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The purpose of this ARSAG document is to provide guidance and information about aerial refueling test methodologies used to certify new tanker/receiver combinations in support of the AR Clearance Process. Covered topics include the ground and flight testing of boom/receptacle systems and probe/drogue systems, test conditions and configurations, test approach and sequence, instrumentation and data analysis, safety concerns, and flight test time estimation.

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AERIAL REFUELING SYSTEMS ADVISORY GROUP

GUIDANCE DOCUMENT

AERIAL REFUELING TEST METHODS

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SUMMARY

Disclaimer: Engineering authorities are responsible for final test requirements and methods. Reference ATP 3.3.4.2 or ARSAG Document No. 43-08-14 for a detailed Flight Clearance processes.

This ARSAG document is initiated to provide a guide to assess technical compatibility to complement the Aerial Refueling clearance process defined in ARSAG document 43-08-14. The purpose of this ARSAG document is to provide guidance and information about aerial refueling test methodologies used to certify new tanker/receiver combinations in support of the AR Clearance Process. Covered topics include the ground and flight testing of boom/receptacle systems and probe/drogue systems, test conditions and configurations, test approach and sequence, instrumentation and data analysis, safety concerns, and flight test time estimation. This document represents the combined efforts of international industry and military test specialists.

This document is not a directive. The degree of testing required to establish a clearance for any particular tanker/receiver combination will always be at the discretion of the organizations that own and operate the tanker and receiver aircraft. The technical, political, and operational authorities for both aircraft must agree that the appropriate amount of testing has been accomplished to satisfy both organizations' requirements. Different organizations will have different test requirements defined by law, regulation, or technical evaluation. This document serves as an informative database for organizations to consult when developing an aerial refueling test program, providing information and rationale learned by many test organizations over the years. This document does not attempt to define the qualification or certification requirements for any aircraft, or tanker-receiver pair.

This document is intended as a living document, to be added to and updated with new information as the testing community and technology advances, and develops new test methods and lessons learned.

The scope of this document currently covers manned tankers and receivers. This document covers ground and flight testing of both tanker and receiver aircraft. Simulator and lab testing are not covered. The initial focus of the testing covered by this document is the certification of tanker-receiver combinations. Additional uses for this document include tanker and receiver qualification and development testing processes.

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Most notably the following personnel should be recognized for their significant involvement on this document including consistently attending multiple workshop meetings, researching existing standards and guidance documents, and compiling the vast majority of information.

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REFERENCES

N°	*TITLE*	*REFERENCE*	*ISSUE*	*DATE*	*SOURCE*
1.	Probe and Drogue Aerial Refueling Data Acquisition and Test Techniques Primer	00-05-01			ARSAG
2.	Aerial Refueling Pressure Definitions of Terms	03-00-03R		Dec ‘12	ARSAG
3.	Air-To Air Refueling Equipment: Probe-Drogue Interface Characteristics	STANAG 3447	Ed 4	May ‘08	NATO

ASSOCIATED DOCUMENTS

TITLE	*REFERENCE*	*ISSUE*	*DATE*	*SOURCE*
Aerial Refueling Clearance Process Guide	43-08-14		Aug ‘14	ARSAG

DEFINITIONS OF TERMS

This section provides definition of terms specific to aerial refueling ground and flight testing; general Aerial Refueling terminology can be found in ATP 3.3.4.2.

