NATO STANDARD

ATP-3.3.4.10

AUTOMATED AIR-TO-AIR REFUELLING (A3R)

Edition A, version 1

OCTOBER 2021

NORTH ATLANTIC TREATY ORGANIZATION

ALLIED TACTICAL PUBLICATION

Published by the
NATO STANDARDIZATION OFFICE (NSO)

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NORTH ATLANTIC TREATY ORGANIZATION (NATO)

NATO STANDARDIZATION OFFICE (NSO)

NATO LETTER OF PROMULGATION

14 October 2021

1. The enclosed Allied Tactical Publication ATP-3.3.4.10, Edition A, version 1, AUTOMATED AIR-TO-AIR REFUELLING (A3R), which has been approved by the nations in the MILITARY COMMITTEE AIR STANDARDIZATION BOARD (MCASB), is promulgated herewith. The agreement of nations to use this publication is recorded in STANAG 7239.

2. ATP-3.3.4.10, Edition A, version 1, is effective upon receipt.

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4. This publication shall be handled in accordance with C-M(2002)60.

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Major General, GRC (A)
Director, NATO Standardization Office

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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS

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RECORD OF SPECIFIC RESERVATIONS

[nation]	[detail of reservation]
EST	Estonia will implement the standard with the following limitation: Estonia will conduct only the procedural part - air-to-air refuelling operations management and coordination via CRC Tallinn.
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Chapter 1 GENERAL

1. This document addresses the international air refuelling community's vision as it relates to common procedures for air-to-air refuelling events involving at least one unmanned or automated tanker and/or receiver. Such events are termed as Automated Air-to-Air Refuelling (A3R). The purpose of this document is to provide guidelines for the development of A3R systems to ensure the solutions are interoperable within the international community. This document is rooted in Aerial Refuelling Systems Advisory Group document number 42-13-17 date 9 June 2017. It is understood this document will serve as a foundation for the future development of an A3R section for Allied Tactical Publication (ATP) 3.3.4.2. and, as such, will be reviewed as technology advances drive changes to this CONOP.

2. As the international community continues in their efforts to develop 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 systems will be designed to accommodate current Air-to-Air Refuelling (AAR) procedures. An unmanned tanker may tank both manned and unmanned aircraft and an unmanned receiver may take fuel from both manned and unmanned aircraft provided these aircraft are suitably equipped. The procedures in this document will accommodate Probe/Drogue and Boom/Receptacle and will mirror ATP-3.3.4.2 as closely as possible.

3. For the purposes of this document, it is assumed that the automated flight control system of the Unmanned Air Vehicle will support A3R. Additionally, it will change its behaviour in response to unanticipated events. For example, if the Unmanned Air Vehicle (UAV) has been commanded to join on a tanker and the tanker changes heading during the intercept, there is no need for the Air Vehicle Operator (AVO) to do anything. The UAV will detect the tanker's heading change, recalculate the intercept geometry and turn to a new heading to complete the rendezvous. Until unmanned A3R is better understood, an AVO will be in the loop giving approval for the UAV to proceed from one phase of AAR to the next. This concept, covered by this document, has the UAV moving through each phase 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 Refuelling. In the future, AAR operations may make full use of autonomy and might need only one message to the UAV: Tank. The UAV 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.

4. A3R can be a mix of manned/unmanned tanker/receiver combinations; however only one tanker and one receiver are addressed by this document. Future versions will cover multiple receivers and multiple tankers. Additionally, a few underlying assumptions are made in the following section.

1.1 Assumptions

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) A3R technologies will not impede legacy receiver aircraft from conducting AAR operations.

3) Fully autonomous AAR from rendezvous (RV) through refuelling is not being considered at this stage as the technology is yet to mature.

4) The AVO is equivalent to a Pilot in Command in terms of authority and responsibility. The AVO will be provided with a sufficient level of situational awareness to manage/monitor A3R operations.

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 direct the receiving aircraft (manned or unmanned) through the tanking procedures while the receiving aircraft or AVO responds to the directions, monitors the event and maintains override authority, except for safety critical commands (see Table 3-3).

    a. Note – Some nations may prefer that the receiving aircraft AVOs maintain control of the UAV in the tanker's airspace. In this case, the tanker crew or AVO would direct the receiving aircraft AVO who would in turn command the UAV except for safety critical commands (see Table 3-3).

6) Communications between the receiver and the tanker (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 direct the UAV throughout the A3R process. However, at any time for any reason, voice communication may be used between tanker crews, and the receiving AVO. The safety critical commands shall be direct tanker to receiver communications implemented without AVO intervention.

7) This document covers the CONOPS aspect of A3R and associated basic technologies (Table 2-1). 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. 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.

8) The A3R system should accommodate air refuelling operations in certain EMCON/COMSEC conditions that will be defined in future revisions of this document.

9) This document does not address Boom Drogue Adapter for A3R operations.

10) The tanker or receiver AVO will be in communication with the appropriate air space controlling authority as required to perform the air refuelling mission.

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Chapter 2 CONCEPTUAL A3R SYSTEMS OVERVIEW

1. The goal of the system is to provide air-to-air refuelling technology for a manned or unmanned aircraft to rendezvous and maintain the standard AAR positions described in Table 3-1. This A3R CONOPS will strive to use existing operational procedures to the greatest extent possible. 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 this precision relative navigation system will provide high-availability, high integrity, four-dimensional guidance. At the core is the ability to accurately determine a system's own precise location in a reference coordinate frame. 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 may 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).

2. The A3R system design should combine automation and procedural methods to ensure safe separation among all participating tankers and receivers. To this end, the UAV should have a sense and avoid system.

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

Table 2-1: Notional A3R Systems

System	Function
Precision Navigation System	Guidance, Navigation and Control
Comms (voice)	Communication between operators
Comms (data)	Communications between systems and systems and between systems and systems operators
Automated Boom System	Provides automatic control of tanker boom refuelling
Automated Probe/Drogue System	Provides automatic control of probe and drogue refuelling

2.1 A3R Segments

1. The A3R system is comprised of 4 segments:

1) Unmanned Tanker or Receiver;
2) Manned Tanker;
3) Manned Receiver;
4) AVO stations.

2. 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).

3. A major difference in A3R is the AVO issuing command and control instructions over a data link rather than speaking to a pilot over the radio. Manned aircraft will need to be made aware of UAV commands by the AVO. If EMCON, procedures will need to be developed. Figures 2-1, 2-2, and 2-3 show how each of these four segments will interact with each other using the notional systems from Table 2-1. Three combinations are addressed: Unmanned tanker and unmanned receiver, unmanned tanker and manned receiver and a manned tanker and an unmanned receiver. The combination of a manned tanker giving fuel to a manned receiver is not addressed because no new systems or procedures are needed for this.

