ARSAG

AERIAL REFUELING SYSTEMS ADVISORY GROUP

Guidance Document

Aerial Refueling Modeling and Simulation Standardization

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This document presents a standardized interface for end-to-end Aerial Refueling Model (ARM) of hose-drogue systems with future revision versions of this document to include the Boom/Receptacle method of Aerial Refueling. The conceptual architectural layout presented in this release allows for the integration of an ARM into an independent simulation environment consisting of tanker model, receiver model, environmental components, and/or visual representation to achieve an AR End-to-End simulation. The fidelity, physical properties, and configuration variations of any give ARM is left to the discretion of the ARM developer along with the modeling and simulation validations by actual testing (e.g., lab, ground, and flight) as appropriate. By standardizing the interface for ARMs, the result is to achieve highly plug and play simulations for multiple end uses that can be easily shared across multiple vendors and platforms

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1.0 EXECUTIVE SUMMARY

This document presents a standardized interface for end-to-end Aerial Refueling Model (ARM) of hose-drogue systems with future revision versions of this document to include the Boom/Receptacle method of Aerial Refueling. The conceptual architectural layout presented in this release allows for the integration of an ARM into an independent simulation environment consisting of tanker model, receiver model, environmental components, and/or visual representation to achieve an AR End-to-End simulation. The fidelity, physical properties, and configuration variations of any give ARM is left to the discretion of the ARM developer along with the modeling and simulation validations by actual testing (e.g., lab, ground, and flight) as appropriate. By standardizing the interface for ARMs, the result is to achieve highly plug and play simulations for multiple end uses that can be easily shared across multiple vendors and platforms

PROJECT INITIATION FORM (PIF)

Items 1 through 3 to be Completed by Requester							
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Project Purpose and Scope	Develop a standardized format (Interface Control Document) for the modeling and simulation of Aerial Refueling Systems to include hose/drogue, boom/receptacle, and BDA (boom-to-drogue adaptor) kit configurations. As the community moves toward certification by modeling and simulation, it will be critical that model components can be easily shared among organizations, and standardization will be key to that.						
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			tbd				
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ARSAG Document Name and Number	**Aerial Refueling Modeling and Simulation Standardization; 54-18-21WD**
Need for Project	Company/academia/government participates are engaged in studying, developing, utilizing aerial refueling models at various levels of fidelity and validation/verification. These models are used for engineering analysis, pilot and operator training, accident investigation, as well as various levels of flight clearance and certification. As more and more work shifts from flight test to simulation the ability to share and compare simulation models is becoming more critical to the advancement of aerial refueling. Providing a standardize format (Interface Control Document) for hose/drogue, boom/receptacle, and BDA(Boom-to-Drogue adaptor) kit configurations is desirable such that models can be readily shared and integrated across partners and platforms.
Background	The initial concept of the ARSAG working group envisioned an ICD document that would detail the interfaces between full Aerial Refueling Models (ARM) and subcomponents; covering hose/drogue, Boom/Receptacle and BDA refueling techniques. Adhering to the ICD would allow for shared "black box" models and modeling components between corporations, academia, and governments. Additionally, it was the vision of the working group to draw from the collective expertise in flight test and simulation of aerial refueling to include in the document best practices for model development, aerial refueling environmental guidelines, recommendations for validation and verification standards of models, and guidance for use of ARM in training and certification efforts was also envisioned.
Changes to Original Project Purpose and Scope	Given the scope of the final document, this first release covers only the standardized interface (ICD) for end-to-end AR modeling of hose-drogue systems. The conceptual architectural layout presented in this release allows for the integration of an Aerial Refueling Model (ARM) into an independent simulation environment consisting of tanker model, receiver model, environmental components, and/or visual representation in order to achieve an AR End-to-End simulation. The intent, is by initial release of the ICD, partners can begin moving towards common model interfaces for shared system modeling.

2.0 ACKNOWLEDGEMENTS

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3.0 REFERENCES

None

4.0 ASSOCIATED DOCUMENTS

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Aerial Refueling Probe/ Drogue System Design Guide	DTIC No. AD1064517	1	15 Oct 2018	ARSAG 04-06-18

5.0 ABBREVIATIONS AND TERMINOLOGY

ABA	Aircraft Body Axis
ARM	Aerial Refueling Model
AR	Aerial Refueling
BDA	Boom-to-Drogue Adaptor
ECEF	Earth Centered, Earth Fixed
FEA	Flat Earth Axis
ICD	Interface Control Document
ISA	International Standard Atmosphere
KCAS	Knots Calibrated Airspeed
KIAS	Knots Indicated Airspeed
KTAS	Knots True Airspeed
KEAS	Knots Equivalent Airspeed
MSL	Mean Sea Level
TADA	Tanker Aircraft Drum-centric Axis
UDP	User Datagram Protocol
UTM	Universal transverse Mercator

Indicated Airspeed (IAS) – This is normally measured from aircraft instruments (Pitot tubes) and is calculated based on the dynamic pressure (which is calculated from the total pressure less the static pressure measured from the Pitot tubes on the aircraft). This is not corrected for angle of attack and is calibrated for standard atmosphere adiabatic compressible flow at sea level.

Calibrated Airspeed (CAS) – This is the indicated airspeed corrected for instrument and installation errors i.e., Pitot tube alignment to the flow. In normal flight KIAS ≈ KCAS when the Pitot tube is aligned to the flow direction. When corrected for angle of attack the indicated airspeed reduces relative to calibrated airspeed.

True Airspeed (TAS) – This gives the actual velocity the aircraft is moving relative to the atmosphere. At increasing altitude, if the equivalent airspeed stays constant, the true air velocity must increase to maintain the same dynamic pressure reading.

Equivalent Airspeed (EAS) – This is the airspeed at sea level ISA at which the dynamic pressure is the same as the dynamic pressure of the true airspeed and altitude the aircraft is flying. Therefore, this term effectively compensates for aircraft altitude in its expression.

Coupling Ball Joint – The coupling ball joint provides for a limited degree of motion in both lateral and vertical axes of rotation between the hose and the drogue.