AZIMUTH	Angular lateral position of receiver aircraft relative to the neutral position of the AR envelope; generally used for Boom-Receptacle refueling
CONTACT-UNCOUPLED	The tanker AR Signal System is in the contact state, the receiver is in the contact position, and the AR boom is approximately 1 foot from the receptacle; generally used for AR Boom-Receptacle flight test
COUPLED	AR condition where the tanker boom nozzle is latched within the receiver receptacle; generally used for AR Boom-Receptacle flight test
ELEVATION	Vertical position of receiver aircraft relative to the neutral position of the AR envelope; generally used for Boom-Receptacle refueling
EXTENSION	Telescopic position of the inner tube relative to the rigid outer tube of the AR boom

ACRONYMS

AR	Aerial Refueling
ARDS	Advanced Range Data System
ARO	Aerial Refueling Operator
BIT	Built-In Test
CG	Center of Gravity
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FAA	Federal Aviation Authority
FMS	Flight Management System
FOD	Foreign Object Damage/Debris
FTZ	Fuel Transfer Zone
GW	Gross Weight
HMD	Helmet Mounted Display
HQ	Handling Qualities
IR	Infrared
IRIG	Inter-Range Instrumentation Group
JAA	Joint Aviation Authority
NVG	Night Vision Goggles
NVIS	Night Vision Imaging System
PDL	Pilot Director Lighting
Q	Dynamic Pressure
TSPI	Time Space Position Information

CONTENTS

1. Qualification vs. Certification

The terms “qualification” and “certification” are often confused or used interchangeably. In other situations, such as FAA or JAA processes, they have differing meanings. However, when discussing aerial refueling test, they both have specific and separate meanings.

The qualification of a tanker or receiver is the process of developing and verifying the properties of the aircraft that allow it to fulfill that role. This would include meeting any required specifications for tanker or receiver aircraft by design and functional test, such as having proper interfaces (fuel, signal system, visual, etc.), adequate handling qualities, acceptable fuel transfer rates, and similar. A qualified tanker or receiver aircraft means that aircraft *can* be a tanker or receiver, to some degree. An aircraft can have a partial or limited qualification, due to incomplete development or qualification testing, or identified performance limitations that do not allow the aircraft to perform at the desired level. The term “fully qualified” generally refers to an aircraft that has finished development and has established envelopes and performance limits for normal operations. A fully qualified aircraft does not have pending development or testing remaining to meet desired performance.

Certification is the process of verifying that a particular tanker and receiver combination is functionally safe and operationally viable. Certification efforts define the aerial refueling envelope for the aircraft combination, the optimum airspeeds and altitudes for aerial refueling, acceptable configurations (gross weight, center of gravity, external stores, flap settings, etc.), pump settings, light settings, procedures, restrictions, and any information required for manuals (notes, cautions, warnings). The certification of a tanker-receiver combination requires that testing requirements defined by the operating organizations of both the tanker and receiver are met and agreed upon.

The primary difference between qualification testing and certification testing is where the focus of testing is. During qualification testing, the objective of testing is to verify and characterize the performance of the system (tanker or receiver) regardless of the other aircraft. This is often tied very closely to development testing, and system changes may be made to bring it into compliance with required specifications or fix deficiencies. In the case of a new tanker, receivers with certifications with similar tankers are used to qualify the tanker, using different receivers to expand the tanker envelope as required. If no changes are made to the tanker during qualification, the data collected with each receiver can also be used toward certification of that receiver, providing additional testing collects all data required for certification.

2. General

The general process of aerial refueling testing is as follows:

- Technical Assessment/Compatibility
- Define Test Objectives
- Determine Data/Instrumentation Requirements
- Determine which Tasks collect the Required Data
- Execute Testing Safely and Efficiently
- Reporting

During each stage of the process, there is normally a large amount of coordination and communication required between many different organizations. Each organization may have its own requirement for technical documentation, data collection, approvals, safety, and aircraft usage.