4. The most complex combination, an unmanned tanker and an unmanned receiver, is shown in Figure 2-1. For the tanker and receiver to find each other and complete the rendezvous and fly formation, an exchange of navigation data is needed between the UAVs. Each AVO, located in a Mission Control Element (MCE), will need a link with their UAV to enable command and control and to display navigational information. Additionally, when the tanker and receiver are in the same link, known as the tanker network, the position of both UAVs will be sent to both AVOs for situational awareness and safety. Voice communication and/or chat between the tanker AVO and the Receiver AVO is needed.

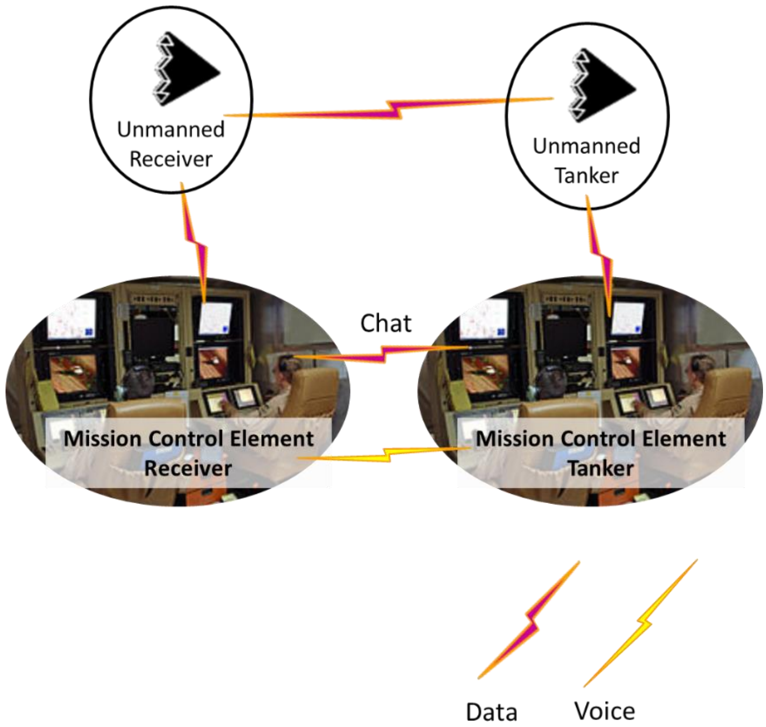

Figure 2-1: A3R System Interactions Between an Unmanned Tanker and an Unmanned Receiver

5. The next combination, shown in Figure 2-2, is an unmanned tanker with a manned receiver. The unmanned tanker will have a link with the AVO providing command and control and navigational information. The manned receiver will communicate with the AVO via voice. A3R mechanization is not needed for the manned receiver as it will perform standard AAR procedures. If so equipped, the AVO and pilot could communicate with Link 16 or similar system.

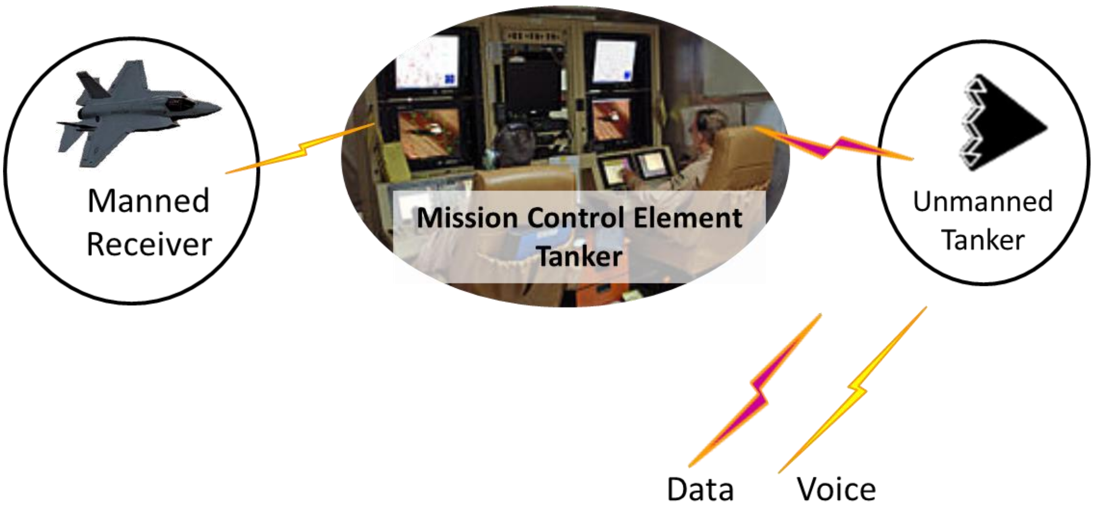

Figure 2-2: A3R System Interactions Between an Unmanned Tanker and a Manned Receiver

6. The last combination, shown in Figure 2-3, is a manned tanker with an unmanned receiver. For the unmanned receiver to find the manned tanker, complete the rendezvous and fly formation, an exchange of navigation data is needed between the two aircraft. If the displays are installed, the tanker crew will know the position of the unmanned receiver. The AVO, located in a Mission Control Element (MCE), will need a link with the UAV to enable command and control and the display of navigational information. Additionally, when the tanker and receiver are in the same link, known as the tanker network, the position of the UAV and tanker will be sent to the AVO for situational awareness and safety. The manned tanker and AVO can communicate via voice or Data Link.

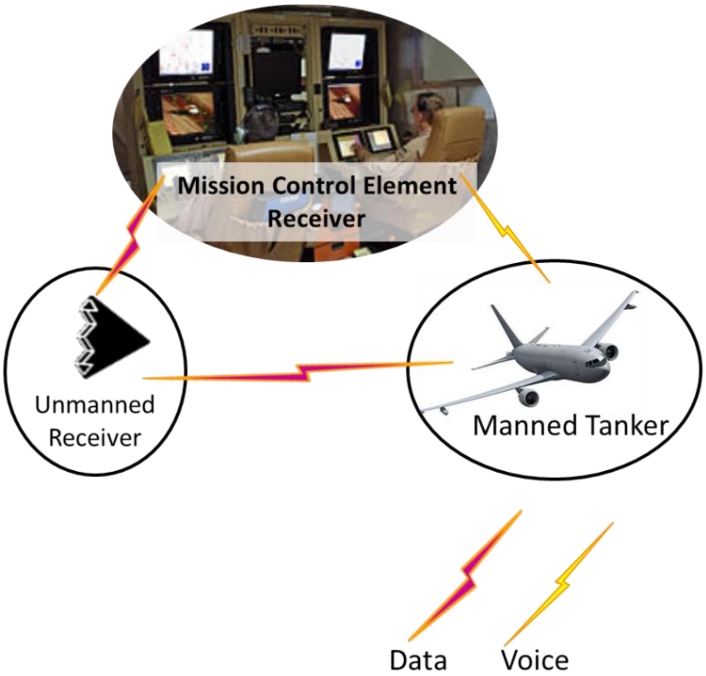

Figure 2-3: A3R System Interactions Between Manned Tanker and an Unmanned Receiver

Chapter 3 A3R POSITIONS

1. Table 3-1 and Figure 3-1 define standard positions for A3R which will be referenced throughout this document. All AAR positions are as defined in ATP-3.3.4.2 unless otherwise noted in Table 3-1 and assumed to be stable and aircraft specific based on design.

