Agenda Item 3: Development and validation of the draft SARPs for VDL Mode 1 (and Mode 2)

3.1 INTRODUCTION

3.1.1 The major effort in Working Group C (WG-C) has been dedicated to the validation of the draft VHF digital link (VDL) Standards and Recommended Practices (SARPs), as per Recommendation 8/2 from the third meeting of the Aeronautical Mobile Communications Panel (AMCP/3).

3.1.2 This work was progressed by four working group meetings, namely WG-C/6 in Kobe (Japan) from 10 to 21 October 1994; WG-C/7 in Martinique (France), from 8 to 19 May 1995; WG-C/8 in San Francisco and Annapolis (United States) from 11 to 22 September 1995; and, finally, WG-C/9 in Malmo (Sweden) from 16 to 25 January 1996. The rapporteur was Mr. F. Tomasello, AMCP member nominated by Italy.

3.2 REQUIREMENTS, GUIDELINES AND CONCEPTS

3.2.1 The role of VDL as a subnetwork of the aeronautical telecommunication network (ATN)

3.2.1.1 The VDL provides subnetwork services within the ATN, as defined in the ICAO Manual of the Aeronautical Telecommunication Network (ATN) (Doc 9578). The VDL is a bit-oriented protocol suite, comprising subnetwork, data link and physical layers. As such, the structure of VDL is based on the logic of the open systems interconnection (OSI) basic reference model and supports the exchange of digital packet data.

3.2.2 VDL guidance material

3.2.2.1 VDL design guidelines

3.2.2.1.1 The VDL architecture is based on the VDL design guidelines. These guidelines, which were agreed to at AMCP/3 and updated as required, are contained in Appendix A to the report on this agenda item.

3.2.2.2 VDL operating concept

3.2.2.2.1 The meeting agreed to the VDL operating concept presented by Working Group C. This operating concept, which is contained in Appendix B to the report on this agenda item, provides guidance for the operational implementation of the VDL. The meeting agreed to recommend ICAO its inclusion in Annex 10, as part of the guidance material for VDL, and developed the recommendation contained in paragraph 3.7.5 below.
3.3 **TECHNICAL FEATURES OF VDL**

3.3.1 **General**

3.3.1.1 The VDL draft SARPs specify two physical layers (i.e. Mode 1 and Mode 2) as described in the following paragraph 3.3.4.

3.3.2 **Common features**

3.3.2.1 **Layered architecture**

3.3.2.1.1 The VDL architecture encompasses the three bottom layers of the ATN: subnetwork layer, link layer and physical layer.

3.3.2.1.2 The subnetwork layer provides subnetwork connection management, packet fragmentation and reassembly, error recovery and connection flow control, conforming to ISO 8208.

3.3.2.1.2.1 The link layer comprises a media access control (MAC) which requires the use of the carrier sense multiple access (CSMA) algorithm. It further includes a data link service (DLS) sub-layer, based on the protocol specified in the ISO standards for high-level data link control (HDLC) and a link management entity (LME) in order to establish and maintain connections between airborne and ground stations on a VHF channel.

3.3.2.1.2.2 The physical layer provides transmitter (and receiver) frequency control, notification services (e.g. channel occupancy), data reception and transmission through appropriate radio frequency (RF) equipment.

3.3.2.2 **Use of VHF channels**

3.3.2.2.1 The physical medium used by VDL is a 25 kHz bandwidth VHF channel within the 117.975 to 137.000 MHz frequency band.

3.3.2.2.2 The four channels already reserved for data link may prove to be insufficient for the full implementation of VDL. Further study on this topic is deemed necessary.

3.3.3 **ATN services**

3.3.3.1 **Message priorities and quality of service (QOS)**

3.3.3.1.1 Handling of message priorities within the subnetwork and invocation of different levels of quality of service (QOS) are not provided by VDL/CSMA (both Mode 1 and Mode 2). This was considered acceptable.
3.3.4 Modulation schemes

3.3.4.1 Mode 1 modulation scheme

3.3.4.1.1 Mode 1 uses a minimum shift keying (MSK) modulation scheme. This modulation scheme is already in use today for the aircraft communications addressing and reporting system (ACARS) and can be implemented for VDL using present day airborne VHF analogue radios. MSK responds to the Standards currently prescribed by Annex 10 for double-side band amplitude modulation (DSB-AM), and allows a channel rate of 2 400 bits/s.

3.3.4.1.2 The VDL Mode 1 protocol is significantly different from ACARS, because of the use of bit-oriented protocols and the use of ATN subnetwork protocols.

