranteed services may be aborted to minimise QOS degradation)

- the provision of explicit QOS negotiation mechanisms, that have to be supported by underlying end-to-end reservations of resources, as is done in a number of modern protocols such as Frame Relay, Asynchronous Transfer Mode (in a real-time distributed environment, implementing priority management measures at the level of individual IS or ES is not sufficient to support mandatory or guaranteed QOS) ;

- a detailed definition of acceptable means of compliance, both on the aircraft side and on the ground side of the telecommunication architecture, so as to enable equipment and system manufacturers or service providers to obtain certification credits for ATS activities.

WG/C comment: RCP is a framework for the specification of communication performance requirements for a given application or service, in a given airspace. The verification of compliance, while necessary, is expected to be left for other groups to detail.

4. RECOMMENDATIONS FOR FUTURE WORK

This section summarises the changes recommended in the preceding sections as a kind of work programme for defining RCP and RCP-driven certifiable equipment, services and systems. A general recommendation is to adopt the terminology of ISO 13236 for the Quality of Service Framework.

4.1 RCP characterisation

A set of RCP characteristics should be defined, that should be common to the various layers and flow integration levels of aeronautical communication.

At least 5 different aspects should be represented in the RCP model (we use here the terminology of ISO 13236 that describes completely generic QOS characteristics that need to be specialised for the application context, e.g. interpreting the time-delay in terms of “information transfer delay” for a telecommunication context.

- Time-delay (i.e. the information transfer delay),
- Integrity-accuracy (i.e. the transmission error rate),
- Availability-reliability-continuity (as explained in the preceding section of this paper the notion of continuity of service, which is not mentioned in the ISO 13236 standard, is not conceptually different from availability and reliability, as it is an assessment of reliability (probability of service failure) over a relatively short time interval)
- Capacity-loading-throughput (i.e. the communication channel capacity)
- Spatial coherence (i.e. the operational range of the communication)

Adequate performance scales must be defined for every characteristic. It is possible to use simultaneously a quantitative performance scale and a qualitative one, so as to facilitate the mapping between operational and technical specification layers, and thus improve the traceability.

For quantitative performance metrics, clearly defined statistical derivations consistent with operational needs should be defined.

WG/C comment: WG/C agrees that the RCP parameters must have adequate quantitative definitions and will review use of these proposed metrics, as appropriate.

4.2 RCP categorisation

QOS categories should be defined by combining several operationally significant performance levels set on the different characteristics retained in the RCP model.

We outline below 5 broad qualitative QOS categories for describing communication performance in the field of CNS/ATM. We have listed their corresponding performance levels in terms of transfer time, throughput pattern and integrity, by using descriptive qualitative scales:

- Highly tactical, continuous, high integrity data flows (e.g. navigation data)
- Highly tactical, continuous, medium integrity data flows (e.g. voice channel, surveillance data)
- Tactical, discrete, high integrity data flows (e.g. ATC dialogues and Meteo warnings)
- Strategic, discrete, medium integrity data flows (e.g. ATFM and ASM data flows)
- Strategic, bulk-wise, medium integrity dataflows (e.g. AIS and normal Meteo data flows)

These categories can be refined by using the same limited set and/or adding other characteristics.

WG/C comment: These categories will be considered as part of the follow-on tasks involved in developing the RCP concept (paragraph 2.4 of draft RCP Concept, for possible inclusion).

For producing testable technical specifications, these qualitative performance levels have to be translated into quantitative requirements tailored after operational needs, and associated with rigorously defined statistical derivations; for example, a “tactical” transfer time may need to be interpreted as “less than 10 seconds in 95 % of cases” in a high traffic density environment and as “less than 20 seconds in 95 % of cases” in a lower traffic density environment.

Eventually, statistical test protocols should be designed so as to define a testable compliance criterion: for example, it might be required that the required transfer delay be demonstrated over any sample of 100 consecutive messages, with a probability of error smaller than 5 % (i.e. defining the 95 % confidence range on the outcome of the test).

Such rigorous definitions of performance will also be required for addressing the apportionment of liability: whenever performance is expressed by means of probabilities, then both the reference sample size and the agreed confidence range need to be carefully defined so as provide explicit criteria for defining (non)compliance.

One key points must be clearly understood here: a performance requirement for a certain type of communication may change according to the various equipment encompassed in the scope of the requirement.

WG/C comment: A performance requirement, such as RCP, must be derived from the operational needs and must be independent of the equipment which is proposed to meet the requirement. The overall requirement may be allocated differently as the components within the communication path change.

An ATC dialogue between a pilot and a controller over a voice channel for example, requires a high level of Total System integrity, meaning that the combination of all the error-correcting schemes (including repetition requests) yields a global probability for the residual undetected error of no more than 10^{-5} or 10^{-6}.

However, the underlying communication medium needs not provide the same level of integrity (the typical requirement for the RBER of a digital voice channel is only 10^{-3}.) This is because the human ear and brain have an extraordinary capacity for using context information to correct errors when interpreting human speech.