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 UAV's relative navigation performance prior to moving closer to the tanker. This position may be tailored for specific tanker/receiver pairings.
Echelon Left	During tanker turns the UAV will maintain the same position relative to the tanker's wing tip.
Astern (Left, Right, Centre)	Probe and Drogue: This position is the transition point from tanker relative navigation to drogue relative navigation. Boom/Receptacle: This position is maintained using tanker relative navigation.
Contact	Probe and Drogue: The position attained when the probe successfully engages the drogue and is pushed in 5-13 ft. Boom/Receptacle: Stabilized position within the AAR envelope.
Echelon Right	During tanker turns the UAV will maintain the same position relative to the tanker's wing tip.
Breakaway	ATP-3.3.4.2 procedures apply.
Safe Position(s)	This is the position taken when there is a boom control system failure and the receiver is in contact. The position will be specific to the tanker/receiver pairing and failure mode.
AAR Exit Point	Mission planned point that an unmanned tanker may use at the conclusion of the AAR mission.

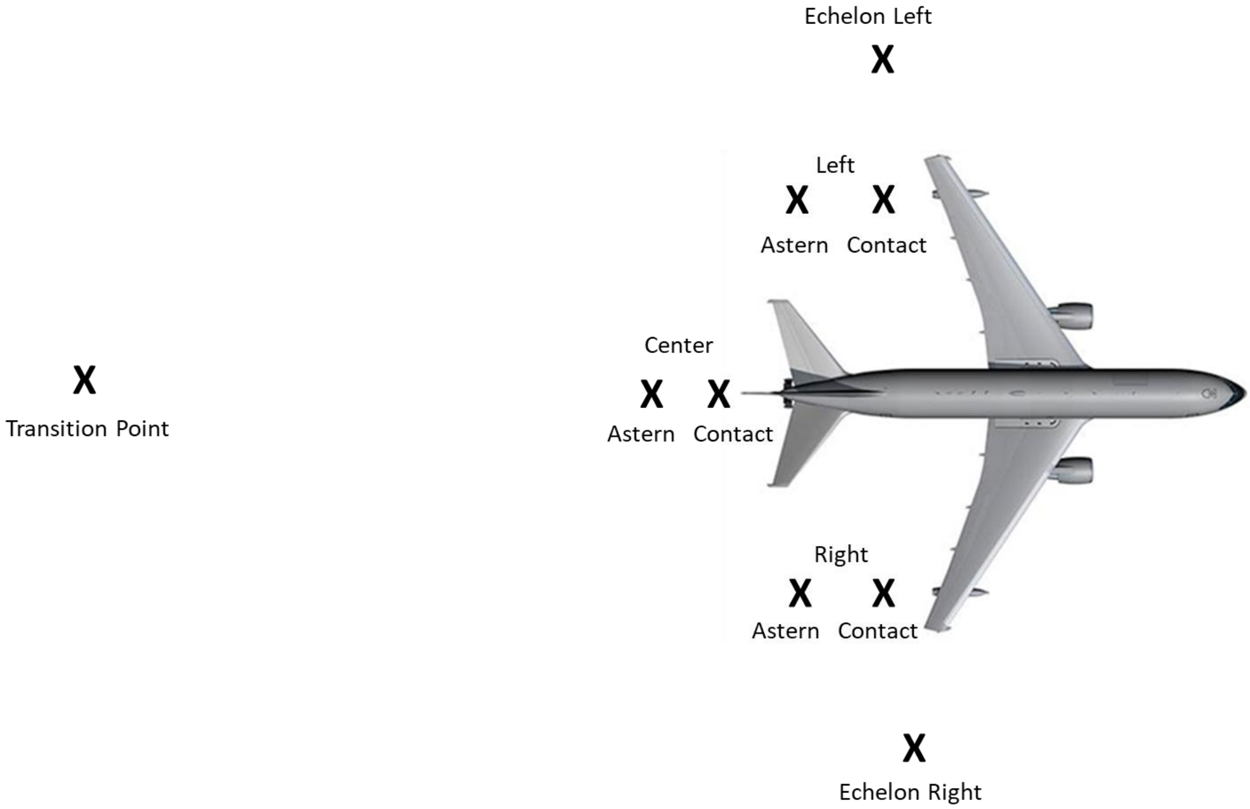

Figure 3-1: A3R Standard Positions

3.1 A3R Messaging

1. Table 3-2 and Table 3-3

Table 3-3 define a message set that translates the existing voice command and control messages/procedures as described in ATP-3.3.4.2 into data link messages with their associated contents. There are two categories of messages to be sent and are termed Tanker Messages. These messages are needed for a manned tanker or a tanker AVO to send to an unmanned receiver. The second are termed Receiver Messages and are used for an unmanned receiver AVO to respond to commands received. Depending on the sophistication of the unmanned receiver it may respond autonomously. For the purpose of this document, these communications can occur BLOS (relayed via the respective AVO) or LOS (direct aircraft to aircraft).

2. 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: Tanker Messages

Message	Message Description
Join Tanking Network	Receiver will join the tanking network with a specified tanker.
Join for Tanking	Navigation changes from earth relative to tanker relative to complete the rendezvous. Join with the designated tanker in the Transition Point.
Transfer (X) lbs/kgs	Response to Request (X) lbs/kgs
Cleared to Tanking Position (X)	All positions are defined in Table 3-1 or ATP-3.3.4.2 **Echelon Left:** Proceed to the Echelon Left/Awaiting AAR position. **Astern (Left, Right, Centre):** Proceed to the assigned Astern position. **Echelon Right:** Proceed to the Echelon Right position. **Transition Point:** Proceed to the Transition Point
Cleared to the Contact Position	Proceed to the assigned Contact position.
Engaged	P&D: Probe engaged in coupling BR: The nozzle is latched in the receptacle.
Positive Fuel Flow	Fuel is flowing from the tanker to the receiver.
Disconnect (Safety Critical)	Probe and Drogue: Command to back out and take the Astern position. Boom/Receptacle: Disconnect from the boom, take the Astern position.
Disconnect in place	Boom/Receptacle: Disconnected from the boom, remain in Contact position
Cleared to Leave (X)	Proceed to defined exit points, requires AVO input to depart the formation
Breakaway (Safety Critical)	Proceed to the Breakaway position in accordance with ATP-3.3.4.2.