If flight testing is required to support a refueling clearance, it is imperative that the Tanker and Receiver operators are fully informed about the technical capabilities of both aircraft. Useful documentation may also include:

- Standardized Technical Data Survey (ARSAG Document 17-81-03R, April ‘14)
- Fuel System and Aerial Refueling System Chapter from Flight Manual
- Lighting Chapter from Flight Manual (specific to external lighting)
- Aerial Refueling Procedures (ATP 3.3.4.2)

3. Compatibility Assessment/Technical Survey

In the case of determining the Aerial Refueling compatibility of a specific tanker/receiver combination, before going into ground or flight test, a compatibility assessment should be completed. This assessment can serve different purposes:

- Assess the compatibility in each field described below, deriving possible limitations
- Determine the areas where gathered evidences are not sufficient to ensure compatibility
- Help define the test program
- Anticipate possible issues during flight test

The compatibility assessment should assess compatibility in the following fields:

- Geometrical compatibility
  - Tanker and receiver 3-view drawings throughout the air refueling envelope, with indication of the inner and outer refueling limits associated with the tanker AR system. An assessment should be made whether the geometrical clearance is adequate or not.
  - Drogue/receiver geometrical compatibility should also be assessed using STANAG 3447. The drogue should not interfere with the receiver nose and canopy in the contact position nor in the approach to contact path. A ground test check is normally performed to confirm good latching and geometrical clearance.
  - Normally a 3-view drawing can also help anticipate interactions between tanker engines efflux and receiver control surfaces.
- Aerodynamic compatibility
  - Normally just a qualitative assessment can be made on this respect, looking at the previous clearances that the tanker and the receiver have separately. Has the receiver/tanker refueled with a similar tanker/receiver? Can some aerodynamic interactions in flight be expected?
- Performance compatibility
  - The AR envelope is normally derived from the overlap of tanker and receiver AR envelopes.
- Loads compatibility
  - Assessment of the tanker or receiver interface design loads should account for the entire operating envelope (including static, dynamic, and impact loads.)
- Fuel system compatibility
  - Compatibility of probe/coupling and boom nozzle/receptacle standards
  - Fuel type compatibility
  - Type of coupling, fuel pressure regulation performance
  - Fuel operation:
    - Fuel flows
    - Fuel pressures for operation, surge, burst (see ARSAG document No. 03-00-03R for definitions)
- EMI/EMC compatibility
  - For those systems that cannot be turned off or put to standby during AR operations, an assessment should be made to confirm each aircraft’s systems are compatible with the EM emitters of the other one
- Lights compatibility
  - Assessment on the compatibility of receiver lights with tanker visual system
  - Assessment on the compatibility of tanker lights with receiver aircrew

In order to be able to perform this assessment, some information should be gathered from tanker and receiver:

- Standardized Technical Data Survey (ARSAG Document 17-81-03R, April '14)
- Current AR clearances (to see which platforms the receiver and/or tanker are cleared against, including acceptable envelopes and indicated restrictions and limitations)
- Fuel system information at Flight Manual level (to gain understanding on the way the fuel systems perform and the conditions that can be most restrictive in terms of fuel surge)
- AR operational manual (to understand the way tanker and receiver aircraft use their systems AR and lighting)

This list is not all-inclusive. This analysis can rely on technical specifications, previous tests or in-service experience. This analysis should list the risks associated with each compatibility item and should help to define the need for additional testing regarding the availability (or the level of confidence) of the information used.

3.1 Certification by Similarity

After performing the technical compatibility assessment of the tanker-receiver combination, the technical authorities may determine that certain technical aspects required for certification do not require flight test due to similarities to already certified receivers with that tanker. For instance, if a new receiver variant requesting certification shares the same fuel system, fuel transfer testing may not be required, or may be greatly reduced. Some receivers may be certified completely by similarity if the differences between the previously certified system and the new system do not impact the aerial refueling task.

4. Defining Test Objectives

If the objective is to qualify a tanker or receiver, then many of the test objectives will be defined through the use of requirements or specification documents specific to that aircraft. The aircraft should have specifications defining the aerial refueling envelope, conditions, fuel pressures and rates, and configurations that are required.

In the case of certification testing, a technical evaluation needs to be performed for the tanker-receiver combination. This technical evaluation uses design, operations, and previous test data to determine the particular testing that is required to allow for certification. At the completion of the technical evaluation, the test team should be able to define the objectives of the test, particular tasks required to complete the objectives, the data to be collected, and the types of reports that are required.

