ARSAG

AERIAL REFUELING SYSTEMS ADVISORY GROUP

Guidance document

Automated Aerial Refueling Concept of Operations

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RECORD OF REVISIONS

REVISION	*DATE*	*REASON FOR REVISION*

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SUMMARY

This document presents ARSAG's vision for the process of ensuring the future safety and interoperability of the Automated Aerial Refueling (A^3R) mission.

Ultimately a number of Concept of Operations (CONOPS), STANAGS, and airworthiness related documents will be needed, however, given the state of the technology associated with A^3R, ARSAG desired to publish its thoughts on the A^3R CONOPS as a recommendation for a guidance document (Standards Related Document (SRD)) to the NATO ATP 3.3.4.2 Air to Air Refuelling document. The document will be submitted to NATO by NAVAIR.

It is intended that this document be submitted by NAVAIR to the Defense Technical Information Center (DTIC) for publication.

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Group 5A would like to thank ALL of the Military and Industry representatives from across the world who has participated in the development of this ARSAG Guide Document. Specifically, this document could not have been created without the help of the following individuals:

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REFERENCES

N°	TITLE	REFERENCE	ISSUE	DATE	SOURCE
1.	ATP-3.3.4.2 Air to Air Refuelling ATP-56		Edition C, Version 1	November 2013	JAPCC/AARWG
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ARSAG Workshop / DOD Joint Standardization Board (JSB) for Aerial Refueling Systems

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ASSOCIATED DOCUMENTS

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NA				

ABBREVIATIONS AND TERMINOLOGY

AR *	Aerial Refueling
AAR *	Air to Air Aerial Refueling
A^3R	Automated Air-to-Air Refueling (Automated Aerial Refueling)
AARWG	Air to Air Refueling Working Group
ARSAG	Aerial Refueling Systems Advisory Group
ATP	Allied Tactical Publication
CONOPS	Concept of Operations
FTAR	Future Technologies in Aerial Refueling
JSB	DOD Joint Standardization Board for Aerial Refueling Systems
NATO	North Atlantic Treaty Organization
SRD	Standard Related Document
STDS	Standardized Technical Data Survey
STANAG	Standardized Agreement
ARCP	AAR Control Point
ARCT	AAR Control Time
ARIP	AAR Initial Point
ARSAG	Aerial Refueling Systems Advisory Group
ATC	Air Traffic Control
ATP	Allied Tactical Publication
AV	Air Vehicle
AVO	Air Vehicle Operator
BLOS	Beyond Line of Sight
B/R	Boom/Receptacle (Boom and Receptacle)
CONOPS	Concept of Operations
DL	Down Link
DoD	Department of Defense
FPM	Feet per Minute
INS	Inertial Navigation System
JSB	Joint Standardization Board
LOS	Line of Sight
NATO	North Atlantic Treaty Organization
P/D	Probe/Drogue (Probe and Drogue)
RV	Rendezvous
UL	Up Link

* AR (aerial refueling) and AAR (air-to-air refueling) are synonymous

Introduction

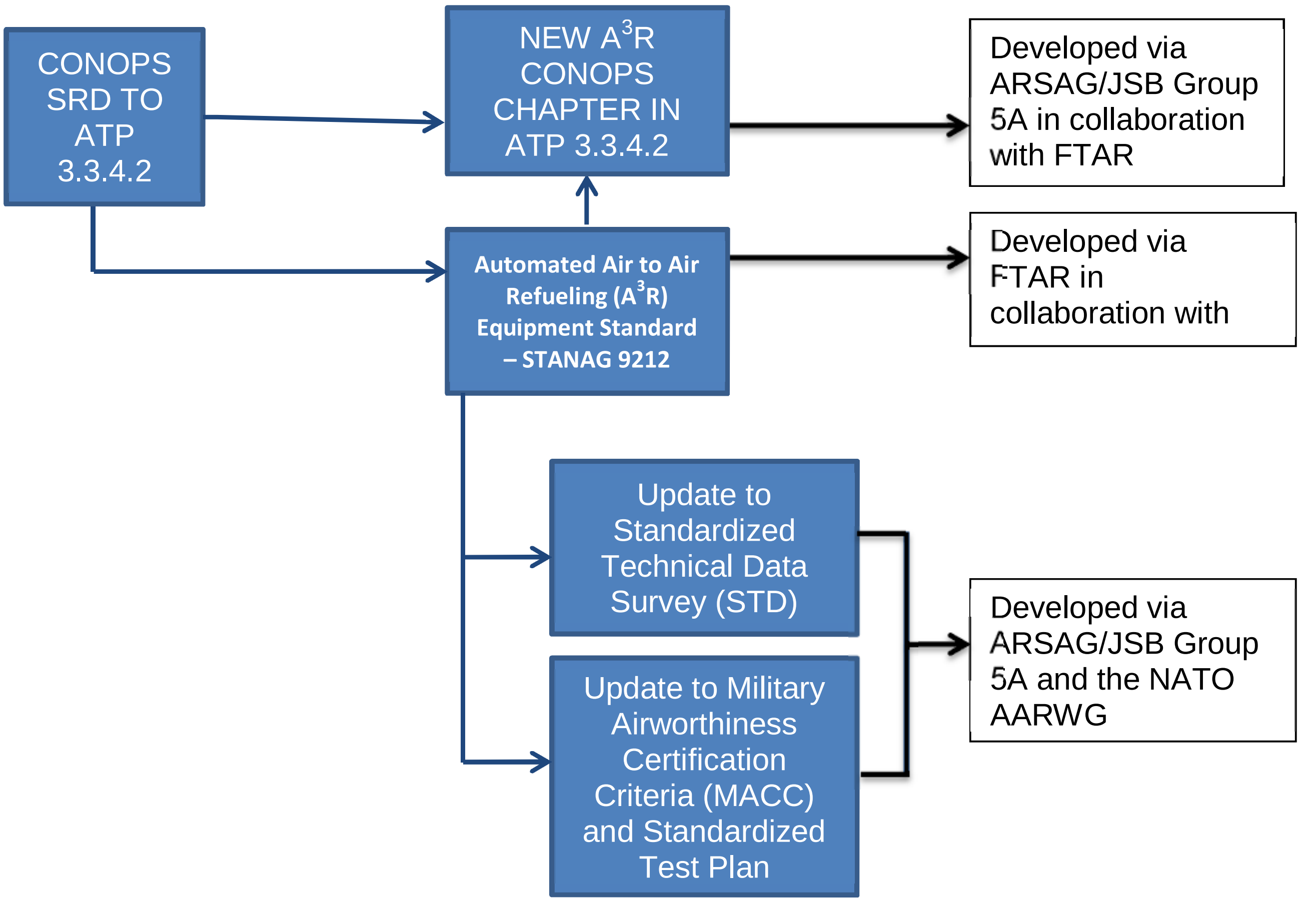
The Aerial Refueling Systems Advisory Group (ARSAG) recognizes that Automated Aerial Refueling (A^3R) will become a reality in the near term. As such, ARSAG wants to lead industry and the services in guiding the standardization and interoperability of the A^3R mission. To achieve this goal, Group 5A of the ARSAG/Joint Standardization Board (JSB) Workshop, the Automated Aerial Refueling working group, has been working on a Concept of Operations (CONOPS) guide document to support A^3R. The ultimate goal of this document is to produce a new A^3R Chapter in Allied Tactical Publication (ATP) 3.3.4.2 (ATP-56 - Air to Air Refuelling CONOPS). However, given that much of the technology is in the development stage, and many countries are not yet actively seeking A^3R capability, ARSAG decided to submit the attached recommendations for a Standardization Related Document (SRD) with two goals in mind;

1) Guide systems development with the goal of future interoperability;
2) Stimulate all nations conducting aerial refuelling to think about how A^3R will be conducted and what their role in it can be (tanker or receiver).