End-to-End – An overall simulation system where the “ends” are defined by the interfaces to the simulation. The end-to-end Aerial Refueling model of the Hose-Drogue system is the simulation process that takes the inputs of the environment, tanker motion, and receiver contact as inputs and provides the output response of the hose/drogue system including the reel response, hose motion and drogue positioning.

6.0 INTRODUCTION

6.1 Scope of Document

The goal of this project is to develop a standardized format (Interface Control Document) and validation/verification best practices for the modeling and simulation of Aerial Refueling Systems to include hose/drogue, boom/receptacle, and BDA (boom-to-drogue adaptor) kit configurations. As the community moves toward certification by modeling and simulation (M&S), it will be critical that the validation of model components is understood/documented and can be easily shared among organizations.

This final issue of this document will consist of segments covering:

- standardized interface for end-to-end AR modeling resulting in highly plug and play simulations for multiple end-uses that can be easily shared across multiple vendors and platforms
- standardized interface for higher fidelity model architecture and interfaces to enable more detailed AR modeling
- discussion and guidance on environmental modeling and best practices as pertains to AR; including turbulence, receiver bow waves, and tanker air wakes
- simulation validation and verification standardization and best practices to include discussions on typical receiver and tanker profiles for model development, verification tools, model validation best practices, and AR component level tests
- recommendations for model documentation
- recommendations for the use of simulations in certification process

6.2 Scope of First Release

Given the scope of the final document, it was envisioned that the first document release would cover the standardized interface for end-to-end AR modeling of hose-drogue systems only, with the intent being to quickly share and adapt this common ICD throughout the modeling community.

The conceptual architectural layout presented in this release allows for the integration of an Aerial Refueling Model (ARM) into an independent simulation environment consisting of tanker model, receiver model, environmental components, and/or visual representation to achieve an AR End-to-End simulation. The fidelity, physical properties, and configuration variations of any give ARM is left to the discretion of the ARM developer, along with the level and type of modeling and simulation verifications and validations conducted by actual testing e.g., lab, ground, and flight as appropriate.

6.3 Generalized Simulation Architecture and interface

The aerial refueling domain as defined for implementation into a simulation environment consists of the interactions between a receiver aircraft, a tanker aircraft, and the aerial refueling system. Currently there are three refueling system methods: BDA, boom/receptacle, and hose-drogue. The three configurations are shown in Figure 1. The Aerial Refueling Model (ARM) can reflect any of these three systems.

Figure 1. Aerial Refueling Systems

The refueling domain also includes the physical environment through which the tanker and receiver aircraft fly and the wind disturbances they each experience and create. For use in the simulation environment, user inputs of ARM system controls and the aerial refueling system failure scenarios are also considered.

A generalized system architecture that relates these elements is shown in Figure 2. Each block is its own model(s) or interface. The arrows representing the flow of data.

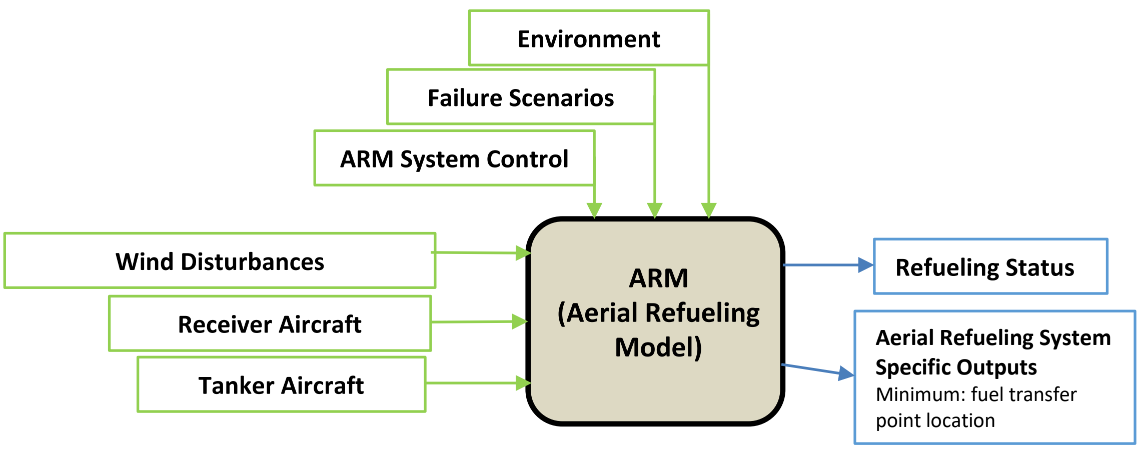


Figure 2. Generalized Simulation System Architecture

Tanker and Receiver Aircraft models provide positions, velocities, orientation, and orientation rates to the ARM. These models can range from high fidelity aerodynamic models to simple time data inputs.

Wind Disturbances can include free air turbulence models, tanker air wake disturbances, and/or receiver bow wave disturbances.

Environment conditions relate the altitude and airspeeds of the tanker and receiver aircraft to air temperature and pressure.

ARM System Control, Failure Scenarios input, Refueling Status, and ARM Refueling System Specific Outputs are unique to the AR system being modeled. In general, ARM System Control provides the controls for the AR system and simulation models. The Failure Scenarios interface allows the option to replicate fault scenarios. The AR System Specific Output format, at a minimum, includes the location of the refueling fuel transfer and refueling status information.

The generalized architecture coupled with a consistent-standardized interface along the data flow lines, strives to allow for the integration of an Aerial Refueling Model (ARM) into any independent simulation environment consisting of tanker model, receiver model, environmental components, and/or visual representation to achieve an AR End-to-End simulation. It also allows various ARMs to be shared across tanker/receiver platforms, and between contractor, government, and international agencies with minimum modifications.

7.0 AERIAL REFUELING MODELING AND SIMULATION

7.1 Aerial Refueling End-to-End Model

7.1.1 General

7.1.1.1 Coordinate System Definitions

ABA – Aircraft Body Axis (commonly referred to as “b” in ISO-1151 standard)

The ABA coordinate system is defined relative to the aircraft platform, Figure 3.