So, we have a example of a communication chain associating a low integrity channel (e.g. a more or less noisy HF or VHF channel) with a high integrity receiving equipment (the human ear and brain) to meet the overall performance requirement.

WG/C comment: RCP is a specification of the overall communications requirements from which lower level component requirements are derived. The appropriate allocation or aggregation of component performance, while important, remains outside of the scope of the development of the operational concept.

4.3 **RCP integration**

From the standpoint of the manufacturers and providers of general purpose telecommunication equipment and services (that is, the first layer of our model), it is important to define integrated RCP establishing standards for their equipment, systems and services to make them more easily certifiable.

Currently, many ATS providers design and operate their own network architecture on the basis of elementary telecommunication services.

If the RCP is to serve the purpose of delegating further to telecom service providers the installation and operation of integrated systems, then the RCP specification technique must also be significantly improved in that direction.

The ideal situation would be to reach a point where a whole set of links and nodes can be specified and certified as meeting the communication requirements of an operationally meaningful set of applications.

This can be done only by providing a methodology for integrating performance requirements from an operational standpoint.

It would be an error to consider that performance requirements can be aggregated in a purely mechanical way, because the applications are not operationally independent, and telecom system integration increases the risk of simultaneously losing or degrading a number of services.

A typical occurrence of this error can be found in a document produced by the 1-4 June 99 C/SOIT meeting: for determining the RCP for CPDLC Build I/IA ; a sophisticated convolution of time delays for different entities in series is proposed, with quantitative results depending on the nature of the distribution law (Gaussian, exponential…).

The trouble with this approach is that although this technique is mathematically correct, it implicitly assumes that the transit times over the different entities are not temporally correlated.

However, it is likely that the occurrence of a special operational situation (e.g. a meteorological problem) could trigger a flurry of activity over the CPDLC links (requests for re-routing etc.) and also among other data link applications that share part or all of the same communication resources (Meteo data uplink, Flight

Plan modifications, ground-ground co-ordinations etc.).

As a consequence, all the entities could, with a high probability, yield a transit time well into their 5 % distribution tail, which defeats the theoretical convolution approach. In fact, to be on the safe side of the total transfer time estimate, it is both better and simpler to take the sum of all the 95 % max delays as a conservative estimate of the overall 95 % delay.

Therefore, the acceptable maximum delay, maximum failure rate or minimum capacity of an integrated network cannot be estimated just by combining the theoretically acceptable values of individual applications (although it can provide useful system dimensioning indications).

For consolidating the RCP in a Total System performance, the performance of all the other components of the CNS/ATM systems, not only of the different layers of communication services as described before, have to be progressively integrated.

In the context of QOS-based performance specification models such as the RCP and the RNP, taking a systematically integrated view of system performance would require that the performance requirements of a variety of ATC monitoring aids and operational procedures be expressed in the same QOS framework as already used for various elements of the CNS infrastructure, for the sake of requirement traceability.

The author of this note is currently experimenting with a generalisation of the QOS specification formalism (in the context the PROCTOR study, a 4th R&D Framework Programme study for CEC DG7.)

This seems a promising approach for relating the RCP to the wider CNS/ATM environment that relies on communication services.

WG/C comment: This section applies to the work of RTCA SC-189/EUROCAE WG53.

4.4 QOS management specification and certification

What is important in designing and validating the communication architecture is to analyse the overall acceptability of certain degraded scenarios. In this respect, the 3 commitment levels (best effort, mandatory, guaranteed) of the ISO 13236 QOS management policy provide a useful starting point.

Depending on the commitment level retained for each application, the still-controllable worst case (the guaranteed services are still running) as well as intermediate performance degradation scenarios can be progressively characterised (this approach is also necessary for undertaking an end-to-end certification process, as explained in the next section.)

Once the QOS management policies applicable to the different applications and the resulting degradation scenarios have been defined, performance requirement on the QOS management processes can be specified (e.g. specifying a maximum delay for a service failure to be notified to all the end users)

On the equipment manufacturer and service provider side, the mechanisms applicable at different levels of the communication system for monitoring, reporting and controlling the QOS along every chain of communication must be described, so as to be certified as acceptable means of compliance against QOS management requirements.

That work is an integral part of any attempt at building an end-to-end certification process for communication services, that is a way of describing the technical means adopted to meet certain requirements, and documenting the results of the tests made on their equipment and systems in a QOS management compliance file, in a way that can be checked and formally certified by an independent third party.

For the most safety-critical applications, the safety regulation authority may require that the users run a separate QOS monitoring and alerting system (i.e. ATS providers may need to demonstrate that they conduct their own independent assessment of certain safety-critical response times or integrity level and that they do not rely blindly on the QOS promised by the service providers).

WG/C comment: This section applies to the States as it would ultimately be the States that would qualify communications systems to various RCP requirements.

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