ATNP WG-2
WP 346 **bis**____

AERONAUTICAL TELECOMMUNICATIONS NETWORK PANEL (ATNP)

Validating ATN with VDL

Prepared by Nicholas Xenocostas and David Leahy
Presented by H. Thulin

SUMMARY

This Working paper presents the VDL Joint Validation Program (JVP) and other VDL validation activities that has been undertaken as a collective venture between American Airlines, Rockwell Collins and SITA to assist in the ICAO VDL and ATN validation efforts.
This version of the document has been re-formatted and updated to use the same terminology as the European ATN validation report.

ATTACHMENT L — Validating ATN with VDL

L.1 Initiative Reference & Title

SITA/American Airline Joint Venture Program

L.2 Type

Prototyping

L.3 Responsible State/Organisation

SITA/ American Airline

L.4 Contact Point

State/Organisation	Contact Details
SITA	H. Thulin 18 rue Paul Lafargue 92904 Paris La Defense 10 France Tel: 33 1 46 41 11 87 Fax: 33 1 46 41 19 78
American Airline	B. White

L.5 Participating States/Organisations

State/Organisation	Contact Details
SITA	H. Thulin
Rockwell Collins	F. Mabe
American Airlines	B. White
CENA	B. Simmenauer

L.6 Validation Tools Involved

- SITA ATN Air/Ground router
- SITA AOC Gateway
- Rockwell Collins DLM-900 CMU / VDR
- Rockwell collins Radio Ground stations
- American Airline Host
- CENA ADS station

- SITA X.25 MTN (international WAN)
- SITA mobility simulator

L.7 Validation Periods

Qualification tests were performed from May to - September 1996

flight tests will start End of 1996 and the service will be evaluated during 1997

L.8 References

[1] *ATN Manual, Version 2.0*, ICAO, 19 November 1993

[2] *Draft VDL SARPs, Version 1.0*, ICAO, 22 April 1994

[3] *IATA Airline Coding Directory*, IATA

[4] *Draft ATN SARP 6.0, 28 June 1996*

[5] CNS/ATM-1 Package Internet SARPs Validation Objectives, WG2-WP318, 17 Jun 1996

L.9 Scope of Report

This report is intended to present an up to date account of the validation program for the use of VDL with ATN as undertaken by the JVP partners. Validation tests were carried out using prototype testing techniques with a real avionics equipment, VDL subnetwork and airborne and Air/Ground ATN routers , complemented by a mobility simulator tool for pre-flight tests .

L.10 Background

American Airlines (AA), Rockwell Collins (RC), and SITA have joined efforts to assist in the ICAO VDL and ATN validation efforts via a *VDL Joint Validation Program (JVP).* The scope of this project comprises of the installation and integration of airborne VDL units, the deployment of VDL Remote Ground Stations (RGS), the deployment of ground ATN routers and Airline (AOC) ATN gateways, the use of AOC and Air Traffic Service (ATS) applications for the purpose of validating the ICAO VDL SARPs. The ATS application (ADS) is being tested with the French Civil Aviation ADS station in Toulouse.

The prime objectives of the Program are:

1. Contribution to the ICAO VDL SARP's validation activities
2. Contribution to the ICAO ATN SARPs validation activities
3. Development and certification of an implementation of VDL airborne equipment supporting the Airlines and ATS applications
4. Installation of VDL airborne equipment on-board specific AA aircraft
5. Development, qualification and deployment of VDL RGSs and ATN Router/Gateway
6. Installation of VDL RGSs at specific locations

7. Validation of the VDL air-ground protocols and of the RF spectrum utilization with reference to applicable standards

8. Evaluation of the ATN mobile routing and relaying functions

9. Evaluation of the ATN Router function

10. Evaluation of use over multiple subnetworks

The JVP system encompasses airborne and ground ATN end systems which will be used to transport ACARS or ATN application data (ADS) over the VDL or AMSS subnetworks. The airborne equipment are able to communicate over both the ACARS and VDL/AMSS subnetworks depending on their availability in a specific region.

In order to support the VDL subnetwork, the JVP includes an ATN end-system implementation up to and including transport layer in both the airborne and ground sides. Using such baseline architecture has not only allowed a standard implementation of the VDL protocol but will also permit the interoperability verification with ATN and the AMSS subnetwork. For the initial JVP implementation, the VDL Mode 1 operations will be used over the RF medium (i.e. MSK, DSB-AM, 2400pbs - same as ACARS) given the Mode 2 ground and avionics equipment (i.e. D8PSK, 31.5 kbps) are not readily available.