- Translational Components

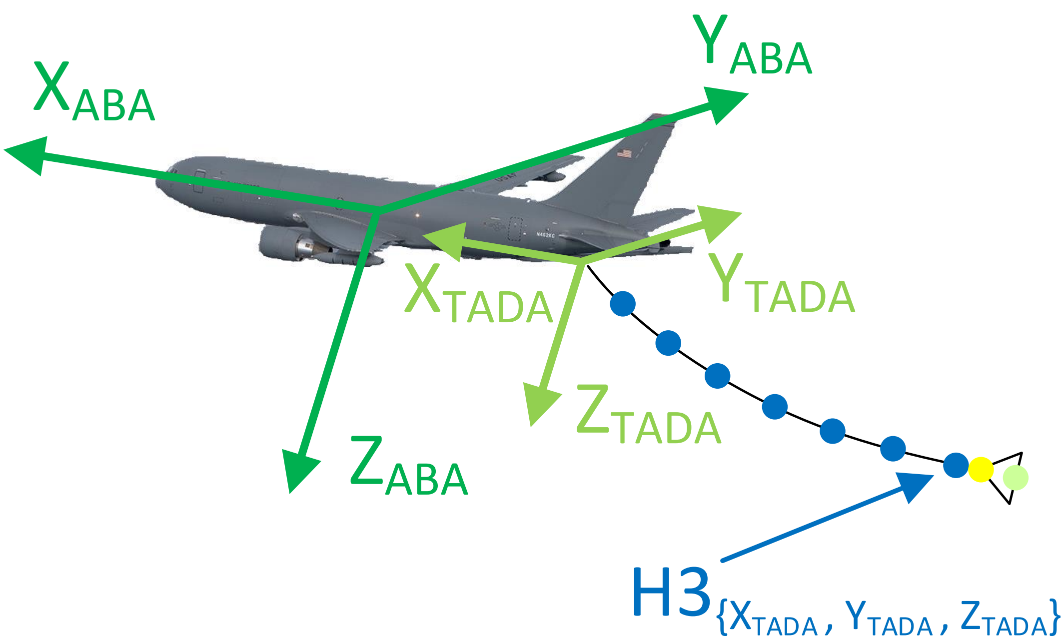
– X: positive forward parallel to aircraft fuselage waterline
– Y: positive starboard wing; parallel to aircraft fuselage buttline
– Z: positive down

TADA – Tanker Aircraft Drum-centric Axis

The TADA is a convenience coordinate system defined as being parallel to the traditional ABA, while having its origin at the center of the hose drum, Figure 3.

- Translational Components

– X_{TADA}: positive forward parallel to aircraft fuselage waterline
– Y_{TADA}: positive starboard wing; parallel to aircraft fuselage buttline
– Z_{TADA}: positive down



Ref: Figure 7. Hose-Drogue Indexed Points- Conceptual

Figure 3. TADA and Ordinary ABA Coordinate Systems

FEA – Flat Earth Axis

The FEA is the inertial coordinate system used within the Aerial Refueling Modeling and Simulation environment. It is a Cartesian right-hand coordinate system and is equivalent to a North East Down (NED) axis system for a flat earth assumption/simplification:

- gravity is constant and everywhere aligned to FEA vertical axis
- earth's curvature and rotation are not considered

Figure 4 shows the FEA coordinate frame, and examples of how the tanker's Euler angles are defined relative to this axis system. The horizontal plane defined by the X_{FEA}, and Y_{FEA} axes represents a flat earth plane located at 0 ft altitude Mean Sea Level (MSL). In this way, (-) Z_{FEA} can be used as an altitude input to the standard atmosphere model and produce the appropriate density for aerodynamic calculations. The initial position of the origin of the TADA, in the FEA, is defined as {0, 0, -MSL of the drum center} at the start of the simulation.

- Translational Components

– X_{FEA}: positive North
– Y_{FEA}: positive East
– Z_{FEA}: positive down

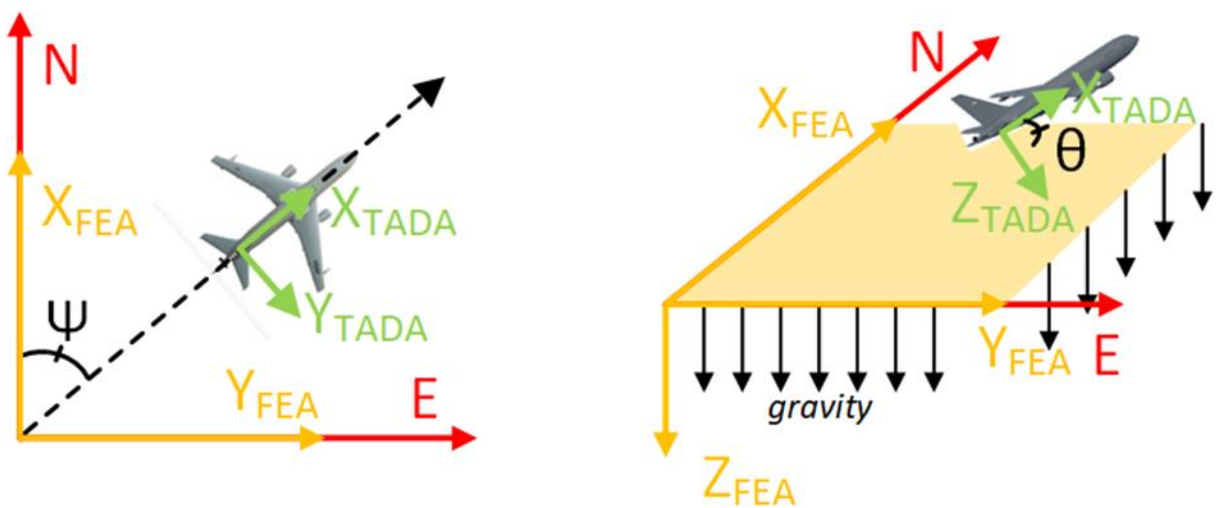


Figure 4. FEA Coordinate System

The tanker position is provided as FEA coordinates of the hose drum center in the message group 50001 to the ARM and the receiver model. This reference allows converting relative coordinates from the TADA frame (e.g., of receiver and hose/drogue system) into FEA coordinates and vice versa.