It is intended that this document will be submitted through NAVAIR to the North Atlantic Treaty Organization (NATO) Joint Air Power Competence Centre (JAPCC) as an ARSAG recommendation for an SRD to ATP 3.3.4.2.

ARSAG understands that multiple documents may be created employing the recommendations in this ARSAG Guidance Document, Automated Aerial Refueling Concept of Operation and/or updated in order for A^3R to become a reality. The goal in producing this document is to allow a quick process for development of automated aerial refueling documents, e.g. a NATO SRD document. Much of the technology required for A^3R is still in development, and as such, it makes certain aspects of the CONOPS tougher to identify.

The flow chart on the next page highlights some of the documents that ARSAG sees as required to enable A^3R to come to fruition. Some of these can be worked in the ARSAG/JSB environment, some can be worked at the associated NATO Air to Air Refueling Working Group (AARWG) meetings, and some will need to be worked during the next round of the Future Technologies in Aerial Refueling (FTAR) effort. The flow chart highlights where those efforts might reside. ARSAG will continue to collaborate with these external groups to bring the documentation to closure and make A^3R, safe, interoperable, and most important, a reality.



Documents that Flow from the AAR CONOPS

1.0 GENERAL

This document addresses the international aerial refueling community's vision as it relates to common procedures, and the associated technology required, for air to air refueling events involving at least one unmanned or automated tanker and/or receiver. Such events are termed as Automated Air-to-Air Refueling (A^3R). The purpose of this document is to provide guidelines for the development of A^3R systems to ensure the solutions are interoperable within the international community. ARSAG is not a governing body and therefore cannot dictate equipment and procedural requirements. However, through its work with the Department of Defense's (DoD) Joint Standardization Board (JSB) and their interface with NATO, it is hoped that this document will serve as a foundation for the future development of an A^3R section for Allied Tactical Publication (ATP) 3.3.4.2. The path to ATP-3.3.4.2 will be to first promulgate this document as a Standards Related Document (SRD) and then moving it into ATP-3.3.4.2 as experience with unmanned tanking is gained.

As the international community continues in their efforts to develop an unmanned aircraft, there are still many unknowns regarding the specifics of the aircraft and associated systems. The overarching assumption is that to the maximum extent possible the system will be designed to accommodate current air to air refueling (AAR) procedures. In its role as an unmanned tanker, it may tank both manned and unmanned aircraft. As a receiver an unmanned aircraft may take fuel from both manned and unmanned aircraft provided the tanker aircraft supports the unmanned receiver aircraft operations. The procedures in this document will accommodate Probe/Drogue and Boom/Receptacle and will mirror ATP-3.3.4.2 as closely as possible. As system designs mature, their impact to this document will be assessed and updated if modifications to standard AAR procedures are needed.

Any unmanned Air Vehicle (AV) that will conduct A^3R will be autonomous. An autonomous AV is one that does not have a stick and throttle for the Air Vehicle Operator (AVO) to manipulate; it knows how to fly itself. Additionally, it will change its behavior in response to unanticipated events. For example, if the AV has been commanded to join on a tanker and the tanker changes heading during the intercept, there is no need for the AVO to do anything. The AV will autonomously detect the tanker's heading change, recalculate the intercept geometry and turn to a new heading to complete the rendezvous. Until unmanned A^3R is better understood, an AVO will be in the loop giving approval for the AV to proceed from one phase of A^3R to the next. This concept, covered by this document, has the AV moving through each phase autonomously when directed by the AVO and stopping at the completion of that phase. In this concept, the AAR process has been automated; hence the term Automated Air-to-Air Refueling. In the future, AAR operations may make full use of autonomy and might need only one message to the AV: Tank. The AV will find the tanker, join, take fuel, depart the tanker and report tanking complete to the AVO. The first step in realizing full autonomy is to exercise and prove the concept of operations in this document.
Automated AAR can be a mix of manned/unmanned tanker/receiver combinations wishing to conduct A^3R. In writing this document, a few underlying assumptions are made;

1) To minimize the training burden and maximize interoperability between manned and unmanned systems, A³R CONOPS will strive to use existing operational procedures as laid out in ATP 3.3.4.2 to the greatest extent possible.

2) The A³R system will support baseline RV Alpha (Anchor RV) rendezvous, as defined in ATP-3.3.4.2. RV Alpha is a flexible RV and best accommodates the capabilities of an AV.

3) A human pilot or AVO will be in control of the AV throughout the refueling process. The AVO is equivalent to a Pilot in Command in terms of authority and responsibility. The AVO will be provided a sufficient level of situational awareness to manage A³R operations.

4) Fully autonomous AAR from rendezvous (RV) through refueling is not being considered at this stage as the technology is yet to mature. AVO action will be required to allow the AV to proceed from phase to phase.

5) The manned tanker crew or tanker AVO will retain control of the airspace and receiver movements around the tanker. The tanker crew or tanker AVO will command the receiving aircraft (manned or unmanned) through the tanking procedures while the receiving aircraft crew or AVO responds to the commands, monitors the event and maintains override authority.

    a. Note – Some nations may prefer that the receiving aircraft AVOs maintain control of the AV in the tanker's airspace.

    b. In this case, the tanker crew or AVO would command the receiving aircraft AVO who would in turn command the AV. These commands will be relayed through the receiving AV to the receiver AVO, via either digital messaging over a datalink, or voice commands.

6) Communications between the receiver and the tanker aircrew (manned or unmanned) will be required. This communication may occur via a control link that is established between the tanker and receiver aircraft. It is envisioned that data link commands will be used to command the AV throughout the A³R process. However, at any time for any reason, voice communication may be used between tanker crews, and the receiving AVO.

7) For manned receivers wishing to receive fuel from unmanned tankers, or wishing to accomplish A³R with manned tankers, the receiver must be capable of exchanging A³R command messages in the same manner as an AV and be in voice communication with the unmanned tanker AVO.

8) This document covers the CONOPS aspect of A³R and associated basic technologies. Equipment standards will need to be developed to compliment

this document and define the critical interfaces such as message content, message format, accuracy, integrity, continuity and availability of navigation data, etc. NATO STANAG 9212 has been reserved for this purpose. Additionally, new A³R airworthiness criteria will have to be developed and AAR Standard Technical Data Surveys (STDS) will be modified to reflect the new airworthiness criteria.