L.11 JVP System Architecture

L.11.1 Avionics Architecture

The American Airlines aircraft that is allocated for these trials is a commercial passenger aircraft (i.e. operational aircraft with passengers boarded) and therefore special consideration were given to ensure that the existing VHF communication and application capabilities were maintained. To this end, a special avionics architecture was devised to interface the existing ACARS MU applications and equipment with the new ATN avionics. As shown below in Figure L-1, the Communication Management Unit (CMU) interfaces with the MU as well as with the VHF Data Radio (VDR) and Satellite Data Unit (SDU).

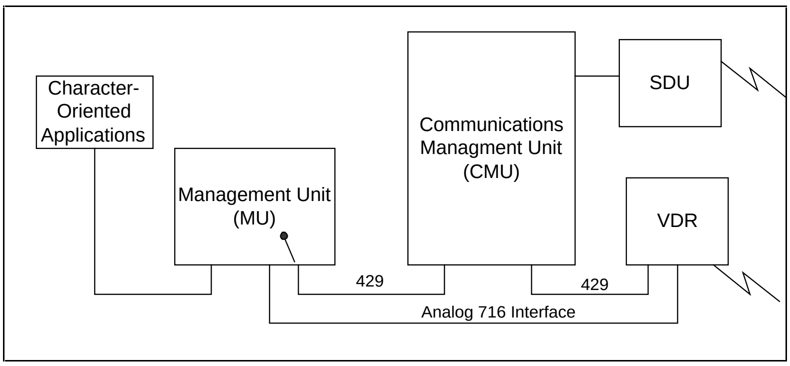

Figure L-1. JVP Avionics Architecture

The MU also interfaces directly with the VDR which provides the ACARS communication path when the VDL subnetwork is not available. The subnetwork priority for the American Airlines AOC applications is :

- First Priority: VDL (ATN)

- Second Priority: VHF ACARS
- Third Priority: AMSS (ATN)

In other words, if there is no VDL service available in a particular region, the aircraft will use the existing VHF AIRCOM service (ACARS). If neither of the VHF subnetworks are available (i.e. over the ocean), the aircraft will revert to AMSS. The aircraft will use special ACARS squitter messages which are transmitted on the present SITA AIRCOM VHF frequency to switch from the VHF AIRCOM service to the VDL pre-operational service.

For example, a typical scenario would be when the AA aircraft is entering European airspace onto its final destination to London Heathrow airport. Before entering VHF coverage, the aircraft would be communicating over the SITA AMSS ATN network. Once into VHF coverage, the aircraft would acquire the VHF ACARS service which at that time would be informed via ACARS squitters that local VDL service is available. At this point the aircraft would tune to the respective VDL frequency and establish a link with the VDL ground station.

L.11.1.1 Avionics Certification Requirements

Given the test avionics will be installed on an Operation aircraft the avionics have to be certified to a "non-interference" level (i.e. same level as the certification requirements for the ACARS MUs).

L.11.2 JVP Ground System

The JVP ground system is composed of a VDL Ground station network, an ATN router, a gateway and the American Airlines application host. Figure L-2 below shows the JVP air and ground configuration.