A simple and universal conversion between FEA (flat earth) and WGS-84 (round earth) coordinates is not available, as this depends on the chosen map projection approach for a selected certain region (e.g., UTM). Therefore, it was decided to omit WGS-84 (and ECEF) coordinates in the simulation for the moment.

The FEA, rather than an NED system, is explicitly defined for inertial calculations to avoid ambiguities that may arise from unintended mixed coordinate system usage. One example of a potential issue is that a tanker aircraft is operating in one NED frame while the receiver aircraft propagates in a second NED frame that is attached elsewhere to the ellipsoid. Another source of incompatibility can arise when one simulation component is integrating accelerations in an Earth Centered, Earth Fixed coordinate system while another component, although acting in the same NED 'neighborhood', is integrating NED accelerations while defining gravity to be parallel with the Down axis. While these issues may not lead to large errors, they can certainly produce the type of numerical methods nuisances such as unwanted relative drift, especially over time.

Operators that wish to blend their round earth simulation environment with the FEA are encouraged to use a vehicle carried NED system, which will remain aligned to FEA at every time step. Relative coordinates of receiver and hose/drogue elements can be easily transformed from the TADA into the vehicle carried NED frame and then – as offset to the tanker WGS-84 position – converted into round earth coordinates. The remaining error from the conversion is negligible, provided that the receiver remains in the neighborhood of the tanker. This concept is depicted in Figure 5.

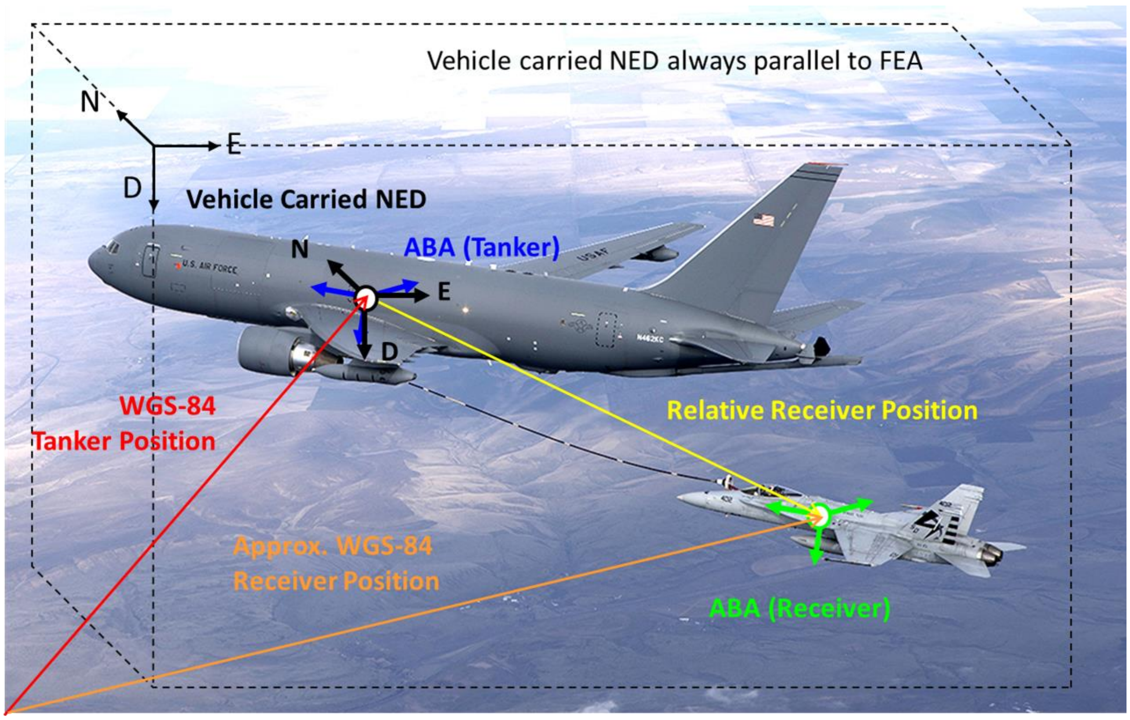


Figure 5. Vehicle Carried NED Example

7.1.1.2 Model Architecture

Figure 6 shows the conceptual architectural layout allowing the integration of an Aerial Refueling Model (ARM) into an independent simulation environment consisting of tanker model, receiver model, environmental components, and/or visual representation to achieve an AR End-to-End simulation. The fidelity, physical properties, and configuration variations of any give ARM is left to the discretion of the ARM developer.