Message	Message Description
Discontinue AAR (Safety Critical)	Emergency command used to direct the receiver to depart the tanker airspace and disconnect from the network at 1 nm when the AVO is unable to command the UAV.
Execute Overrun	Direction for the Receiver to initiate overrun procedures. This message is applicable only when a big wing tanker is used.
Request Manual Boom Latch	Request for receiver to engage the manual boom latch option, if receiver is equipped.
Terminate Overrun	Direction for the Receiver to terminate overrun procedures. This message is applicable only when a big wing tanker is used.
Take AAR Initial Point (ARIP) Holding at AAR Control Time (ARCT)	Proceed direct to the ARIP holding point and enter holding at assigned ARCT.
Safe Position while in contact (Safety Critical)	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.
Controlled Tension Disconnect	Used when a Controlled Tension Disconnect is needed.
Terminate Toboggan	Notification from tanker to receiver that the toboggan is terminated

Table 3-3: Receiver Messages

Message	Message Description
Joined Tanking Network	Response to Join Tanking Network
Request (X) lbs/kgs	AVO can request, in lbs/kgs, a specific amount of fuel.
Established in (X) Position	All positions are defined in Table 3-1 or in ATP-3.3.4.2 **Transition Point:** Established at the Transition Point **Echelon Left:** 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
Latched/Engaged	Sent by the receiver when the boom nozzle latches with the receiver's receptacle or the probe engages the drogue.
Receiving	Receiver is receiving fuel from the tanker.
Failed to Engage	Receiver's probe has failed to engage the drogue. Or, boom failed to latch. For Probe Drogue the UAV will return to the Astern position.
Breakaway (Safety Critical)	Sent by the receiver in the event of an autonomous breakaway or as an acknowledgement to the Breakaway message. Breakaway procedures shall be executed in accordance with ATP-3.3.4.2.
Terminate Emergency Separation	Acknowledgement to terminate Breakaway procedures.

Message	Message Description
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.
Terminate Overrun	Receiver sends this message when it terminates overrun procedures. This message is applicable only when a big wing tanker is used.
Disconnected	The boom has disconnected from the UAV or the probe has disconnected from the drogue for any reason.
Tanking Complete	Sent by the Receiver when reaching 1 nm separation from the tanker.
Wilco (X)	Receiver sends as acknowledgement that it will execute a tanker command. This message will include acknowledgement of the specific message. E.g.: Wilco Left Echelon.
Request Toboggan (X)	Request from receiver to tanker to initiate toboggan at receiver specified fpm.
Terminate Toboggan	Request from receiver to tanker to terminate toboggan.
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. Unable to Execute: Example would be to command the UAV to join on the tanker, but Join Tanking Network message has not been sent.

NOTE: The UAV's responses to the data link command and control messaging, both acknowledgement and action, are automatic and near instantaneous once received. Beyond Line of Sight messages will have a noticeable latency. Therefore, operators need 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 describes a notional message set specific to the precision navigation information that will be shared in order to successfully operate around and engage the tanker.

Table 3-4: Precision Navigation System Messages

Message	Message Description
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.
Tanker State Data	Provides the tanker navigation reference data to support relative navigation, may include drogue reference position
Receiver Geometry Information	Provides receiver geometry offsets to be used to support the generation of the relative navigation vector for precision navigation and aircraft guidance and control.
Receiver State Data	Provides the receiver navigation reference data to support relative navigation

Table 3-5 describes a set of messages that provide the status of the communication and navigation system. These messages will be sent to all participants in the tanker network.

Table 3-5: Network Status Messages

Message	Message Description
Heartbeat	Ensures continuity of link
UAV Connection Lost	Connection with UAV has been lost
UAV Connection Restored	Connection with the UAV has been restored
System Registration Request	Associates the UAV with an IFF code
System Register	Correct IFF code has been received
Host Network Broadcast	Host system network information
Disconnect Acknowledgement	Acknowledgement of system disconnect message
Relative Navigation Performance Status	Relative Navigation Performance status

3.2 A3R Procedures

1. The following sections will describe refuelling procedures that have 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. If at any time

during the AAR process the receiver's relative navigation system is not performing at the level of accuracy needed to maintain a position, it will execute procedures discussed in paragraphs 4.1.2.1 and 4.1.2.3.

3.3 Phases of Flight

3.3.1 Refuelling Phases of Flight – Overview

1. There are eight refuelling phases of flight, described below which define operations during aerial refuelling. Refuelling phases of flight are defined as air vehicle "modes" so that the response of the air vehicle in each phase of flight is precisely defined, predictable and consistent. As the air vehicle moves from phase to phase UAV systems will adjust. For example, as the air vehicle moves closer to the tanker, flight control laws and relative navigation performance will change to accommodate close formation flying, such as when in echelon or contact. A shift in a phase of flight can cause the system to prompt the AVO to take actions like extent the probe and check weapons safe/nose cold, commands given by the tanker operator, or the AVO may result in air vehicle actions within a phase of flight or initiate a phase of flight change itself. Shifting from one phase of flight to another is generally automatic and is dependent on commands sent or received. Requirements for shifting phases of flight are explained in this section. Figure 3-2 shows nominal refuelling phases of flight transitions.