9) The A³R system should accommodate aerial refueling operations in certain EMCON/COMSEC conditions that will be defined in future revisions of this document.

10) One tanker and one receiver are addressed by this document. Future versions will cover multiple receivers on one tanker.

2.0 CONCEPTUAL A³R SYSTEMS OVERVIEW

The goal of the system is to provide air to air refueling technology for a manned or unmanned aircraft to rendezvous and maintain the standard AAR positions described in Table 3-1. The introduction of unmanned A³R will have a huge impact to the technologies in use today while at the same time minimizing changes to proven and safe AAR procedures. The heart of the A³R system will be a precision navigation system that provides a precision relative navigation solution between the tanker and receiver beginning with the rendezvous through contact and on to post tanking operations. It is envisioned that a precision relative navigation system will be used in conjunction with Inertial Navigation System (INS) technology to provide high-availability, high integrity, four dimensional guidance. A robust datalink will be needed with the capability of sending and receiving high volumes of relative navigation data with low latency and high integrity. The datalink will also be used for communication, but initially Line of Sight (LOS)/Beyond Line of Sight (BLOS) voice communications may be required between the AVO(s), manned aircraft and Air Traffic Control (ATC).

To aid in avoiding uncooperative traffic, the AV should have a sense and avoid system.

Table 2-1 lists the notional systems needed to accomplish these tasks.

Table 2-1: Notional A³R Systems

System	Function
Precision navigation system (TBD)	Navigation
INS	Precision Navigation
LOS UHF (data)	C2 between AVO and AV
LOS UHF (voice)	Communication between manned aircraft and AVO
Link-16	Situational awareness for AVO and manned aircraft
High Data Flow Radio	Transmission of navigation data, supporting messaging and C2
Stabilized Drogue	Provides stability to drogue
Drogue Positioning System	Determines Precise location of the drogue

The A³R system is comprised of 4 segments: 1) Unmanned Tanker or Receiver, 2) Manned Tanker, 3) Manned Receiver, 4) AVO stations. The unmanned tanker and receiver are counted as one segment because they will each have the same systems that will enable them to act as a tanker or receiver. Manned receiver aircraft will be able to receive fuel from an unmanned tanker without A3R mechanization (i.e., perform standard AAR). **Figure 2-1** shows how each of these four segments will interact with each other using the notional systems from **Table 2-1**. For illustration purposes Figure

2-1 shows all of the possible combinations of voice and data links that are needed for any combination of manned or unmanned tankers and receivers. For example, in the case of an unmanned tanker giving fuel to an unmanned receiver, Figure 2-1 shows that data links (red lightning bolts) are needed between:

- The unmanned tanker and the tanker AVO
- The unmanned receiver and receiver AVO
- The tanker AVO and the receiver AVO
- The unmanned tanker and unmanned receiver

Voice communication (yellow lightning bolt) is needed between:

- The tanker AVO and the receiver AVO

In the Case of a manned tanker and an unmanned receiver, data links are needed between:

- The unmanned receiver and receiver AVO
- The manned tanker and receiver AVO
- The manned tanker and unmanned receiver

Voice communication is needed between:

- The tanker and the receiver AVO

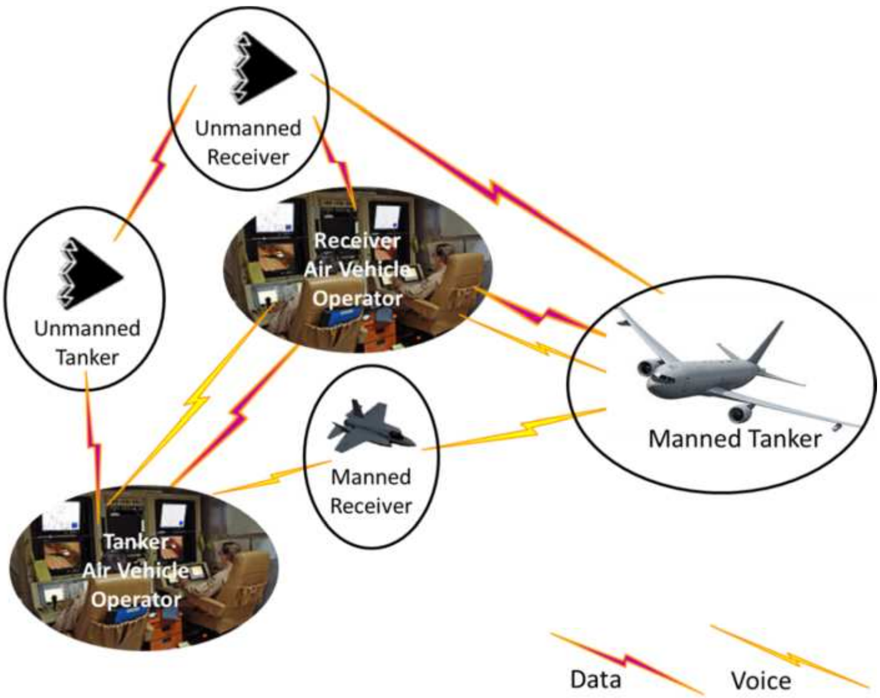


Figure 2-1: A³R System Interactions

A³R CONOPS will strive to use existing operational procedures to the greatest extent possible. The major difference for the operators issuing command and control instructions to the unmanned air vehicles will be in transmitting and receiving messages via data link versus speaking to a pilot over the radio. However, if necessary, AVOs and manned aircrews can communicate via voice communications.

The A³R system design should combine automation and procedural methods to ensure safe separation among all participating tankers and receivers.

3.0 A³R POSITIONS

Table 3-1 and
Figure **3-1** Define standard positions for A³R which will be referenced throughout this document.

Table 3-1: AAR Position Definitions

Position Name	Position Location
Transition Point	1000 ft. below and 1500 ft. aft of the tanker. This is a new position and not in ATP 3.3.4.2. It will be used to assess the AV's relative navigation performance prior to moving closer to the tanker. The precise location will be embedded in the Nav2 message shown in Table 3-4.
Echelon Left/Awaiting A³R	On the tanker's left side, co-altitude or slightly above the tanker's altitude on the tanker's extended wing line approximately one receiver wingspan from the tanker's left wingtip. The exact position will vary between tanker types. During tanker turns the AV will maintain the same position relative to the tanker's wing tip. The precise location will be embedded in the Nav2 message shown in Table 3-4.
Astern (Left, Right, Center)	Probe/Drogue (P/D): The probe tip 50 ft. aft of and centered on the drogue with zero rate of closure. This position is the transition point from tanker relative navigation to drogue relative navigation. Boom/Receptacle (B/R): The AV fuel receptacle is located 50 ft. behind and slightly below the boom nozzle, zero rate of closure. The precise locations will be embedded in the Nav2 message shown in Table 3-4.
Contact	P/D: The position attained when the probe successfully engages the drogue and is pushed in 5-13 ft. B/R: The exact position of the AV's fuel receptacle will vary between tanker types. The precise locations will be embedded in the Nav2 message shown in Table 3-4.
Echelon Right	On the tanker's right side, co-altitude or slightly above the tanker's altitude on the tanker's extended wing line approximately one receiver wingspan from the tanker's right wingtip. The precise location will be embedded in the Nav2 message shown in Table 3-4.