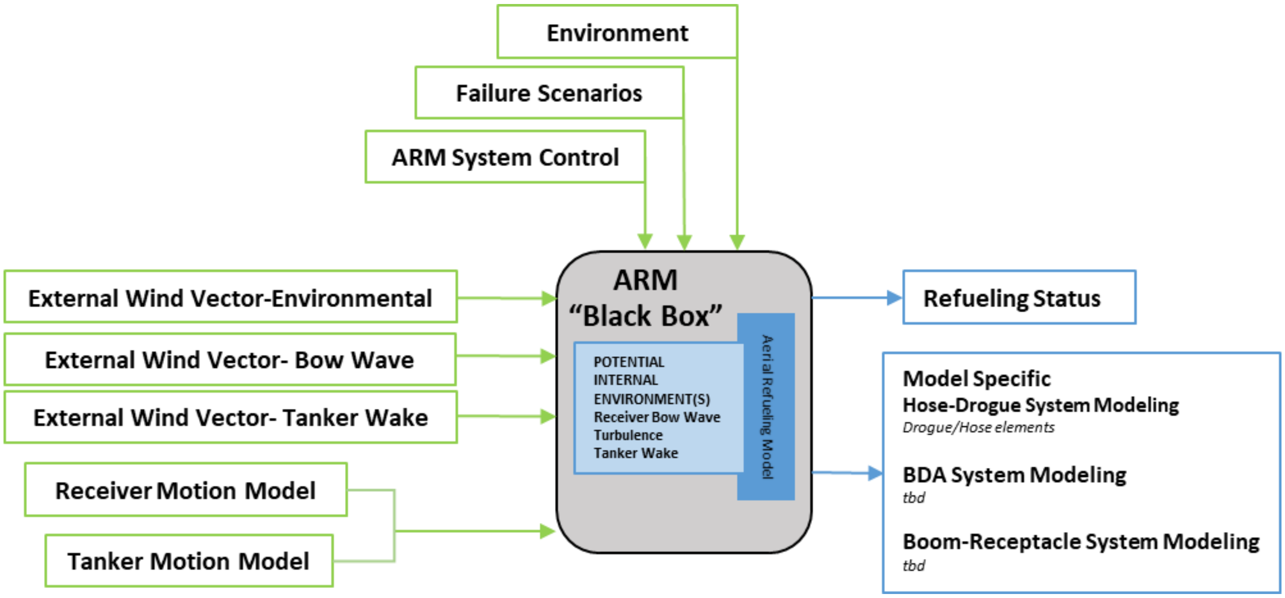


Figure 6. AR End-to-End Simulation Architecture

7.1.1.3 Interface Structure and UDP Ports

The data transferred between the external environment and the ARM "Black Box" are defined in US customary units to maintain consistency. Angle definitions are specified in radians defined between the values of -π (pi) to π. For developers using SI units in modeling, SI to US Customary conversion values are included in Table 1 below for reference. In addition to the columns outlined in Table 2 thru Table 11, the users could choose to provide reference ranges of variable values for system integration and flagging of off scale conditions, including occasions where only positive values are accepted to a variable.

SI Units	**US Customary Units**	**Conversion Factor SI to US Customary**
Meters	ft	3.28084
Kilograms	lbm	2.20462
KPa	psig	0.145038
ºC	ºF	ºF = (ºC * 9 / 5) + 32
N (newton)	lbf	0.224809

Table 1. SI to US Customary Conversions

Interaction between the various subsystems is achieved using messages transmitted via UDP. The messages will comprise matrices of doubles or integers. In some cases, where integer types are used, the values will be scaled prior to transmission to preserve precision;

these scaling factors are detailed in this document. Send and receive port numbers and IP addresses are specified in scripts at build time. A port is a computer networking endpoint. Along with the type of transport protocol (the most common being TCP and UDP) and IP address, it defines the network address for the destination or origination of a message. The messages from the ARM to the host may be sent to multiple ports to ensure that the messages are not split up into packages.

Messages shall be grouped and sent to a target port as required. The message group and their port numbers will always remain fixed. Additional ports have been reserved for any future requirements. The generic message structure is outlined in Table 22.

Members of the working group researched and tested different message protocols and found that UDP (User Datagram Protocol) was the preferred method of passing data between models. For time-sensitive applications UDP is useful because dropping packets is preferable to waiting for packets delayed due to retransmission, which may not be an option in a real-time system. The aim is to standardize on one interface solution to make model sharing easier, reduce integration costs and stimulate innovation. However, if developers choose to use a different interface, then the document provides guidance on the input/output variables for which another interface protocol could be used. In this case the end users would need to coordinate extensively with one another

Integration of the hose-drogue black box model:

The hose-drogue black box model is integrated into the flight simulation or simulation executive using the co-simulation method. This method specifies that the hose-drogue black box contain its own numerical solver. The flight simulator and the black box model exchange inputs and outputs at a predetermined time interval known as the communication interval or co-simulation interval. The flight simulation provides inputs to the black box model at each communication interval. The black box solves its equations of motion and returns the requested outputs to the flight simulator at the next communication interval. This approach allows the black box to simulate with a smaller time step than the flight simulator, which is typically needed to solve the higher frequency hose-drogue system dynamics.

	Message Group	UDP Send/Receive Port Number	Message Description	Section
Host to ARM	Receiver Motion Tanker Motion	50001	Provides receiver positions/velocities and orientations/orientation rates Provides tanker positions/velocities and orientations/orientation rates	7.2.1.1
	ARM System Control	50002	Provides the controls for the AR system and simulation models	7.2.1.2
	Environment	50003	Provides the controls for environmental variables	7.2.1.3
	Failure Scenarios	50004	Provides the option to replicate fault scenarios	7.2.1.4
	External Wind Vector-Environmental (including turbulence)	50005	Host generated wind vector reflecting environmental wind conditions to include turbulence	7.2.1.5.1
	External Wind Vector-Bow Wave	50006	Host generated wind vector reflecting receiver bow wave	7.2.1.5.2
	External Wind Vector- Tanker Wake	50007	Host generated wind vector reflecting tanker wake	7.2.1.5.3
ARM to Host	Model Specific Hose/Drogue Modeling	50011	Provides hose and drogue positions	7.2.2.1
	Refueling Status	50012	Provides information on refueling status	7.2.2.2

Table 2. Messaging Structure and UDP Ports

7.1.2 Hose Drogue Simulation Message Structure

The hose and drogue aerial refueling "end-to-end" model is intended to be generic, robust, and easily exchangeable and used for real-time and pilot in-the-loop simulations. For loads or stress analysis higher-fidelity models are required.

7.1.2.1 Messages Host-to-ARM

7.1.2.1.1 Aircraft Positions

The host will send Aerial Refueling Model the following as a single UDP packet as an 8 x 3 matrix of type double. This message will be transmitted at a rate of at least 100Hz. This transmission rate is intended to support real-time simulation and pilot-in-the-loop simulations. Higher fidelity models are expected to require finer simulation time steps. All transmitted position data is in the FEA, Table 3.