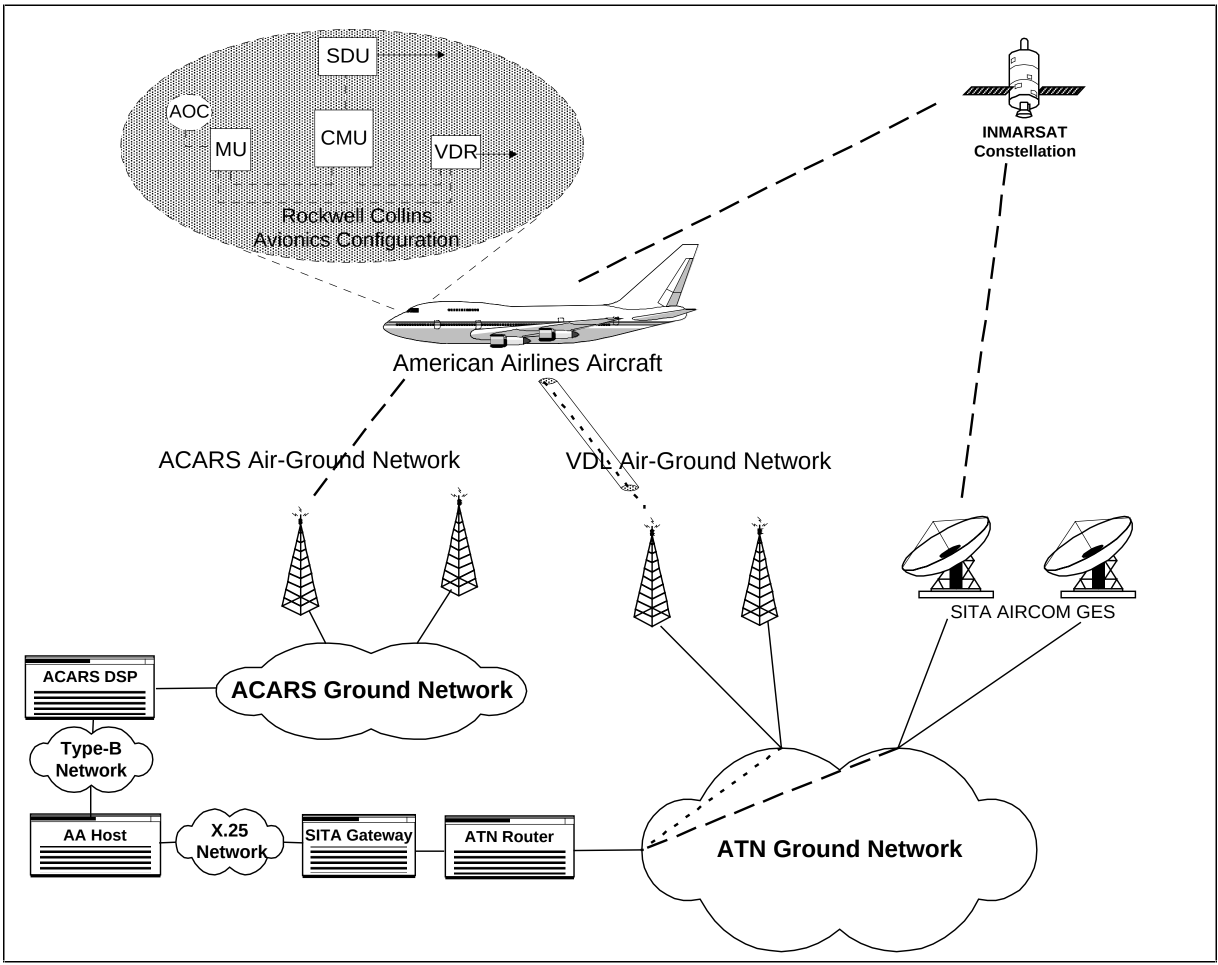

Figure L-2. JVP Architecture

To meet the AA flight schedule requirements for the VDL equipped aircraft, VDL ground coverage at both the Heathrow and Gatwick airports have already been installed. Moreover, ground station installations are also planned at Shannon and Dublin which will be used for enroute coverage as well as for further verification of the handoff processes. Figure L-3 below outlines the existing and planned VDL coverage in Europe to support the JVP.

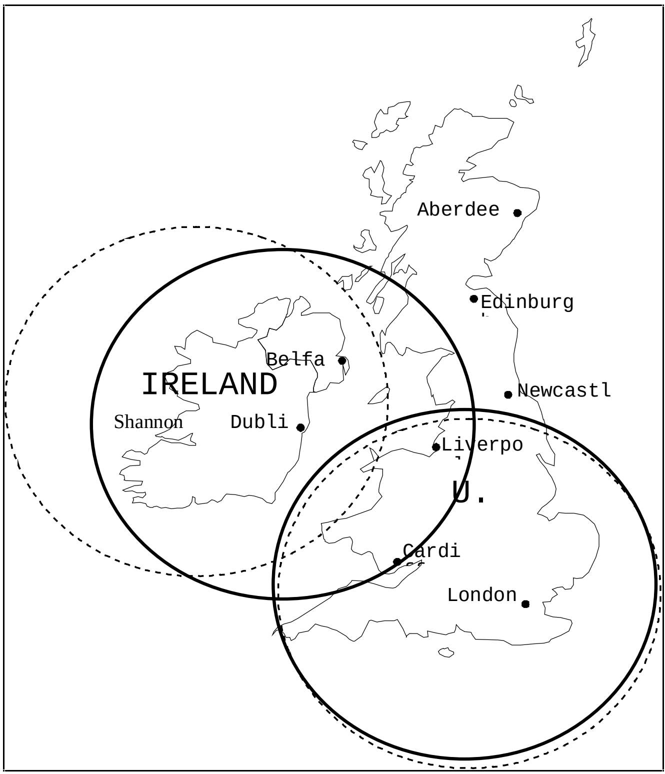

Figure L-3. JVP VDL coverage

The ATN router supports the ATN internetworking functions while the SITA gateway acts as an end-system for the AA host. The AA host interfaces to the SITA gateway and supports the peer airborne AOC applications.