Position Name	Position Location
Breakaway	If tanking on the boom or on the right wing station the Breakaway position is 1000 ft. below and 1500 ft. aft of the tanker on a relative bearing line of 170. If tanking on the left wing station the Breakaway position is 1000 ft. below and 1500 ft. aft of the tanker on a relative bearing line of 190. See Figure 5-6. See ATP-3.3.4.2 for lost wingman. The precise location will be embedded in the Nav2 message shown in Table 3-4.

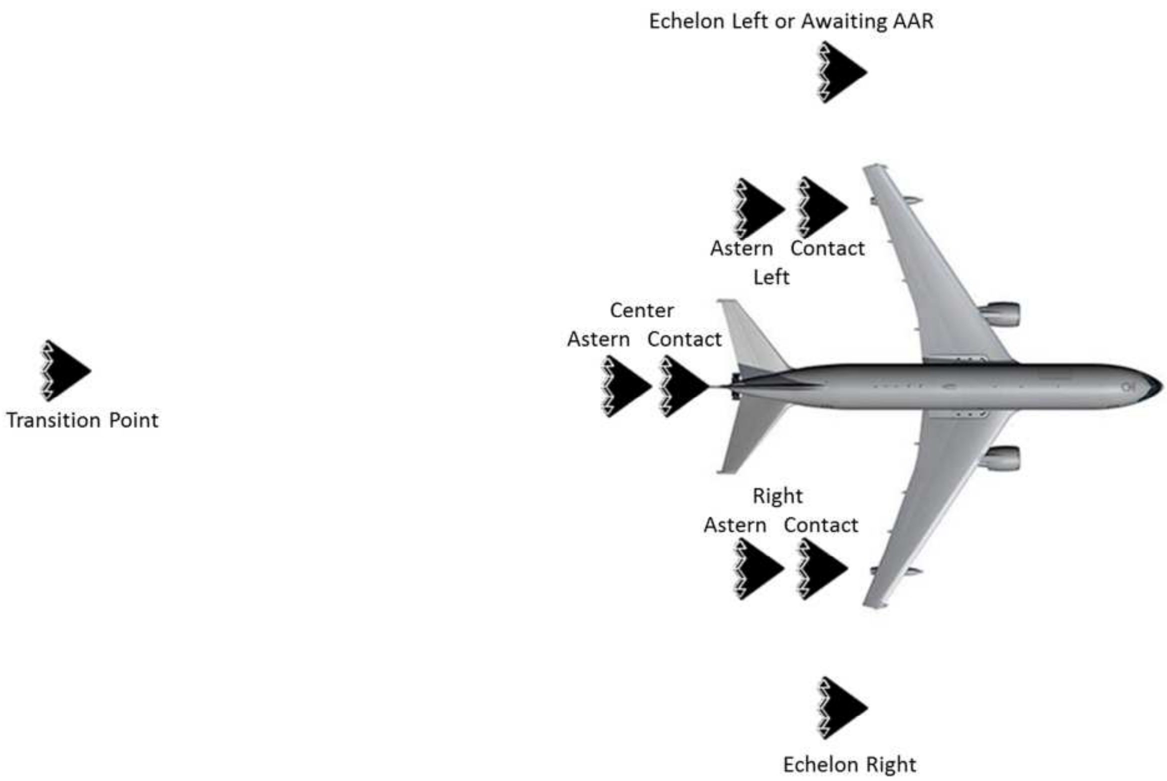


Figure 3-1: AAR Standard Positions

3.1 A³R COMMANDS/MESSAGING

The following tables define a data link message set that takes the existing voice command and control messages/procedures as described in ATP 3.3.4.2 and translates them into data link messages with their associated contents. Up Link (UL) messages are commands that are sent either by the AVO or the tanker to the AV. down Link (DL) messages are responses to UL commands and are sent automatically by the AV or manually by the AVO depending on system design. These tables functionally describe the messages for purposes of CONOPS illustration. Specific format and content of the messages will need to be defined in a NATO standard.

Table 3-2 and Table 3-3 describe the normal command and control messages between a tanker (or AVO) and receiver to effect a rendezvous and engagement. Table 3-4 describes a notional message set specific to the precision navigation information that will be shared in order to successfully engage the tanker. Table 3-5 describes a notional set of data link messages that provide the status of the communication system.

Table 3-2: AVO/Tanker to Receiver Up Link Command and Control Messages

Message	Command Name	AV Procedures
UL1	Join Tanking Network	Receiver will join the tanking network with a specified tanker.
UL2	Join for Tanking	Navigation changes from earth relative to tanker relative to complete the rendezvous. Join with the designated tanker in the Transition Point.
UL3	Transfer (X) lbs.	Response to DL2 Request (X) lbs.
UL4 Cleared to Tanking Position (X) All positions are defined in Table 3-1	Echelon Left/Awaiting AAR Astern (Left, Right, Center) Echelon Right Transition Point	Proceed to the Echelon Left/Awaiting AAR position. Proceed to the assigned Astern position. Proceed to the Echelon Right position. Proceed to the Transition Point
UL5	Cleared to the Contact Position	Proceed to the assigned Contact position.
UL6	Engaged	P/D: Probe engaged in coupling BR: The nozzle is latched in the receptacle.
UL7	Positive Fuel Flow	Fuel is flowing from the tanker to the receiver.

Message	Command Name	AV Procedures
UL8	Disconnect/Disconnected	Probe/Drogue: Command to back out and take the Astern position. Boom/Receptacle: Disconnected from the boom, take the Astern position.
UL9	Cleared to Leave	Only executed from Echelon Right. Right 30 degree turn, maintain altitude or climb.
UL10	Breakaway	Proceed to the Breakaway position. Can be automatically initiated. Example: In the case of inadequate hose reel response.
UL11	Terminate Breakaway	Direction for the Receiver to terminate Breakaway procedures.
UL12	Execute Overrun	Direction for the Receiver to initiate overrun procedures. This message is applicable only when a big wing tanker is used.
UL13	Terminate Overrun	Direction for the Receiver to terminate overrun procedures. This message is applicable only when a big wing tanker is used.
UL14	Take AAR Initial Point (ARIP) Holding at AAR Control Time (ARCT)	Proceed direct to the ARIP holding point and enter holding at assigned ARCT.
UL15	Safe Position while in contact	Used when there is a Boom Flight Control Malfunction. Generally, the Safe Position is down and back while remaining in Contact with the boom. See paragraph 5.3.4 for further discussion of the Safe Position and Boom Flight Control Malfunction. The precise location will be embedded in the Nav2 message shown in Table 3.4.
UL16	Tension Disconnect	Used when a Tension Disconnect is needed.