Size	8 x 3	**Data Type**	Double	**Transmission Rate**	100 Hz	**Port Number**	50001

Index	**1**	**2**	**3**	**Units**	**Comment**
P1	X_R	Y_R	Z_R	ft	Receiver Probe Tip Position*
P2	V_{RX}	V_{RY}	V_{RZ}	ft/s	Receiver Probe Tip Velocity*
P3	Φ_R	Θ_R	Ψ_R	Rad	Receiver Probe Orientation
P4	P_R	Q_R	R_R	Rad/s	Receiver Probe Orientation Rate
P5	X_D	Y_D	Z_D	ft	Hose Drum Center Position
P6	V_{DX}	V_{DY}	V_{DZ}	ft/s	Hose Drum Center Velocity
P7	Φ_D	Θ_D	Ψ_D	Rad	Hose Drum Center Orientation
P8	P_D	Q_D	R_D	Rad/s	Hose Drum Center Orientation Rate

Table 3.Host to Aerial Refueling Model Aircraft Position Message Structure

*The assumption is the contact model between the probe and the drogue is computed in the ARM. The receiver probe position and velocity in Table 3. is described as tip position; however, this could potentially be a more generic coordinate point depending on the fidelity of the receiver probe modeling and contact to drogue interaction.

7.1.2.1.2 ARM System Control

This section summarizes the commands sent from the tanker AR panel to the hose drum, Table 4.

Size	11 x 1	**Data Type**	Int16	**Transmission Rate**	100 Hz	**Port Number**	50002

Note that default values are denoted in square brackets, [ ].

Index	Name	Units	Scaling	States
A1	Pause Simulation	-	1	[0 = Run] 1 = Pause
A2	Deploy/Stow	-	1	[0 = Stow] 1 = Deploy
A3	Pre-contact Hose Fuel State	-	1	0 (empty) to 100% (full)
A4	Fueling Status	-	1	[0 = Automatic] 1 = Stop Fuel
A5	Hose Jettison	-	1	[0 = Off] 1 = On
A6	Red Signal Lamp Override	-	1	[0 = Off] 1 = On
A7	Fuel Mass Flow Rate	lbm/min	1	
A8	Hose end delivery pressure set point	Psig	1	
A9	Inlet Pressure at tanker-hose interface	Psig	1	
A10	Receiver back-pressure downstream of probe	Psig	1	
A11	Simulation Time Step Identifier	-	1	

Table 4.ARM System Control Message Structure

Hose Jettison:

This functionality mirrors the jettison behavior of the aerial refueling system. For the guillotine operated systems, it immediately cuts the hose; for the non-guillotine systems, it trails to standby and then releases the hose.

7.1.2.1.3 Environment

This section summarizes variables that define the operating environment of the hose-drogue system, Table 5.

Size	6 x 1	**Data Type**	double	**Transmission Rate**	1 Hz	**Port Number**	50003

Sys	**Index**	**Name**	**Units**	**States**
Environment	E1	Airspeed (Calibrated)	Knots	-
	E2	Air Temperature	ºF	-
	E3	Altitude (MSL)	ft	-
	E4	Environmental Wind Source (includes turbulence)	-	0 = Only External Velocities Used; 1 = Only Internal Velocities Used
	E5	Bow Wave Wind Source	-	0 = Only External Velocities Used; 1 = Only Internal Velocities Used
	E6	Tanker Wake Wind Source	-	0 = Only External Velocities Used; 1 = Only Internal Velocities Used

Table 5. Environment Control Message Structure

7.1.2.1.4 Failure Scenarios

This section summarizes variables that define various failure scenarios of the hose-drogue system, Table 6.

Size	6x 1	**Data Type**	Int16	**Transmission Rate**	100 Hz	**Port Number**	50004

Note that default values are denoted in square brackets, [ ].

Sys	Index	Name	Units	Scaling	States
Failure Scenarios	F1	Dead Hose	-	1	[0 = No Fault] 1 = Fault
	F2	Damaged Drogue	-	1	[0 = No Fault] 1 = Fault
	F3	Drogue Spoking	-	1	[0 = No Fault] 1 = Fault
	F4	Stuck Latches	-	1	[0 = No Fault] 1 = Fault
	F5	Failure to Latch	-	1	[0 = No Fault] 1 = Fault
	F6	Severed Hose	-	1	[0 = No Fault] 1 = Fault

Table 6. Failure Scenarios Message Structure

Dead Hose:

This functionality means that there will be no drum torque. The hose length would be locked, as the drum will not be able to rewind during contact mode.

Damaged Drogue:

The functionality means that there would be a reduction in drogue drag.

Drogue Spoking:

Spoking refers to an off-nominal contact where the probe-tip penetrates and gets entangled with the ribs of the drogue basket. Based on receiver approach profile and contact conditions, identify when spoking is likely to occur and update visuals and release forces accordingly.

Stuck Latches:

This functionality would mean an increase in coupling latch disconnect force levels

Failure to Latch:

This functionality would mean an increase in coupling latch engagement force levels

Severed Hose:

This functionality enables situations where the hose severs, for example at the coupling interface

7.1.2.1.5 External Wind Vectors

For unsteady aerodynamic effects such as turbulence, tanker wake, and receiver bow wave, either the host or ARM can calculate the wind vectors as velocity deltas to the free stream aerodynamics, with the source as specified in Table 5. For the external wind vector case, the host sends a wind vector generated by the host that will be applied to the ARM, this wind vector will be velocity deltas added to the ARM wind vector, information to the ARM in a single UDP message as an 83 x 3 matrix of double type. All transmitted position data is in TADA coordinates. For models with fewer than 80 hose elements (N elements), use row H4 through H(N+3) for the hose element start coordinates with H1 as the drogue end, H2 as the coupling ball joint articulation point, and H3 as the end coordinate of the final hose element. Table 7, Table 8, and Table 9 define the UDP for external wind vectors of turbulence, bow-wave, and tanker-wake, respectfully.