3.3.4.2 Mode 2 modulation scheme

3.3.4.2.1 To achieve greater spectrum efficiency, AMCP/3 had accepted a differential eight phase shift keying (D8PSK) modulation scheme as the basis for validation of Mode 2. The main features of this modulation scheme are:

a) three bits per symbol;

b) raised cosine alpha = .6 amplitude shaping; and

c) 10.5 kHz baud rate (or symbols rate), therefore leading to a channel rate of 31.5 kbit/s and would be compatible with the 25 kHz channel spacing.

3.3.4.2.2 The criteria leading to the validation of the modulation scheme for Mode 2 are:

a) acceptable adjacent channel interference (ACI) for the data link-to-data link interference;

b) acceptable ACI for the data link to voice interference and vice-versa; and

c) demonstrated technical feasibility and availability of commercial off-the-shelf components.

3.3.4.2.3 In addition, it should be observed that this modulation scheme was also considered compatible for the VDL Mode 3 (integrated digital voice and data).

3.3.4.3 Mode 2 physical layer protocol

3.3.4.3.1 The physical layer protocol for Mode 2 consists of a training sequence containing five segments: pre-key, bit synchronization, reserved symbol, transmission length and header forward error correction (FEC).
3.4 ICAO Standards and Recommended Practices

3.4.1 VDL draft SARPs

3.4.1.1 The draft VDL SARPs were presented to the meeting and are contained in Appendix C to the report on this agenda item. The SARPs were considered complete and sufficiently mature to be incorporated into Annex 10. Validation activities are described below.

3.5 Validation

3.5.1 General

3.5.1.1 The validation of the VDL SARPs has been carried out along the lines agreed by AMCP/3 (reference Appendix A to the Report on Agenda Item 7 from that meeting), and followed the same methodology used by AMCP to validate the aeronautical mobile-satellite (route) service (AMS(R)S) draft SARPs.

3.5.1.2 The validation activity has been managed by the Validation Sub-Group (VSG). Details on the validation activities are presented below.

3.5.2 The methods of work of the VSG included:

a) to keep the draft SARPs under strict configuration control;

b) to establish a mechanism of “change reports” to identify problems, and to propose and justify changes to the draft SARPs;

c) to make the latest version of the draft SARPs available, on a regular basis, for review by all interested parties and for interim and final assessment by Working Group C; and

d) to maintain a database recording methods used to validate each requirement within the draft SARPs – the validation cross reference index (VCRI) (see paragraph 3.5.4).

3.5.2.1 The detailed flow of the configuration control mechanism is shown and explained in Figure 3-1.
Explanation of the Configuration Control process

The configuration control process is based on the processing of change requests (CRs) that identify a problem and eventually a corresponding solution. The diagram above shows the major stages in processing the CRs.

Each CR has a status and a review result. Only certain combinations of these classifications are meaningful:

<table>
<thead>
<tr>
<th>Status</th>
<th>Review result</th>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>None</td>
<td>[O/-]</td>
<td>The CR has just been raised, but has not been considered by the VSG. It is a new CR.</td>
</tr>
<tr>
<td>Active</td>
<td>Accept</td>
<td>[A/A]</td>
<td>The CR has been reviewed by the VSG. The problem has been accepted as real and the proposed solution has been accepted for incorporation in the SARPs.</td>
</tr>
<tr>
<td>Implement</td>
<td>Accept</td>
<td>[I/A]</td>
<td>The solution proposed has been implemented into a specific issue of the SARPs.</td>
</tr>
<tr>
<td>Close</td>
<td>Accept</td>
<td>[C/A]</td>
<td>The implementation of the solution to the CR has been correctly incorporated in the SARPs, reviewed by the VSG and endorsed by WG-C.</td>
</tr>
<tr>
<td>Active</td>
<td>Hold</td>
<td>[A/H]</td>
<td>The CR is awaiting some action: e.g. a proposed solution or some further investigation of the exact nature of the problem so that a solution may be proposed.</td>
</tr>
<tr>
<td>Close</td>
<td>Reject</td>
<td>[C/R]</td>
<td>The CR has been rejected for one of several reasons: e.g. it is a duplicate of another CR; it is an incorrect statement of a problem.</td>
</tr>
</tbody>
</table>

Figure 3-1. VDL SARPs Configuration Control Process
3.5.3 The VSG has held nine meetings to progress its work.

3.5.4 **Validation cross reference index (VCRI)**

3.5.4.1 The VCRI contains the information on specific validation of every requirement in the SARP s. It consists of a sequential list, by paragraph number, of SARP s, against which the techniques used for complete validation are shown. The VCRI is contained in Appendix H to the report on this agenda item.