Table 3-3: Receiver to AVO/Tanker Down Link Command and Control Messages

Message	Command Name	When the Message is Sent
DL1	Joined Tanking Network	Response to UL1 Join Tanking Network
DL2	Request (X) lbs.	AVO can request, in pounds, a specific amount of fuel.
DL3 Established in (X) Position All positions are defined in Table 3-1	Transition Point	Established at the Transition Point
	Echelon Left/Awaiting AAR	Established in the Echelon Left/Awaiting AAR position.
	Astern	Established in the Astern position.
	Contact	Established in the Contact position.
	Echelon Right	Established in the Echelon Right position.
	Breakaway	Established in the Breakaway position.
	ARIP	Established in ARIP holding.
	Safe Position	Established in the Safe Position
DL4	Latched/Engaged	Sent by the receiver when the boom nozzle latches with the receiver's receptacle or the probe engages the drogue.
DL5	Receiving	Receiver is receiving fuel from the tanker.
DL6	Failed to Engage	Receiver's probe has failed to engage the drogue. Or, boom failed to latch. For Probe/Drogue the AV will return to the Astern position.
DL7	Breakaway	Sent by the receiver in the event of an autonomous breakaway or as an acknowledgement to UL10 Breakaway. Breakaway procedures shall be executed immediately by the tanker, and receiver, see paragraph 5.3.1.
DL8	Terminate Breakaway	Acknowledgement to terminate Breakaway procedures.

Message	Command Name	When the Message is Sent
DL9	Execute Overrun	Receiver sends this message when it detects and initiates overrun procedures. This message is applicable only when a big wing tanker is used.
DL10	Terminate Overrun	Receiver sends this message when it terminates overrun procedures. This message is applicable only when a big wing tanker is used.
DL11	Disconnected	The boom has disconnected from the AV or the probe has disconnected from the drogue for any reason.
DL12	Tanking Complete	Sent by the Receiver when reaching 1 nm separation from the tanker.
DL13	Wilco (X)	Receiver sends as acknowledgement that it will execute a tanker command. This message will include acknowledgement of the specific UL message. E.g.: Wilco Left Echelon.
DL14*	Unable (X)	Receiver sends this message when it is unable to comply with a tanker or AVO command. Invalid Command: Example is to send Proceed to Contact before the rendezvous is complete. Action Already Complete: Example is commanding the AV to Contact when it is already in the Contact position. Unable to Execute: Example would be to command the AV to join on the tanker (UL2), but UL1 Join Tanking Network has not been sent.

*The AVO for each unmanned air vehicle is responsible for monitoring all data link messages and voice communications that occur between the other segments and his/her respective AV. At any time, the AVO may counteract a command sent by the tanker (for safety or other reasons) by sending the intended message. In this case, the AVO should contact the tanker to clear up any confusion.

NOTE: The AV's responses to the data link command and control messaging, both acknowledgement and action, are automatic and near instantaneous. Therefore, the operator needs to be very aware of the consequences of a command they are about to issue. If an operator sends an incorrect command, the operator cannot retract the command with a simple "disregard my last" as is done with UHF voice communications.

Rather, the operator must issue a new command to correct the previously sent incorrect command.

Table 3-4: Notional Precision Navigation System Data Exchange Messages

Message	Command Name	Message Description
Nav1	Tanker Geometry Information	Provides tanker geometry offsets to be used to support the generation of the relative navigation vector for precision navigation and aircraft guidance and control.
Nav2	Tanker Position Information	Provides a list of valid tanker relative refueling positions configured for each individual tanker, to be used to support the generation of UL4 Cleared to Tanking Position X and the DL3 Established in X Position.
Nav3	Tanker Motion Sensor Data	Provides the tanker navigation reference data for all aircraft checked into the tanker network.

Table 3-5: Notional Network Status Messages

Message	Message Description
Net1	Heartbeat
Net2	AV Connection Lost
Net3	AV Connection Restored
Net4	System Registration Request
Net5	System Register
Net6	Host Network Broadcast
Net7	Disconnect Acknowledgement

4.0 A³R NAVIGATION REQUIREMENTS

A³R will be possible through the use of precision navigation combined with a networked data link. All nodes in the system (tanker, receiver, AVOs) will be required to check into a common data link network (known as the tanker network) and transmit and receive the required message content. The requirements for the content and format of these messages shall be specified in a STANAG document. At a minimum, requirements for accuracy, integrity, continuity, and availability of the underlying sensors and systems will be included. At the core is the ability to accurately determine a system's own precise location in a reference coordinate frame.

5.0 A³R PROCEDURES

The following sections will describe rendezvous for RV Alpha that has been modified for A³R and some contingency scenarios associated with A³R. As much as possible these procedures will match those in ATP-3.3.4.2 with the primary difference being digital messaging and the use of precision navigation systems.

5.1 RENDEZVOUS

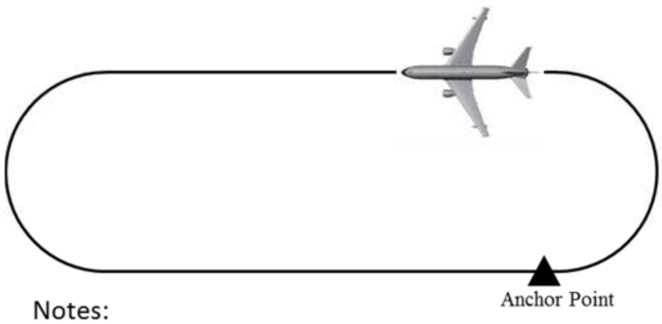
Of the seven types of rendezvous described in ATP-3.3.4.2, only RV Alpha will be discussed in this document. Based on comments from the AAR community others may be added to future revisions. The tanking process begins when the tanker and receiver conduct a communication check. This is followed by the tanker and receiver entering the tanking network. This can be part of the mission plan, but may also be manually commanded by the tanker by sending UL1 (Join Tanking Network). When the network has been established, the AV will send DL1 (Joined Tanking Network) and receiver/tanker data will begin to be exchanged and will be displayed to the AVOs and/or the manned tanker. The tanker and receiver will also be able to message each other.

In the discussion of RV Alpha that follows, the tanker, whether manned or unmanned, will command the receiving AV directly while the receiver AVO observes the messaging and the progression of the A³R procedures. The AV's responses to a message are automatic and near instantaneous. In the event the AVO disagrees with a command that the tanker has sent, the AVO should verbally contact the tanker and send the new command. For any changes to the briefed AAR plan, the tanker and receiver AVOs should coordinate with each other; this could be via voice or datalink communications. Individual country policy may require that only the AVO can command the AV.

The A³R procedures for a manned or unmanned tanker refueling a manned or unmanned receiver are the same and will not be broken out. A manned receiver without A³R technologies will rendezvous, join up, refuel and communicate verbally with the tanker or tanker AVO as is done today. A³R technologies will not impede legacy receiver aircraft from conducting AAR operations.

5.2 RV ALPHA

As described in ATP-3.3.4.2, RV Alpha centers on a ground/air/ship controller verbally providing vectors to the receiver to effect a join up with the tanker. For A³R, the data link system allows the tanker and receiver to know each other's position making them able to run an intercept leading to a join up. Therefore, a controller is not needed for the join up but may be needed for traffic deconfliction/coordination in some scenarios. The tanker will execute its mission plan to arrive at the anchor point at the designated time and altitude. Upon arrival the tanker will fly the pattern as shown in
Figure **5-1**.