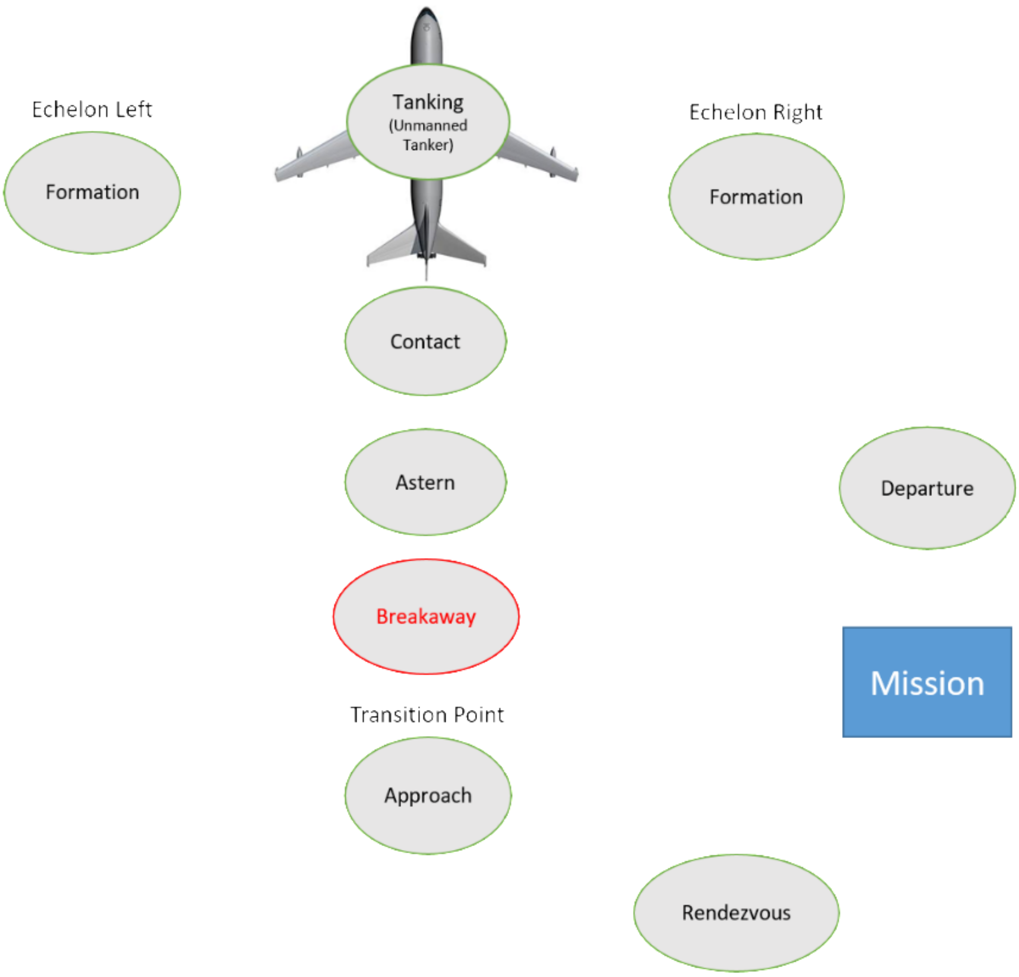

Figure 3-2: Refuelling Phases of Flight

3.4 Rendezvous Phase

1. The A3R Rendezvous phase normally starts 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 “Join Tanking Network”. When the network has been established, the UAV will send “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. The receiver transitions to tanker relative navigation. Normally, the Rendezvous phase ends when the UAV is established at the Transition Point and transition to the Approach phase, but may end with the transition to Formation, Astern, Contact, Departure phases of flight.

3.4.1.1 Approach Phase

The Approach phase normally starts when the UAV sends “Established at the Transition Point” and transitions from the Rendezvous phase of flight to the Approach phase of flight provided that minimum navigation performance is confirmed. When the UAV receives the command that it is cleared to either Astern, Echelon Left, or Echelon Right, the UAV will depart the Transition Point and commence its approach to the commanded position. Normally, the Approach phase ends when the UAV sends “Established at either the Astern, Echelon Left or Echelon Right”, and the UAV transitions to the Formation phase, but may end with transition to Astern, Contact, Breakaway, or Departure phases of flight.

3.4.1.2 Formation Phase

The Formation phase normally starts when the UAV sends “Established at either the Echelon Left or, Echelon Right Position” and the UAV transition to the Formation phase of flight. When the UAV receives the command that it is “Cleared to the Astern Position” (Left, Right or Centre), the UAV will depart Echelon Left or Right position and commence it approach to the commanded Astern position. Normally, the Formation phase ends when the UAV sends “Established at Astern Position” (Left, Right or Centre), and the UAV transitions to the Astern phase, but may end with transition to Breakaway or Departure phases of flight.

3.4.1.3 Astern Phase

The Astern phase normally starts when the UAV sends “Established at the Astern position” and the UAV transition to the Astern phase of flight. When the UAV receives the command that it is “Cleared to the Contact Position” the UAV will depart the Astern position and commence its approach to the Contact position (boom/receptacle) or engage the drogue (probe/drogue) provided relative navigation precision is ensured. Normally, the Astern phase ends when the UAV receives the “Cleared to Contact” message and transitions to the Contact phase, but may end with transition to Formation, Breakaway, or Departure phases of flight.

3.4.1.4 Contact Phase

The Contact phase normally starts when the UAV receives the “Cleared to Contact” message. When the UAV completes refuelling, disconnects, or fails to engage, the UAV will depart the Contact position and return to the Astern position transitioning from Contact phase of flight back to Astern phase of flight. Normally, the Contact phase ends when the UAV sends “Established in the Astern Position”, and the UAV transitions back to the Astern phase, but may end with transition to the Breakaway phase of flight.

Note: During boom/receptacle refuelling, a receiver may be commanded to “disconnect in place” where the receiver would disconnect from the boom but remain in the contact position and contact phase of flight

3.4.1.5 Departure Phase

The Departure phase normally starts from the Echelon Left, Right or Centre Astern positions. When the UAV receives the command “cleared to leave”, or “discontinue AAR” the UAV transitions to the Departure phase. The Departure phase ends when the UAV sends “Tanking Complete” and the UAV transitions to geo navigation and proceeds on its mission.

3.4.1.6 Breakaway Phase

The Breakaway phase starts when either vehicle receives the command “Breakaway” and the tanker and UAV conduct breakaway procedures in accordance with ATP-3.3.4.2. The Breakaway procedures end when the UAV is established at the Breakaway position. However, the Breakaway phase of flight ends when the UAV receives, “Terminate Emergency Separation” from the tanker. During breakaway, an unmanned tanker will execute ATP-3.3.4.2 procedures.

3.4.1.7 Tanking Phase

The Tanking phase is for unmanned tankers only. The Tanking phase of flight starts when the tanker is commanded to the tanker holding pattern or conducts a rendezvous with a receiver. Normally, the Tanking phase ends when the tanking mission is complete and the unmanned tanker proceeds on another mission, but may end with transition to Breakaway, or Rendezvous phase of flight.

3.5 *Rendezvous*

1. There are seven types of rendezvous described in ATP-3.3.4.2 and UAV tankers and receivers will be able to conduct each of them. As an example, RV Alpha will be discussed here in detail. For UAVs, each of these rendezvous procedures will end at the Transition Point. The procedures from the Transition Point to the different positions around the tanker are the same no matter which rendezvous is used. 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 “Join Tanking Network”. When the network has been established, the UAV will send “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.

2. In the discussion of RV Alpha that follows, the tanker, whether manned or unmanned, will command the receiving UAV directly while the receiver AVO observes the messaging and the progression of the A3R procedures. The UAV’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 UAV.