7.1.2.1.6 External Wind Vector- Environmental (including turbulence)

Size	83 x 3	**Data Type**	Double	**Transmission Rate**	100 Hz	**Port Number**	50005

Index	**1**	**2**	**3**	**Units**	**Comment**
H1	U	V	W	ft/s	Drogue End
H2	U	V	W	ft/s	Coupling Ball Joint Articulation Point
H3	U	V	W	ft/s	End coordinate of final hose element
H4	U	V	W	ft/s	Start coordinate of final N^{th} hose element
H5… H(N+2)	U	V	W	ft/s	Start coordinate of 2^{nd} to (N-1) hose elements
H(N+3)	U	V	W	ft/s	Start coordinate of 1^{st} hose element

Table 7. Tanker Wake External Wind Vector Message Structure

7.1.2.1.6.1 External Wind Vector – Bow Wave

Size	83 x 3	**Data Type**	Double	**Transmission Rate**	100 Hz	**Port Number**	50006

Index	**1**	**2**	**3**	**Units**	**Comment**
H1	U	V	W	ft/s	Drogue End
H2	U	V	W	ft/s	Coupling Ball Joint Articulation Point
H3	U	V	W	ft/s	End coordinate of final hose element
H4	U	V	W	ft/s	Start coordinate of final N^{th} hose element
H5… H(N+2)	U	V	W	ft/s	Start coordinate of 2^{nd} to (N-1) hose elements
H(N+3)	U	V	W	ft/s	Start coordinate of 1^{st} hose element

Table 8. Bow Wave External Wind Vector Message Structure

7.1.2.1.6.2 External Wind Vector- Tanker Wake

Size	83 x 3	**Data Type**	Double	**Transmission Rate**	100 Hz	**Port Number**	50007

Index	**1**	**2**	**3**	**Units**	**Comment**
H1	U	V	W	ft/s	Drogue End
H2	U	V	W	ft/s	Coupling Ball Joint Articulation Point
H3	U	V	W	ft/s	End coordinate of final hose element
H4	U	V	W	ft/s	Start coordinate of final N^{th} hose element
H5… H(N+2)	U	V	W	ft/s	Start coordinate of 2^{nd} to (N-1) hose elements
H(N+3)	U	V	W	ft/s	Start coordinate of 1^{st} hose element

Table 9. Tanker Wake External Wind Vector Message Structure

7.1.2.2 Messages ARM-to-Host

7.1.2.2.1 Hose-Drogue Positions

ARM sends hose information to the host in a single UDP message as an 83 x 3 matrix of double type, Table 10. All transmitted position data is in TADA. For models with fewer than 80 hose elements (N elements), use row H4 through H(N+3) for the hose element start coordinates with H1 as the drogue end, H2 as the coupling ball joint articulation point, and H3 as the end coordinate of the final hose element, Figure 7.

Figure 8 shows an example of a 5-element hose-drogue modeling system. This figure is not to imply that elements need to be equal in size or exist beyond the TADA origin. The index points exported from the ARM should give the external user information as to the hose shape and drogue position as well as provide query points for environmental tanker wake, bow wave, and turbulence effects. Indices “wrapped” about the hose reel may be zeroed or continue to have values in TADA depending on the ARM design.

Size	83 x 3	**Data Type**	Double	**Transmission Rate**	100 Hz	**Port Number**	50011

Index	**1**	**2**	**3**	**Units**	**Comment**
H1	X	Y	Z	ft	Drogue End
H2	X	Y	Z	ft	Coupling Ball Joint Articulation Point
H3	X	Y	Z	ft	End coordinate of final hose element
H4	X	Y	Z	ft	Start coordinate of final N^{th} hose element
H5… H(N+2)	X	Y	Z	ft	Start coordinate of 2^{nd} to (N-1) hose elements
H(N+3)	X	Y	Z	ft	Start coordinate of 1^{st} hose element