Notes:

1. Distance between inbound and outbound legs may be adjusted to accommodate the mission.
2. The standard leg length for this pattern is 50 nm.

Figure 5-1: RV Alpha Anchor Pattern

While holding at the anchor point, the tanker will monitor the briefed AAR frequency. The receiving AV would be mission planned to arrive at the AAR Initial Point (ARIP) prior to joining with the tanker. Upon arrival at the ARIP the receiver AVO will check in with the controller (if needed) and the tanker. If the tanker has not yet arrived, the receiver will hold at the ARIP. When communication is established, the tanker will send UL1 (Join Tanking Network), the receiver will respond with DL1 (Joined Tanking Network). With both aircraft in the network, the receiver AVO will command the AV to join on the tanker at the Transition Point by sending UL2 (Join for Tanking). The receiver AV will respond with DL13 (Wilco Join for Tanking) and will autonomously fly an intercept to arrive at the Transition Point. The tanker and receiver AVO will be able to monitor each other's positions through data link displays. When at the Transition Point, the AV will send DL3 (Established at the Transition Point). The Transition Point places the AV 1000 ft. below the tanker. The receiver may not climb to the tanker's altitude until cleared to do so by the tanker. During the intercept, airspace permitting, the receiver AVO may request the tanker to alter its heading to expedite the intercept.

When in receipt of DL3 (Established at the Transition Point), and relative navigation performance checks are complete, the receiver AVO will clear the tanker to begin commanding the AV. The tanker will command the receiver using the messages in Table 3-2 and the receiver will respond with the messages in Table 3-3. The tanker may command the receiver to the positions shown in Figure 3-1 as needed. To command the receiver to a position, the tanker will send UL4 (Cleared to Tanking Position (X)). The receiver will respond with DL13 (Wilco (X)), and when in the assigned position will send DL3 (Established in (X) Position). When in receipt of UL5 (Contact) the receiver will send DL13 (Wilco Contact). For probe/drogue, when in contact with the drogue the receiver will send DL4 (Engaged). When transferring fuel, the tanker will send UL7 (Positive Fuel Flow). When receiving fuel, the receiver will send DL5 (Receiving). If boom/receptacle, the receiver will wait in the Contact position until engaged by the boom and then will send DL4 (Latched) followed by the tanker sending UL6 (Engaged). When transferring fuel, the tanker will send UL7 (Positive Fuel Flow). When receiving fuel, the receiver will send DL5 (Receiving Fuel).

When fuel transfer is complete, for probe/drogue, the tanker will send UL8 (Disconnect) and the receiver will send DL13 (Wilco Disconnect). The receiver will back out of the drogue, take the Astern position and will send DL3 (Established in Astern). For boom/receptacle, after disconnecting the boom, the tanker will send UL8 (Disconnected) and the receiver will send DL13 (Wilco Disconnected). This message sequence remains the same in the event the disconnect was unintentional. The receiver will move to the Astern position and will send DL3 (Established in Astern). If tanking is complete, the tanker will send UL4 (Cleared to Echelon Right) and the Receiver will send DL13 (Wilco Echelon Right). When in Echelon Right the AV will send DL3 (Established in Echelon Right) and the AVO will coordinate the end of AR clearance with ATC. When ready for the receiver to depart, the tanker will send UL9 (Cleared to Leave) and the Receiver will send DL13 (Wilco Cleared to Leave). The receiver will make a 30 degree right turn away from the tanker and the AVO will alter the AV's altitude as briefed. At 1 nm from the tanker, the AV will send DL12 (Tanking Complete), switch from tanker relative navigation to earth referenced navigation and will exit the tanker network. As an example, Figures 5-2 through 5-5 show graphically message sequencing and AV actions for a nominal probe/drogue refueling operation. The sequence begins at the Transition Point and ends with the receiver leaving the tanker. Boom refueling positions are similar to those shown in Figures 5-2 through 5-5.