3. The A3R procedures for a manned or unmanned tanker refuelling 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.

3.5.1 RV Alpha

1. As described in ATP-3.3.4.2, RV Alpha centres on a ground/air/ship controller verbally providing vectors to the receiver to affect 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 3-3.

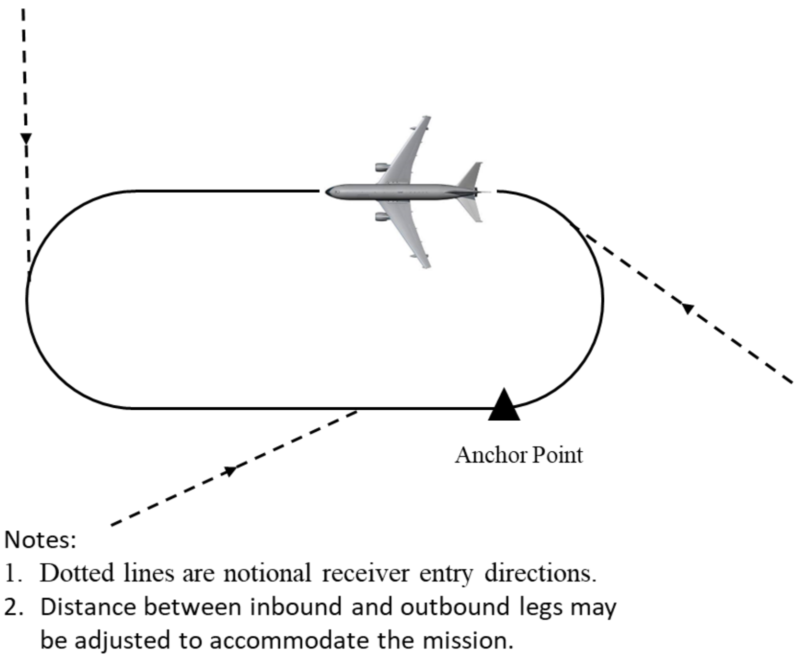

Figure 3-3: RV Alpha Anchor Pattern

2. While holding at the anchor point, the tanker will monitor the briefed AAR frequency. The receiving UAV 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 Join Tanking Network, the receiver will respond with Joined Tanking Network. With both aircraft in the network, the receiver AVO will command the UAV to join on the tanker at the Transition Point by sending Join for Tanking. The receiver UAV will respond with 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 UAV will send (Established at the Transition Point). The Transition Point places the UAV 1000 ft. below and 1500 ft behind 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 "Established at the Transition Point", and relative navigation performance checks are complete, the receiver AVO will clear the tanker to begin commanding the UAV. 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 "Cleared to Tanking Position (X)". The receiver will respond with "Wilco (X)", and when in the assigned position will send "Established in (X) Position". When in receipt of "Contact" the receiver will send "Wilco Contact". For probe and drogue, when in contact with the drogue the receiver will send "Engaged". When transferring fuel, the tanker will send "Positive Fuel Flow". When receiving fuel, the receiver will send "Receiving". If boom/receptacle, the receiver will wait in the Contact position until engaged by the boom and then will send "Latched" followed by the tanker sending "Engaged". When transferring fuel, the tanker will send "Positive Fuel Flow". When receiving fuel, the receiver will send "Receiving Fuel".

3. When fuel transfer is complete, for probe and drogue, the tanker will send "Disconnect" and the receiver will send "Wilco Disconnect". The receiver will back out of the drogue, take the Astern position and will send "Established in Astern". For boom/receptacle, after disconnecting the boom, the tanker will send "Disconnected" and the receiver will send "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 "Established in Astern". If tanking is complete, the tanker will send "Cleared to Echelon Right" and the Receiver will send 3 (Wilco Echelon Right). When in Echelon Right the UAV will send "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 "Cleared to Leave" and the Receiver will send "Wilco Cleared to Leave". The receiver will make a 30 degree right turn away from the tanker and the AVO will alter the UAV's altitude as briefed. At 1 nm from the tanker, the UAV will send "Tanking Complete, switch from tanker relative navigation to earth referenced navigation and will exit the tanker network. As an example, Figures 3-4 through 3-7 show graphically message sequencing and UAV actions for a nominal probe and

drogue refuelling operation. The sequence begins at the Transition Point and ends with the receiver leaving the tanker. Boom refuelling positions are similar to those shown in Figures 3-4 through 3-7.