Table 10. Hose Information Message Structure

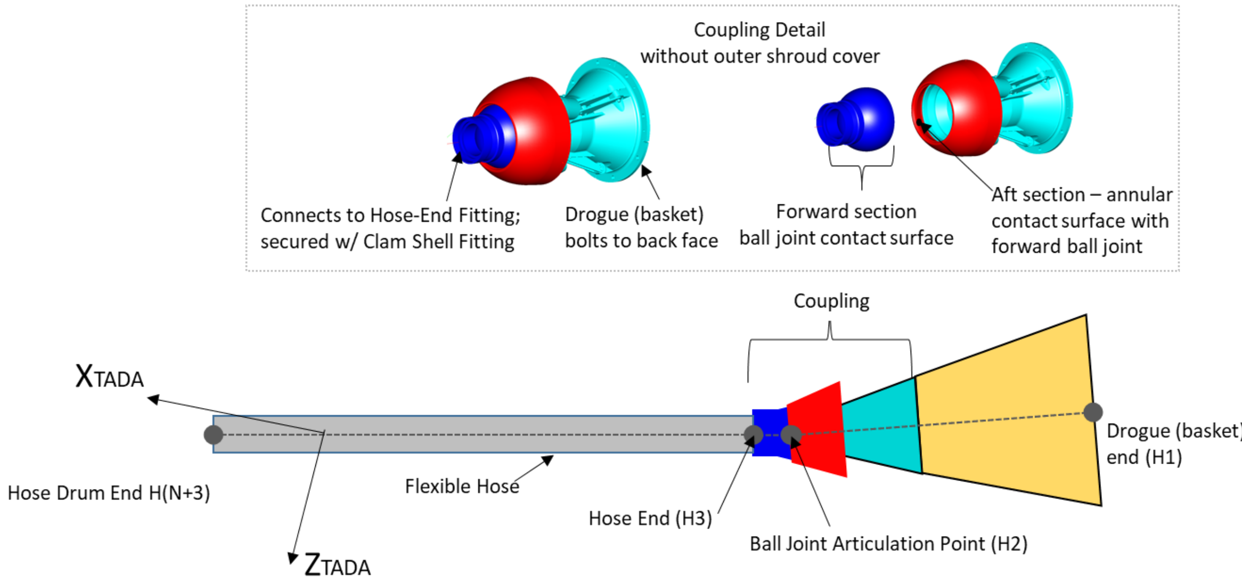


Figure 7. Hose-Drogue Indexed Points- Conceptual

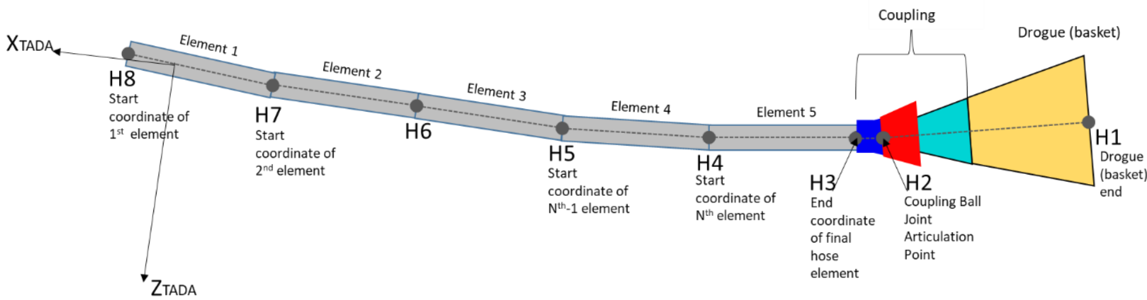


Figure 8 Hose-Drogue Indexed Points: Five Element Example

7.1.2.2.2 Refueling Status

ARM sends refueling status to the host in a single UDP message as a 12 x 1 vector of double type, Table 11.

Size	12 x 1	**Data Type**	double	**Transmission Rate**	100 Hz	**Port Number**	50012

System	Index	Name	Units	States
Refueling Status	S1	Green Signal Lamp	-	0 = Off 1 = On
	S2	Amber Signal Lamp	-	0 = Off 1 = On
	S3	Red Signal Lamp	-	0 = Off 1 = On
	S4	Deployed Hose Length	ft	-
	S5	Drum Speed	rad/s	-
	S6	Hose Linear Speed	ft/s	-
	S7	Hose Tension at Drum	lbf	
	S8	Mean Probe Load X	lbf	-
	S9	Mean Probe Load Y	lbf	-
	S10	Mean Probe Load Z	lbf	
	S11	Fuel Mass Flow Rate	lbm/min	
	S12	Hose End Pressure	psig	
	S13	Probe Engaged		0 = not engaged 1 = engaged

Table 11. Refueling Status Message Structure

Sign Convention:

Positive Drum Speed and Hose Linear Speed is in the trail direction, negative is rewind.

Probe Loads:

The probe loads passed from the ARM to the Host are the mean contact forces over each coarse 10 ms time-step. These loads are only intended to inform evaluation of pilot response and receiver flight dynamics and should not be used for higher-fidelity analysis such as probe structural analysis.

7.1.3 Boom-Receptacle Model

This section is reserved for future use

7.1.4 BDA Model

This section is reserved for future use

7.2 AR COMPONENT LEVEL MODELING

This section is reserved for future use

7.3 ENVIRONMENTAL MODELING – BEST PRACTICES

This section is reserved for future use.

7.4 SIMULATION VALIDATION AND VERIFICATION-STANDARD SIMULATION RESULTS

This section is reserved for future use.

7.5 MODELING DOCUMENTATION

This section is reserved for future use.

7.6 USING SIMULATION IN CERTIFICATION PROCESS

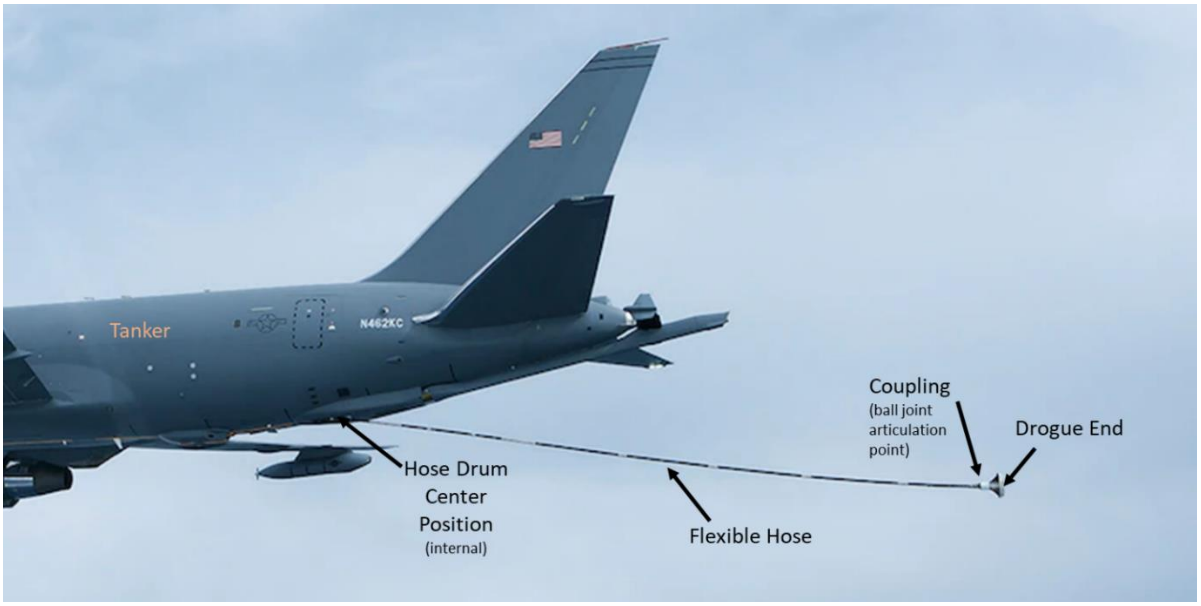
This section is reserved for future use.

7.7 SURVEY OF COMPONENTS AND MAP TO REAL WORLD AR SYSTEM

This section is reserved for future use.

8.0 APPENDIX / AUXILIARY SECTIONS

8.1 Tanker Hose-Drogue Refueling System Nomenclature.



8.2 Receiver Hose-Drogue Refueling System Nomenclature.