L.11.3 Validation of the VDL protocol

The Joint Validation Program focuses primarily on the VDL protocol stack which includes the Link and Subnetwork layers. As mentioned above, the physical layer used for the JVP is Mode 1.

Rockwell Collins International have developed a Communication Management Unit (CMU) and a VHF Data Radio (VDR) to support these trials. These are real avionics which have been installed on a operational aircraft. This is to emphasize the point that the certification and configuration management processes internal to the JVP partners and externally have been a major activity within this project.

L.11.4 Integration Testing & Flight Trials

Extensive bench tests (i.e. full integration system tests) have been completed by the JVP team at the Rockwell Collins facilities at Cedar Rapid. The bench test setup is shown in Figure L-4 below. The VDL protocol has been exercised for at least 500 hours without entering into any deadlock states or any adverse conditions. (Rockwell Collins has already sent the validation matrix to the VSG outlining the validated VDL SARPs paragraphs).

The operational flight trials are to commence during the fourth quarter 1996. It is expected that the avionics will be upgraded with the Mode 2 physical layer by year-end 1996.

L.11.5 Mobility simulation Tools

In order to validate handover procedures in the ATN Air/Ground router during pre-flight trials, VDL and airborne router are simulated using a mobility simulator which consists of connecting an Airborne simulator via a low throughput X.25 ground line to the SITA air ground router. The data throughput of the X.25 line is configured to a speed similar to that of a VDL link. This tool allows the possibility of simulating a handover between several RGS. The airborne simulator is capable of generating routing initiations and establishing BIS-BIS connections.

L.12 VDL/ATN validation approach and results

L12.1 Introduction - JVP Tests

The validation objectives can be grouped under some broad headings. These are Routing Initiation, Routing Termination, Handover, CLNP and Transport Interfaces. The basis for this validation are the results of tests carried out by the joint venture program partners. The aim is the validation of the ATN stack using the VDL subnetwork.

Three types of tests have been identified :

1. Simulation These tests are performed using the SITA mobility simulator , to validate handovers procedures

2. Prototyping These tests were performed operating the Rockwell Collins avionics and a VDL station in a testbed, this VDL station being connected via the SITA X.25 WAN to the SITA ATN Air/ground router in Paris. This Air/Ground router provide access to the American airline Host operational system located in Tulsa via a SITA AOC gateway, as well as ATN ADS stations connected to the SITA MTN .ADS testing were done cooperation with CENA using their Toulouse ADS station.

3. Flight testing It should be noted that the JVP flight testing encompasses the exchanges of operational AOC data on VDL, thus requiring backup solutions on Acars VHF and ATN satellite network , as well as intensive qualification testing.

At the end of september 1996 ,Tests performed to date have been of types 1 & 2 only.the infrastructure for the flight trials is deployed and type 3 validation will start on the fourth quarter of 1996

Regarding applications, the avionics equipment developed by Rockwell Collins is capable of forwarding AOC traffic for the American Airline Host or ADS traffic for CENA via the SITA air ground router and SITA AOC gateway. These tests can be done in parallel and simultaneously over the VDL and Satellite subnetwork thus meeting the validation requirement of multi network use.

A general decription of what was validated is given here.

	Simulation of VDL	VDL network	Simulation of Satellite	Satellite network
Routing Initiation	✓	✓	na	na*[1]
Routing Termination	✓	✓	na	na*[1]
VDL VDL Handover	✓	✗	na	na*[1]
VDL Sat Handover	✓	✓	✓	✓
Sat VDL Handover	✓	✓	✓	✓
Peer-Peer Interoperability	✓	✓	✓	✓
Application Support	✓	✓	✓	✓
IDRP support	✓	✗	✓	na
Multi network support	✓	✓	✓	✓
QoS Support	✓	✓	na	na

Note 1 : *As this document concerns only VDL validation, the column on Satellite validation is deemed relevant only where done in the context of VDL validation and thus validation of satellite outside the context of VDL is marked not applicable or "na".*

L.12.2 Routing Initiation

Air initiated route initiation has been validated over VDL subnetwork. The VDL subnetwork is an event driven subnetwork, this means that it does provide connectivity information. The ATN airborne and Air/Ground routers implemented the ATN routing initiation procedure with non use of IDRP on the Air/ground subnetwork Use of mobile routing initiation without IDRP was validated over real and simulated VDL while IDRP routing initiation was validated over simulated VDL environment.