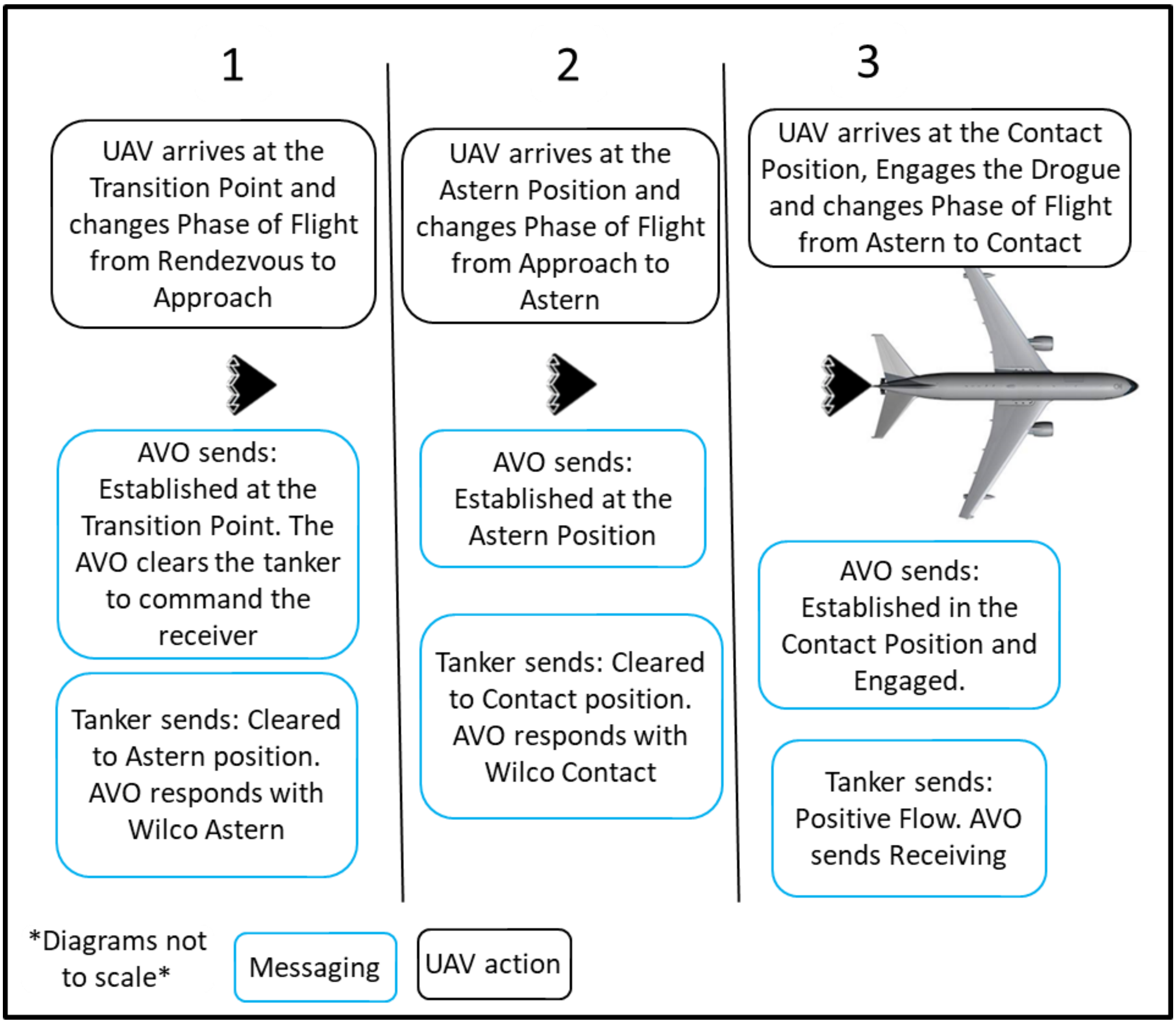

Figure 3-4: Messaging Diagram for Probe and Drogue, Part 1

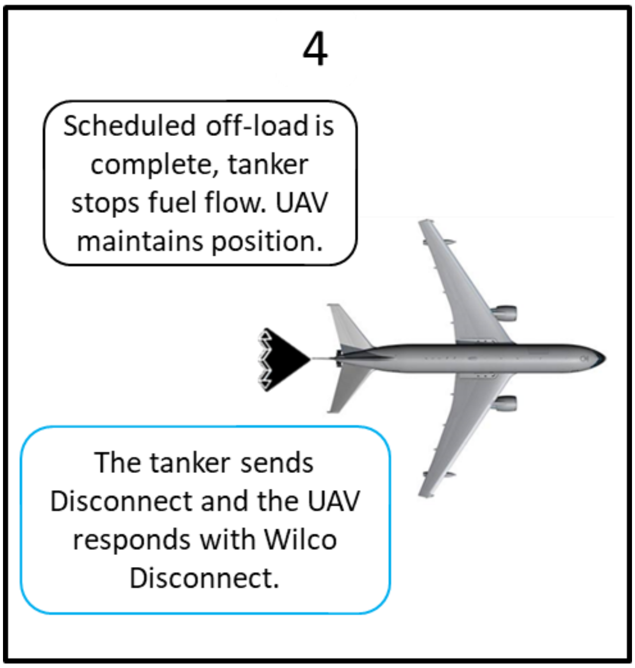

Figure 3-5: Messaging Diagram for Probe and Drogue, Part 2

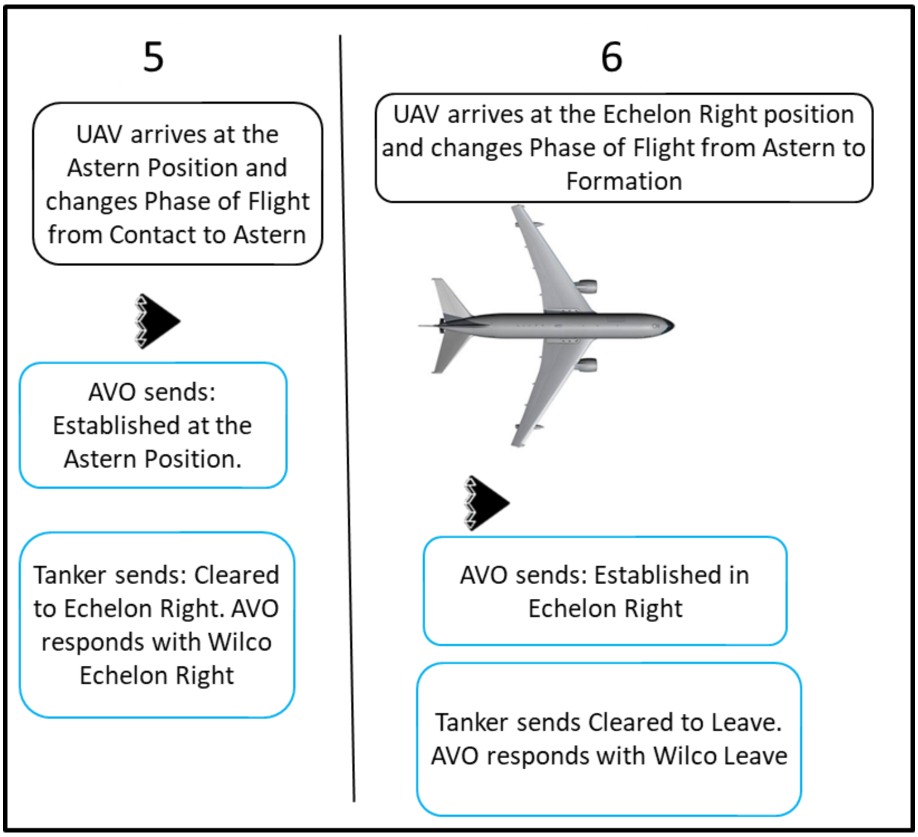

Figure 3-6: Messaging Diagram for Probe and Drogue, Part 3

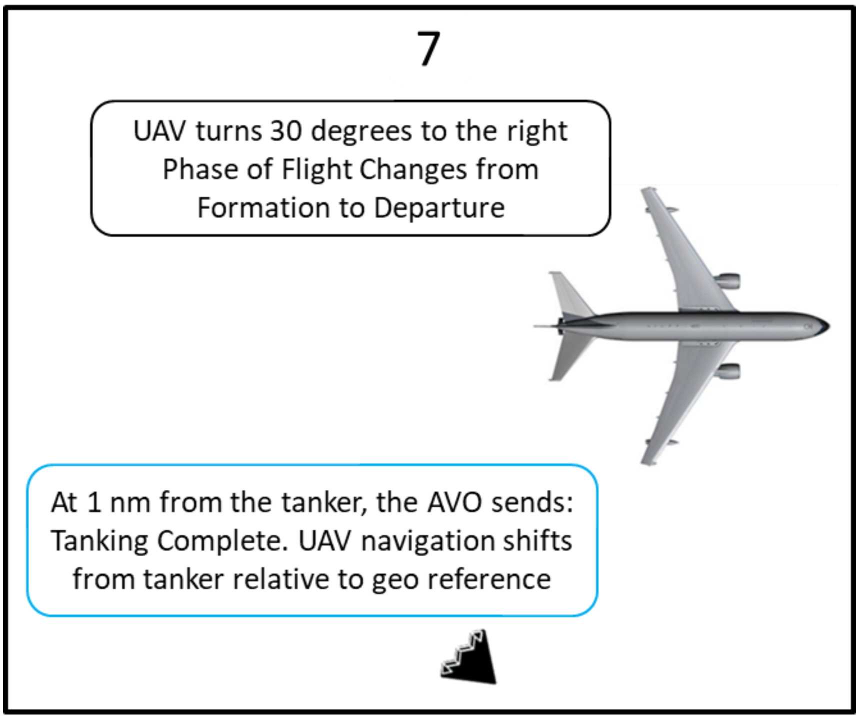

Figure 3-7: Messaging Diagram for Probe and Drogue, Part 4

Chapter 4 CONTINGENCIES

4.1 Breakaway

The tanker can send “Breakaway” and the receiver will respond with “Breakaway”. The receiver AVO can also initiate a breakaway by sending “Breakaway”. The UAV can autonomously initiate breakaway by sending “Breakaway” if it detects a system problem. Whoever sends the Breakaway message will also transmit verbally “Tanker Call Sign Breakaway”. 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 “Breakaway”, or if initiating an autonomous Breakaway, the UAV will send “Breakaway”, disconnect the latches, back out of the drogue/depart the boom contact position and will take a position defined in ATP-3.3.4.2. If at the Transition Point during a Breakaway, the UAV will remain at the Transition Point until the next action is determined, i.e.: continue with tanking or depart the tanker. During a Breakaway, messaging authority goes back to the receiver AVO and tanker relative navigation will be maintained by the UAV. Whoever initiated the Breakaway will determine when the need for Breakaway has passed and will send “Terminate Emergency Separation” from the tanker or “Terminate Emergency Separation” 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. Note: Any Breakaway call made by the AVO may be subject to significant BLOS latency.

4.1.1 Degraded Communication and Navigation

4.1.1.1 Loss of Receiver Relative Navigation

1. In the event the receiver loses relative navigation, the tanker crew or tanker AVO and receiver AVO or crew will receive a lost navigation notification.

2. All aircraft will follow Loss of Visual Contact procedures per ATP-3.3.4.2.

3. If the receiver loses relative navigation at the Transition Point or prior to the Transition Point, the receiver will remain 1000 ft. below the tanker’s assigned altitude and attempt to regain relative navigation.

4.1.1.2 Loss of Receptacle/Drogue Position Data

1. For an automated boom-equipped tanker that has lost receptacle position data:

   If contact has been established, fuel transfer may continue

   If contact has not been established, contact will not be possible until the problem is resolved.

2. For a drogue positioning system equipped tanker that has lost drogue positioning data:

If contact has been established, fuel transfer may continue

If contact has not been established, contact may not be possible until the problem is resolved.

NOTE: The underlying assumption for both cases is that receiver to tanker relative navigation is not affected.

4.1.1.3 Loss of Tanker Relative Navigation

In the event the tanker loses relative navigation, certain RV types will not be possible.

4.1.1.4 Loss of Tanker to Receiver Command & Control Link

Due to latencies involved with BLOS, the receiver automatically executes a breakaway.