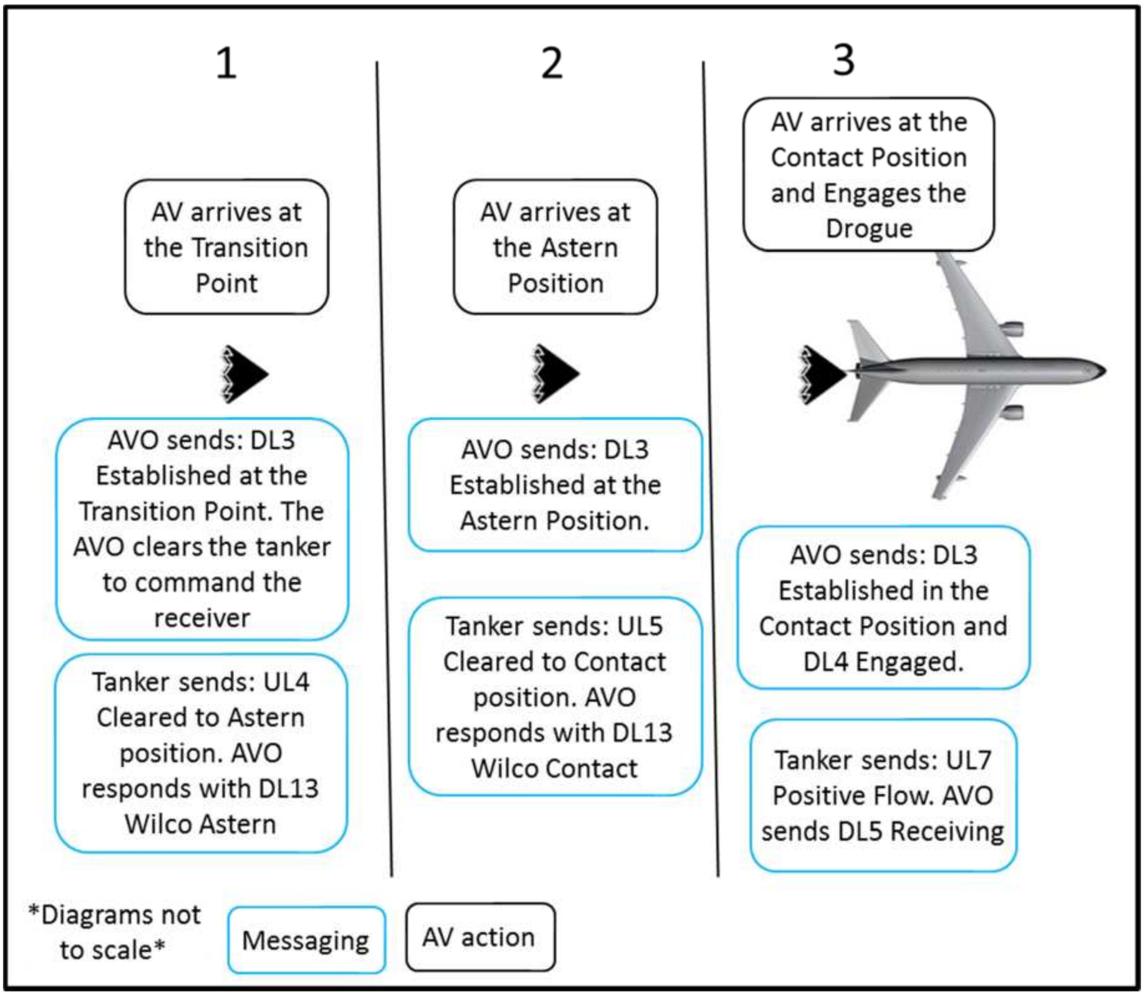


Figure 5-2: Messaging Diagram for Probe and Drogue, Part 1

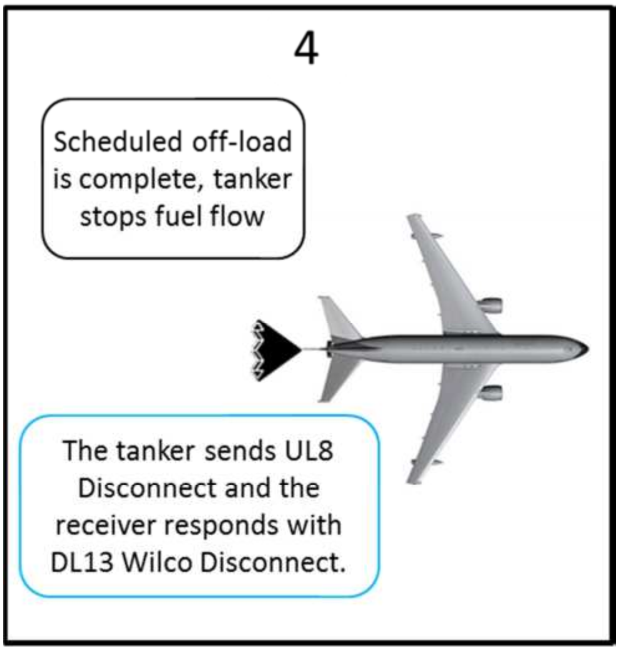


Figure 5-3: Messaging Diagram for Probe and Drogue, Part 2

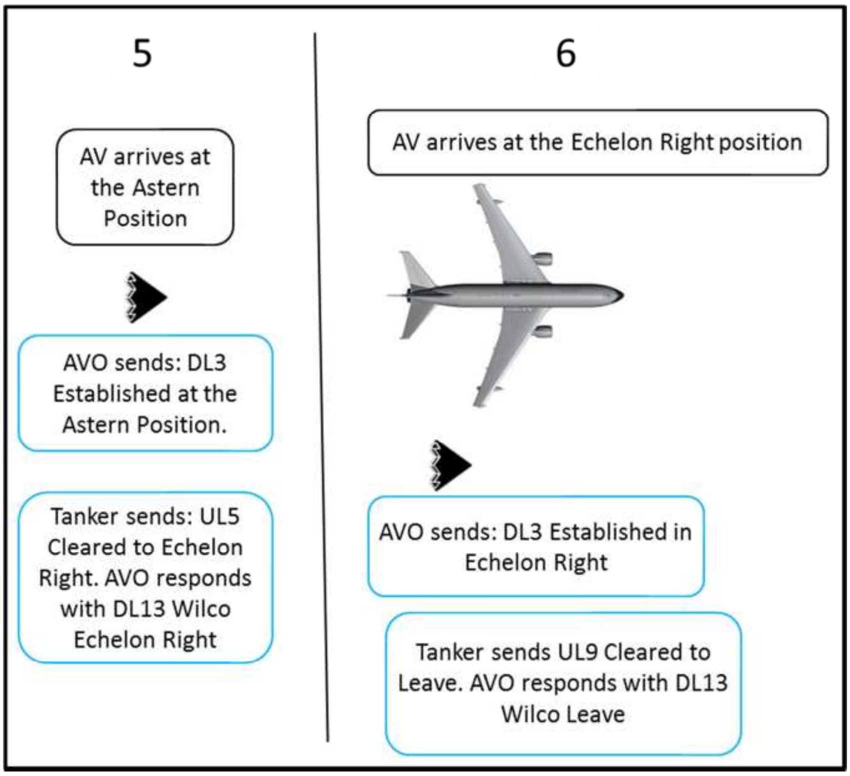


Figure 5-4: Messaging Diagram for Probe and Drogue, Part 3

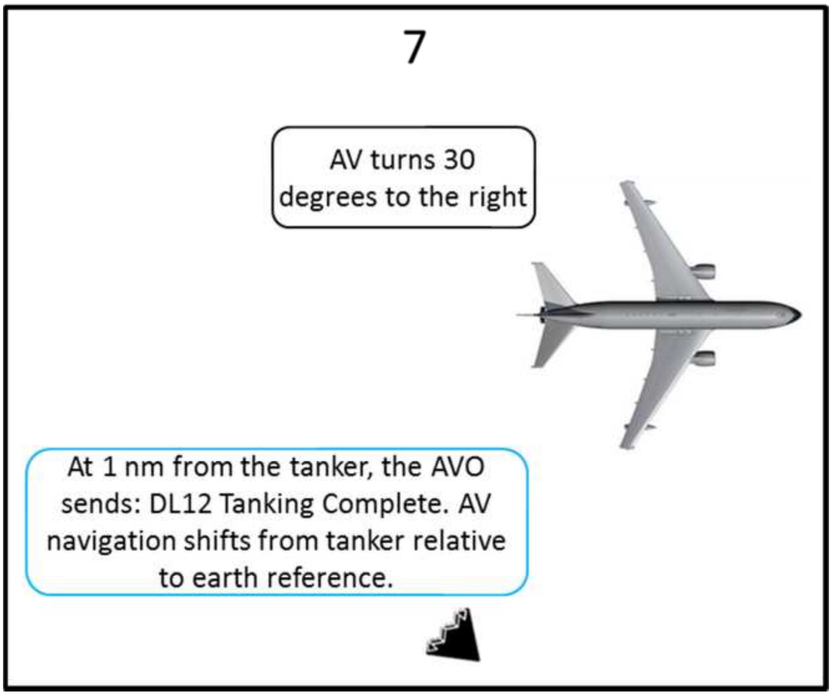


Figure 5-5: Messaging Diagram for Probe and Drogue, Part 4

5.3 CONTINGENCIES

5.3.1 Breakaway

The tanker can send UL10 (Breakaway) and the receiver will respond with DL7 (Breakaway). The receiver AVO can also initiate a breakaway by sending DL7 (Breakaway). The AV can autonomously initiate breakaway by sending DL7 (Breakaway) if it detects a system problem. Whoever sends the Breakaway message will also transmit verbally “Tanker Call Sign Breakaway, Breakaway, Breakaway”. (In accordance with ATP 3.3.4.2, para 2.35) Upon hearing or initiating the Breakaway, the Boom Operator will immediately disconnect from the receiver. If it is an autonomous Breakaway, the AVO will make the radio call. When in receipt of UL10 (Breakaway), or if initiating an autonomous Breakaway, the AV will send DL7 (Breakaway), disconnect the latches, back out of the drogue/depart the boom contact position and will drop back to one of the Breakaway Positions shown in Figure 5-6. If the AV is not in Contact but is in either right or left echelon, it will remain in position during the Breakaway procedure. If at the Transition Point during a Breakaway, the AVO will command the AV to a holding point while avoiding the Breakaway positions shown in Figure 5-6. After Breakaway, messaging authority goes back to the receiver AVO and tanker relative navigation will be maintained by the AV. Whoever initiated the Breakaway will determine when the need for Breakaway has passed and will send UL11 (Terminate Breakaway) from the tanker or DL8 (Terminate Breakaway) from the AVO. The receiver AVO and

tanker will verbally communicate with each other to determine if A³R ops should resume or if they are terminated.
For the purposes of practicing a Breakaway, the verbal term Practice Emergency Separation will be transmitted in place of Breakaway. This terminology is consistent with ATP3.3.4.2, page 1A-13. This is to ensure that all participants are aware that there is no emergency and that Breakaway procedures will be executed as described above.