4.1 Ground Test

Ground testing generally falls into three categories: Test Asset Compliance, Functional Tests, and Performance Tests.

Test asset compliance testing is used to verify that the test asset that is being used for testing is operating inside operation guidelines. Examples of this type of testing are verifying pump output pressures, signal system functionality, or valve operations. These tests ensure that good data is being collected by a representative system, and reduces the chance of having to re-perform test later due to a bad system under test. This data will also aid in the event of troubleshooting anomalies, and tracking down the cause of any failures.

Functional tests consist of testing the various interfaces between the tanker and receiver while in contact. Examples of this would be the boom signal system and drogue coupling.

Performance tests are used to measure performance of the tanker and receiver while transferring fuel. Examples include various refueling modes of the receiver, or different pump configurations on the tanker. Of interest during this phase of testing are fuel pressures including both steady state and surge transients and flow rates, proper sequencing of valves, and proper operation of vents and other systems critical to fuel transfer.

4.2 Flight Test

Flight test generally falls into one of the following categories: Wake Survey, Functional Checks, Handling Qualities Evaluations, Physical Compatibility, Closure Rate Testing, Fuel Transfer, and Night Operations.

Wake survey testing consists of flying the receiver at specific locations around the tankers for the purpose of evaluating the airflow effects between the two aircraft, any impacts to handling qualities, turbulence, and visual cues for maintaining position. Wake survey and handling qualities should be evaluated throughout the refueling envelope.

Functional checks cover testing such things as the signal system operates properly and can be controlled from all crew stations as intended, the boom interphone is properly interfaced with the aircraft interphone system on both aircraft, external lighting such as PDLs and pod lights are indicating properly, and other similar types of system checks.

Handling qualities evaluations cover a broad range of evaluations pertaining to the handling qualities and aircrew workload associated with the aerial refueling task. HQ testing involves evaluations of the receiver aircraft flight controls, available thrust, and ability to stabilize in and around the refueling positions. Evaluations are also performed for the tanker systems, such as impacts to boom flying qualities by receiver bow waves, and impacts to tanker auto-pilot responses.

Physical compatibility includes establishing the contact disconnect envelope of the receiver, evaluations of load effects on the boom generated by the receiver, and probe loads generated during air refueling operations to include engagements and fuel transfer.

Closure rate testing evaluations are critical for both receptacle equipped receivers and hose and drogue systems. When testing receptacle equipped receivers with large bow wave effects, it is intended to evaluate the effects of the receiver bow wave on tanker HQ, auto-pilot response, and boom HQ. Large bow wave receivers are often limited in closure rate to the contact position based on this testing. During hose and drogue system testing, closure rate testing is required to confirm proper hose reel response during engagements for all types of receivers. It will also assess the interaction of receiver bow wave with the drogue at different closure rates.

Fuel transfer testing includes determining the maximum number of pumps to use on the tanker, evaluating the pressures and flow rates (including receiver fill times) with different refueling modes or configurations, and ensuring the fuel systems of both aircraft are compatible and functioning properly under all conditions.

Night Operations testing is used to determine AR compatibility with regard to pilot/ARO visual cues, tanker and receiver aircraft lighting to determine optimum lighting settings, AR markings and position references for the tanker and receiver pair, and acceptable degraded lighting configurations. Lighting evaluations should also include assessment of compatibility with NVGs.

4.2.1 Flight Conditions

Flight conditions for certification of tanker-receiver combinations will be determined by the operating organizations for both aircraft, and the requirements they have to fulfill prior to allowing their aircraft operate together. If the largest aerial refueling envelope is desired, the tanker (boom or drogue) refueling envelope is overlaid onto the receiver aerial refueling envelope, and the common altitude and airspeed area is the envelope to be tested. If a smaller subset is all that is desired, then that envelope can be developed based on operational requirements.