3.5.5 The following validation techniques applied:

a) **Inspection.** Judgement based on reading the SARP s.

b) **Analysis.** Validation on the basis of analytic examination including detailed calculation.

c) **Simulation.** Validation on the basis of a software model of all or part of the VDL that has been built and run on a computer.

d) **Unit test.** Validation on the basis of prototype and/or pre-production equipment that is designed to test a section of the VDL SARP s, e.g. by inducing very unusual failure conditions.

e) **Integration test.** Validation on the basis of an integrated system. An integration test could be the same as a flight test, but without becoming airborne.

f) **Flight test.** Validation on the basis of testing equipment in a (close to) operational environment. This technique will test the system as a whole, but may not necessarily test all states that the system can reach because for some of these it is very difficult to set up the correct conditions.

g) **Manufacturer's data.** This category is reserved for a statement by a manufacturer that his equipment has satisfied a particular SARP, in the case where the manufacturer may wish to retain confidentiality of the details of the validation that has been done.

3.5.6 The meeting noted that a comprehensive validation activity has been carried out which confirmed the completeness and correctness of the VDL/CSMA Mode 1 draft SARP s.

3.5.6.1 **Mode 2 validation**

3.5.6.1.1 The meeting noted that the validation for the link and subnetwork layer protocols was complete. The minimum necessary activity for the validation of the physical layer and the modulation scheme was equally completed. Additional integration and flight testing is, however, expected to be completed by August 1996.
3.5.6.1.2 In particular, it was confirmed by tests carried out in Japan that a D/U signal ratio of 17 dB (with Eb/No = 22 dB) was achieved. This confirms earlier tests results.

3.5.7 The meeting considered further information on the work carried out on behalf of AENA in Spain*. This information, in general, supported the conclusions of the VSG.

3.6 **VDL benefits**

3.6.1 **Mode 1 benefits**

3.6.1.1 The meeting noted the following benefits that could be achieved by implementing Mode 1:

a) compliance with FANS(II)/4 Recommendation 8/3 for the early implementation of data links;

b) backward compatibility with present day analogue ground and airborne radios, which would ease the introduction of Mode 1;

c) greater spectrum efficiency, compared to existing character-oriented protocol, due to bit-oriented protocols which allow applications to encode the information into shorter messages;

d) availability of an ATN constituent subnetwork;

e) greater end-to-end reliability, due to the mentioned ATN protocols;

f) availability in time for initial operational ATN in the North Atlantic Region, expected to occur in the near future;

g) early introduction of data link ATS services (e.g. pre-departure clearance (PDC), oceanic clearances, CPDLC and others), whose operational requirements are well advanced in the ADSP and whose implementation is currently foreseen at least in Europe; and

h) consequent reduction of communication load on individual voice channels.

3.6.1.2 It was further noted that since Mode 1 protocol suite architecture is identical to Mode 2, and most parts of the protocol themselves are actually identical, Mode 1 can be seen as a stepping stone towards Mode 2.

3.6.2 **Mode 2 benefits**

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* This information was presented in AMCP/4-WP/36 and AMCP/4-WP/37.
3.6.2.1 VDL Mode 2 will introduce a digital modulation scheme capable of supporting different protocol suites for different operational applications, greatly increasing the efficient use of the VHF channel.

3.6.2.2 Preliminary estimates indicate that the net throughput for Mode 2 is in the range of 5 000 to 8 000 bits/s.

3.7 Amendments to Annex 10

3.7.1 The meeting discussed at length the type of material for the VDL SARPs necessary to be included in Annex 10. It expressed that some of this material would require a more responsive amendment mechanism, compared with the current amendment procedure for ICAO Annexes. Such a mechanism should respond more effectively to the need of introducing system improvements while maintaining the interoperability with existing equipment.

3.7.2 Various options were reviewed. However, the meeting could not recommend one particular approach. It was noted that in case it would be decided to introduce a new layer of documentation (e.g. “technical specifications”) it would be necessary that this should be referenced in Annex 10, which would provide for their appropriate status.

3.7.3 The meeting decided that additional work in the panel would be necessary with a view to further investigate this matter. Concerning the adoption of the VDL Mode 1/Mode 2 SARPs by ICAO, the meeting noted that the validation of the SARPs was successfully completed. It was recognized that some further testing, including flight trials, are still ongoing and expected to be completed by August 1996. This testing is expected to confirm the maturity of the SARPs. However, it is not inconceivable that some minor changes may be forthcoming. These changes, if continued, could be submitted to the International Civil Aviation Organization (ICAO) along with comments from States and international organizations resulting from the traditional consultation process.