The following has been validated:

1. ATN routing initiation on VDL , with VDL connection establishment , and exchange of ISO 9542 ISH using the fast select procedure

2. The FIBs of the air ground and airborne router are correctly updated

The transmission of ISH PDUs ceases on establishment of VC (ISH are filtered by the SNDCF function in the airborne and Air/Ground route

⇒ Including layer 2 initialisation , in mode 1, the initial trials shows a connection time of 60 seconds. Once layer 2 is established , if the virtual circuit is closed by the user, the re-establishment of such virtual circuit takes 5 seconds.

L.12.3 Routing Termination

Routing termination can occur for different reasons:

> When the RGS detects the loss of coverage for a given aircraft, all the appropriate calls between the ground ATN Router and the airborne ATN router get cleared.
>
> The loss of all VCs with a given aircraft is detected by the ground VDL SNDCF, which then activates the Routing Termination phase. Leave event are generated to the network layer entities .

⇒ Leave event were correctly generated in the Air/Ground router and detected in the airborne unit (In the JVP environment, the loss of VDL coverage in airborne unit causes the AOC traffic to be forwarded on the regular ACARS unit)

L.12.4 Handover

Internal VDL handover procedures (RGS to RGS) have been validated through simulation, using the SITA mobility simulator. ATN handover procedure between the VDL subnetwork and the AMSS subnetwork have been validated using the prototyped VDL network (RGS located in a testbed) and the a real access to the AMSS satellite subnetwork (WEIR GES).

L.12.4.1 VDL-VDL Handover:

At time of handover there exists two VCs between ground router and airborne router (active and old VC)NPDU traffic is accepted from the airborne router on both VCs by the ground router.

The unused VC is cleared by the air ground router SNDCF after the expiration of the G_TG5 timer

The G-TG5 timer was set at 20 seconds.

⇒ AOC traffic was permanently sent via the mobility simulator. The Transport connection remains unaffected by the subnetwork handoffs procedure and there was no AOC message lost or delay

L.12.4.2 VDL-Satellite and Satellite -VDL Handover

A simple routing policy preference for VDL first then satellite was configured in the Air/Ground router.and several handover procedures were performed

⇒ It was observed that the value of the transport timers parameters must be set to an optimal value in order to avoid transport disconnection or congestion due to TPDUs retransmissions while either the satellite or the VDL connection is being reestablished. It is recommended that the ATN guidance material provide a recommendation for a mobile transport profile. Optimal values obtained in the JVP trials are provided in section 12.8.1

L.12.5 Peer-Peer Interoperability

The airborne ATN router and the Air/Ground router used in the JVP are built from a different set of OSI software and interoperabilty tests had to be performed

⇒ The interoperability problems detected during initial test were mainly due to inconsistent transport profile in the airborne and air/ground system. Inconsistent segmentation (size of 8473 NPDus) can also increase the Transport retransmission rate

As a result of initial test a common parameter profiles was established - see section 12.8.1L.12.6 ApplicationSupport

Though some tests were performed (test applications) using transport security ,VDL does not offer subnetwork priority so no significant impact was observed Security was not used due to limitations in the airborne router however on the Air/ground router a simple default routing policy of preference of VDL over the satellite subnetwork has been implemented.

⇒ In term of quality of service, the main achievement of the use of the VDL technology in an ATN infrastructure is that when the transport profile is correctly set, the transport connections remains unaffected by the frequent VDL/VDL handovers procedures which remain fully transparent for the application.