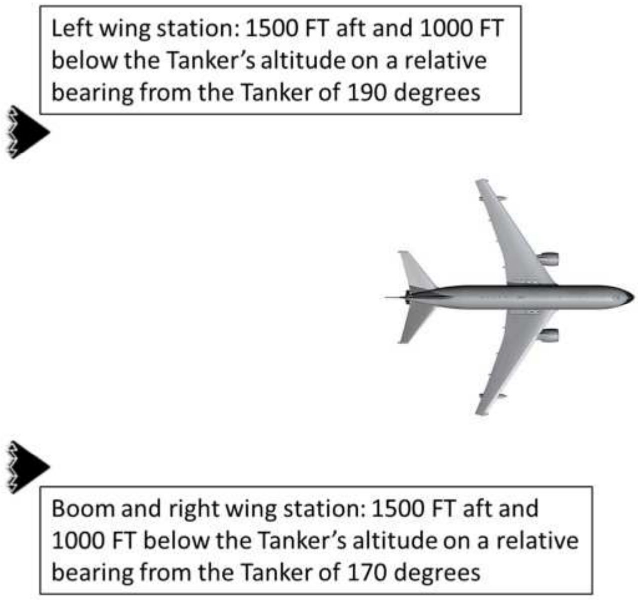


Figure 5-6: Breakaway Positions

5.3.2 Lost Link

In the event of a lost link, the tanker (manned), tanker AVO and receiver AVO will all receive a lost link notification. For an unmanned receiver with lost link conducting Boom refueling, the receiver will automatically unlatch, the Boom Operator will see the unlatched condition, trigger a disconnect, retract the boom and fly the boom away from the receiver and the receiver will immediately back out of the contact position. For drogue refueling, the receiver will immediately back out of the drogue. If the AV is not in Contact but in one of the positions shown in Figure 3-1, the AV will back out of the position. In all cases, the AV will descend 1000 ft. below the tanker's altitude and turn 30 degrees to the right of the tanker's last known heading and execute lost link procedures. The receiver AVO and tanker will verbally communicate with each other as necessary. Airspace planning should include a lost link AV proceeding to a point/route that does not violate any airspace boundaries.

If the unmanned AV loses link at the Transition Point or prior to the Transition Point, the receiver will remain 1000 ft. below the tanker's assigned altitude and execute lost link procedures.

For an unmanned tanker that has lost link, it will remain on heading and altitude for a predetermined amount of time to allow the receiver to execute the above procedure. After this period of time, the tanker will execute lost link procedures.

5.3.3 Overrun

In an Overrun situation, the first aircraft to recognize the Overrun will send the message. The tanker will send UL12 (Execute Overrun) or the AV will send DL9 (Execute Overrun). The tanker and receiver will then complete Overrun procedures. When the Overrun condition has passed, the aircraft that initiated the Overrun will terminate the Overrun procedure by either sending UL13 (Terminate Overrun) if the tanker, or DL10 (Terminate Overrun) if the receiver.

5.3.4 Boom Flight Control Malfunction

Some tankers are equipped with a boom that uses fly-by–wire technology. When using this technology a potential malfunction is when the boom is uncontrollable – this condition is called a Boom Flight Control Malfunction. If there is a Boom Flight Control Malfunction while in Contact, the Boom Operator will not command a Break Away as this could result in the boom impacting the receiver. The Boom Operator will command the receiver into the Safe Position (UL15) before commanding a Disconnect. The Safe Position is defined as: as far down and as far back as the receiver can go while remaining in Contact with the boom. This position provides the greatest margin of safety when disconnecting from a boom that is experiencing a Boom Flight Control Malfunction. The AVO will respond with DL13 (Wilco) and then when in the Safe Position will send DL3 (Established in Safe Position). This will ensure the boom will not hit the receiver once disconnect is commanded. Or, the tanker will verbally communicate the fly-by–wire failure to the AVO and the AVO will send UL15 (Safe Position). The exact position that the AV takes when in receipt of UL15 will vary depending on specific tanker and malfunction inputs and will be defined in the Nav2 message.

5.3.5 Tension Disconnect (Boom/Receptacle Only)

A Tension Disconnect is needed when the receiver's latches fail to release the nozzle. After verbally coordinating with the tanker, the AVO will command the AV to execute a Tension Disconnect (UL16). The AV will respond with DL13 (Wilco) and will be between 30 and 37 degrees of Boom depression as it backs out. When full Boom extension is reached, the nozzle will release, the Boom Operator will retract the Boom and the AV will continue to the Astern position. Note that if the depression angle is greater than 37 degrees, damage may result to the nozzle and receptacle. A properly executed Tension Disconnect does not preclude the tanker from continuing refueling operations with other receivers.

5.3.6 Fuel Leakage

During aerial refueling contact and fuel transfer, no fuel spray or leakage should occur. If fuel spray is continuous, the receiver pilot or AVO will be notified and aerial refueling will be discontinued at the receiver's discretion. If fuel is observed leaking from the boom, boom nozzle, boom drogue adaptor or drogue coupling, fuel transfer will be terminated and the receiver will disconnect. A small amount of fuel spray from the boom, probe nozzle or receptacle during disconnect (after fuel transfer) is normal. This fuel spray should be expected and does not require any action from the crew or termination of aerial refueling operations.

5.3.7 Toboggan Maneuver

In some conditions the receiver, while in contact, cannot go fast enough to keep up with the tanker. <u>The following may be employed when tanker procedures permit</u>: To assist the receiver, the tanker will go into a shallow descent (up to 300 fpm) to help the receiver gain airspeed and maintain the Contact position. Toboggan will be terminated when the aerial refueling formation approaches the bottom of the aerial refueling block or at the request of the AVO. If this is needed, the AVO and tanker will verbally coordinate the execution of the Toboggan maneuver. The AVO will have no action to initiate this with the AV as the tanker relative navigation automatically maintains the commanded position, in this case Contact, throughout Tanker climbs, descents and turns. The toboggan maneuver is not permitted for many hose reel (hose and drogue) systems because as the altitude changes, the HR should technically be reset to compensate (similar to having to reset the system if the airspeed changes). This is not possible with the receiver in contact.