3.7.4 It was noted that frequency planning material for VDL Mode 1 and Mode 2 still has to be completed. AMCP will undertake to further develop such material as required. Frequency planning criteria are necessary to introduce VDL in the band 117.975 - 137 MHz. The physical layer of VDL Mode 1 is already in use in many areas of the world.
3.7.5 Having considered the compliance with the VDL design guidelines recommended by AMCP/3, the completion of the validation activity and the potential benefits offered to civil aviation, the meeting agreed to the following recommendation:

<table>
<thead>
<tr>
<th>Recommendation 3/1 – Amendment to Annex 10, VHF digital link (VDL) Mode 1 and Mode 2</th>
</tr>
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<tbody>
<tr>
<td>That Annex 10, Volume III be amended as shown in Appendices B and C to the report on Agenda Item 3 in order to include:</td>
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<tr>
<td>a) guidance material for the VDL operating concept; and</td>
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<tr>
<td>b) the VDL Standards and Recommended Practices (SARPs) for Mode 1 and Mode 2</td>
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</table>

3.8 **VDL implementation aspects**

3.8.1 The meeting, when considering the VDL validation activities, noted that the material developed in support of this work contained additional material which included guidance on implementation aspects of the VDL system. The meeting agreed that this material would be of benefit to States when implementing VDL and should be made available by ICAO in an appropriate format. This material should also include, as appropriate, elements of the VDL design guidelines, as contained in Appendix A to the report on this agenda item. Therefore, the meeting developed the following recommendation:

<table>
<thead>
<tr>
<th>Recommendation 3/2 – ICAO Manual – VHF digital link (VDL) implementation aspects</th>
</tr>
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<tbody>
<tr>
<td>That ICAO publish the contents of Appendix A and Appendix D to the Report on Agenda Item 3 as a manual entitled “Manual on VDL Implementation”.</td>
</tr>
</tbody>
</table>

3.9 **Proposed changes concerning VDL system characteristics**

3.9.1 Radio frequency SARPs, currently incorporated in Annex 10, for the VDL were developed by AMCP/3 (Recommendation 8/3 refers). These SARPs are adopted for inclusion in Annex 10 as part of Amendment 71 and will become applicable in November 1996.

3.9.2 Some of the comments received from States could not be dealt with in a timely manner and were referred to the panel for further study. Working Group C, therefore, analyzed these comments and developed proposals for amendments.
3.9.3 The meeting reviewed the results of these studies and agreed to propose changes to Annex 10 as presented in Appendix E to the report on this agenda item. The meeting developed the following recommendation:

RSPP  Recommendation 3/3  -  Amendment to Annex 10  -  Changes to VHF digital link (VDL) radio frequency (RF) Standards and Recommended Practices (SARPs)

That Annex 10, Volume III be amended as shown in Appendix E to the report on Agenda Item 3 in order to update material related to VDL radio frequency standards and recommended practices.

3.10 Proposed new definition for VHF air-ground data link

3.10.1 The meeting noted that the current definition of the VHF air-ground data link contained in Annex 10 does not reflect a capability to accommodate digital data as well as digital voice. The meeting agreed that Annex 10 should be amended to replace the existing definition which would identify both of these features.

3.10.2 Furthermore, the meeting noted that Annex 10, Volume II contained a definition for VHF air-ground data link which was not relevant to any text existing in this volume and, therefore, could be deleted.

3.10.3 Therefore, the following recommendation was developed:

RSPP  Recommendation 3/4  -  Amendment to Annex 10  -  New definition for VHF digital link (VDL)

That Annex 10, Volumes II and III and V, be amended as shown in Appendix F to the report on Agenda Item 3 concerning the definition for VDL.

3.11 Deletion of obsolete material related to air-ground data interchange

3.11.1 In addition to its work on the development of draft SARPs for VDL, the meeting carried out a review of the existing material contained in Annex 10 related to air-ground data interchange. It was noted that the material, found in Annex 10, Volume I, Part I, Chapter 4.12 had been adopted into the Annex in 1973.

3.11.2 Based on its examination of Chapter 4.12, the meeting concluded that this chapter in its entirety, was outdated for the following reasons:

a) the inclusion in Annex 10 of SARPs for Mode S data link and aeronautical mobile-satellite service (AMSS) data link, as well as the expected inclusion of SARPs for VDL and possibly other links (e.g. HF data link);

b) the possibility of today's technology of achieving channel data rates higher than 9600 bits/s; and
3.11.3 The meeting, therefore, agreed that the material contained in Chapter 4.12 (post Amendment 71 – Volume III, Part I, Chapter 6.4) is obsolete and should be deleted. The meeting developed the following recommendation:

RSPP Recommendation 3/5 – Amendment to Annex 10 – Removal of obsolete material related to air-ground data link

That Annex 10, Volume III, be amended as shown in Appendix G to the report on Agenda Item 3 in order to remove obsolete material related to the air-ground data link.