L.12.7 IDRP Support

In addition to the JVP trials , some additional tests which use non IDRP routing initiation on VDL in conjunction with ground/ground IDRP advertisement were performed successfully in a limited ground protyped network. (four ATN routers) with correct propagation of routing information. however propagation time were not measured as this was the scope of other ATN cooperative trials

L.12.8 Multiple Use of Subnetworks

This was validated using the Rockwell Collins DLM-900 to generate AOC traffic for the American Airline host simultaneously with ATS traffic for the French CAA. This parallel test was done with one communication type over a prototyped VDL and the other over the real AMSS Satellite subnetwork

⇒ No impact could be observed when parallel traffic was sent without congestion situation.all congestion situation observed lead to a disconnection of the transport connectivity thus interrupting the service. (there is no congestion management algorithm implemented for these trials)

L.12.8.1 VDL Profiles

Transport profile used was the following for the JVP experiments:

- Checksum used
- Maximum TPDU size: 1024 bytes
- Maximum Credit used: 4
- Initial Credit used: 2
- Extended format
- NSDU lifetime: 50 secs
- Acknowledgement Delay: 2
- Time for Retransmission: 100 secs
- Retransmit Count: 3
- Window Timer: 100 secs

- Inactivity Timer: 10 minutes

L.12.9 Performances

The following figures were derived from the validation experiments without any attempt at optimization. They are intended to give an overall impression of the VDL subnetwork.

L.12.9.1 Throughput

In mode 1, which is used for early VDL validation (see paragraph 2.1) the expected throughput is 600 bit/s . In Mode 2 technology , the expected throughput should reach 16.5 kbits seconds -

L.12.10 Meeting ATN Validation Objectives

The following table lists validation objectives met or partially met as they apply to VDL. There are no specific validation objectives relating to VDL, rather reference is made to the more general [5]. The validation reference objectives numbers are taken also from this document.

Validation Identifier	Description	Results
Airborne BIS AVO_102	Airborne ES	transport compliance (the system is built on a short stack with no upper layer)
AirGround BIS AVO_104	Air-ground BIS and SARPs compliance	Compliant
Airborne BIS without IDRP AVO-106	Airborne BIS not supporting IDRP	Compliant
ATN Subnetworks AVO-112 ,AVO_113	Use of Satellite and VHF subnetwork with the ATN	Compliant
ATN adressing AVO-121	ATN requirements on addressing	Compliant
Routing Architecture AVO_122	Routing architecture and policy and SARPs compliance	Partial compliance - Routing policies based on subnetwork preferences
Default Interworking Profiles AVO_201 AVO_202	COTS and CLTS Transport Service	Validated for COTS
A/G no IDRP AVO_232 AVO_234, AVO_240 AVO_244 AVO_245	Various aspects of BIS BIS communication not using IDRP: route initiation, ISH monitoring	Routing initiation, connection establishment, handoff procedures validated.
Policy AVO_247	Routing policy rules in VDL environment	Subnetwork preference has been tested, VDL in preference to satellite..
Application Support AVO_301 AVO_310 AVO_311 AVO_312 AVO_313	User application transparency, support of various types of user comms: admin, operational, general	AOC and ATS communication types have been used simultaneously over VDL.
S/N Independence AVO_303 AVO_304	Fallback on another S/N if problem on default.	Tested with Satellite and VDL. VDL link cut communication then resumed on Satellite without data loss.
Protocol Overheads AVO_420 AVO_431 AVO_460	BIS BIS communication, Transport/CLNP overhead	Has been examined without IDRP. The max data throughput has been found to be 600 bits/sec.
Mobile Handover AVO_421 AVO_422 AVO_423 AVO_424 AVO_426 AVO_429	Maintenance of communication, acceptable downtime, reliability.	Transport connections are maintained without interruption during handoffs.

QoS AVO_441 AVO_442 AVO_443 AVO_444 AVO_445	QoS for network configurations, effect of transport ack strategy, transport timer values, TPDU size, max VDL SNSDU, impact of traffic load.	Evaluations have been done - see L.12.8.1
Compression AVO_454 AVO_455 AVO_456	Compression algorithms: none, LREF, LREF and ACA, LREF and V42bis, LREF ACA and V42bis.	LREF compression has been used

L.13 Conclusions

Based on the Joint Validation Program, the following conclusions can be made:

1. The ATN SNDCF for mobile subnetwork as specified in the ATN SARPs is interoperable with the VDL protocol as specified in the VDL SARPs and both technologies can be implemented in real avionics and ground systems.

2. The resulting ATN and VDL architecture is stable and no deadlock states or adverse conditions have been uncovered based on the subset of the VDL and ATN protocols that the JVP program has based its implementation.

3. The ATN SARPs validation approach criteria as outlined in [5] i.e. requirement implementation, interoperability, satisfying user requirements, good performance have been met in the ATN/VDL architecture selected for these JVP tests.