4.1.1.5 Loss of AVO to Receiver Command & Control Link

1. The receiver will continue to execute the last command given. The tanker crew/AVO will coordinate the next actions.

2. The tanker crew/AVO has the ability to issue any of the safety critical messages at any time.

4.1.1.6 Loss of AVO to Unmanned Tanker Command & Control Link

Response will be dependent on individual platform configurations and national procedures.

4.1.2 Overrun

1. In an Overrun situation, the first aircraft to recognize the Overrun will send the message. The tanker will send Execute Overrun or the UAV will send Execute Overrun. The tanker and receiver will then complete Overrun procedures IAW ATP-3.3.4.2. When the Overrun condition has passed, the aircraft that initiated the Overrun will terminate the Overrun procedure by either sending Terminate Overrun if the tanker or Terminate Overrun if the receiver.

NOTE: Consideration should be given for BLOS latency effects especially on termination timing effects.

4.1.3 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 before commanding a Disconnect. The UAV will acknowledge and move to the Safe Position without initiating a disconnect. When in position, the UAV will send Established in Safe Position message. This will ensure the boom will not hit the receiver once disconnect is commanded.

4.1.4 Controlled Tension Disconnect (Boom/Receptacle Only)

The tanker sends Controlled Tension Disconnect request message, the AVO will command the UAV to execute a Controlled Tension Disconnect. The UAV will respond with Wilco and will maintain a receiver tanker/receiver pairing specific boom elevation as it backs out at a receiver specific extension rate. When full Boom extension is reached, the nozzle will release, the UAV will continue to the Astern position.

4.1.5 Fuel Leakage

NOTE: When fuel spray can be detected by manned aircraft, procedures are per ATP-3.3.4.2. For unmanned operations, considerations need to be given for fuel leak detection.

4.1.6 Toboggan Manoeuvre

1. Toboggan manoeuvre procedures will be IAW ATP-3.3.4.2.

2. Consideration should be given to latency effects for BLOS links.

4.1.7 Manual Boom Latching

Tanker will send Request Manual Boom Latch message. AVO or receiver UAV will close boom latches using Manual Boom Latch command. Disconnects will be per normal messaging.

4.1.8 Pressure Refuelling

Can be handled per ATP-3.3.4.2 procedures.

INTENTIONALLY BLANK

Acronym Definitions

A3R	Automated Air-to-Air Refuelling
AAR	Air-to-Air Refuelling
ARCP	AAR Control Point
ARCT	AAR Control Time
ARIP	AAR Initial Point
ARSAG	Air Refuelling Systems Advisory Group
ATC	Air Traffic Control
ATP	Allied Tactical Publication
AVO	Air Vehicle Operator
BLOS	Beyond Line of Sight
B/R	Boom/Receptacle
CONOPS	Concept of Operations
DoD	Department of Defence
FPM	Feet per Minute
INS	Inertial Navigation System
JSB	Joint Standardization Board
LOS	Line of Sight
NATO	North Atlantic Treaty Organization
P&D	Probe and Drogue
RV	Rendezvous
SRD	Standards Related Document
STDS	Standard Technical Data Surveys
STANAG	Standardization Agreement
UAV	Unmanned Air Vehicle

ATP-3.3.4.10(A)(1)