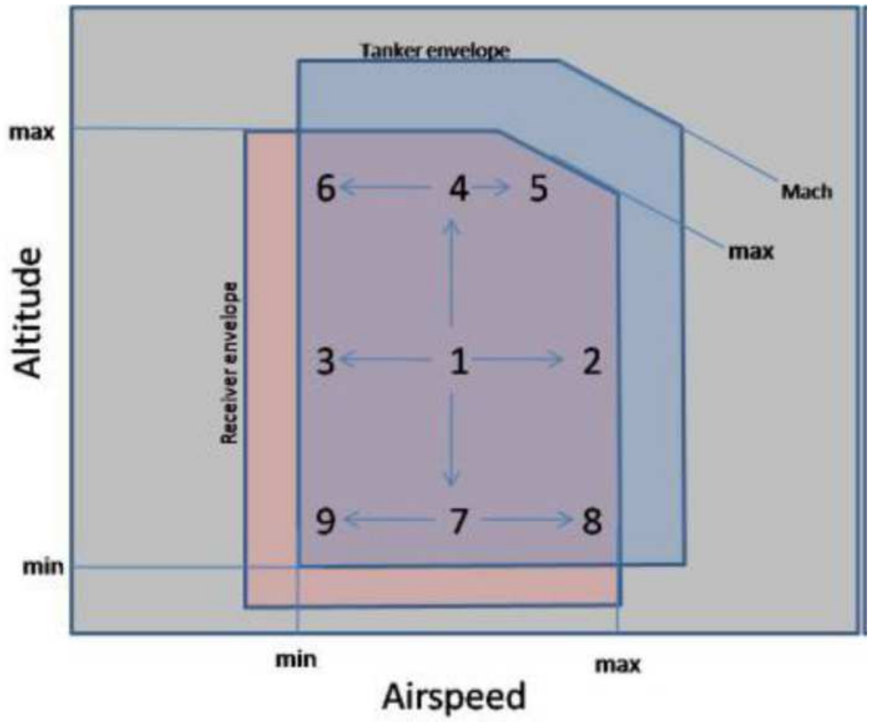


Figure 4-1. Typical assessment for determining aerial refueling test envelope.

The flight conditions that can be evaluated are:

- Initial Targeted Condition
- Maximum Mach
- Maximum Dynamic Pressure
- Minimum Mach
- Minimum Dynamic Pressure

Testing may be performed at additional conditions for build-up as required for safety or for the investigation of performance related limitations.

4.2.2 Aircraft Configurations

In addition to determining the flight conditions, the configurations of the tanker and receiver aircraft need to be considered for both qualification and certification testing.

Configuration items that are of interest during aerial refueling test are:

- Gross Weight – Tanker and Receiver
  - Maximum, Minimum
- Drag – External stores of tanker and receiver
  - Clean, High Drag, Asymmetric
- Center of Gravity – Tanker and Receiver
  - Forward, Aft CG Limits
- Visibility – Paint Schemes, Lead-In Lines, Lighting
- Flight Controls

- Flaps, Slats, Speedbrakes,

The number of different configurations tested will depend on the degree that the configuration impacts the aerial refueling task, and the type of testing that is being performed. For instance, the number of configurations for the tanker and receiver during qualification testing will generally be far larger than those tested during the certification of a qualified tanker and qualified receiver.

5. Boom-Receptacle Systems Tasks

Boom-Receptacle testing tasks are listed in the table below. The detailed description of the task is provided in Appendix A – Boom Flight Test Tasks. As new tasks are added to this document, they will be listed in this table, and then attached in Appendix A.

REF NO.	NAME	TYPE	SOURCE
A001	Boom Tracking 300/100/50 Ft	Flight – HQ	USAF
A002	Boom HQ - Bowtie	Flight – HQ	USAF
A003	Heavy Receiver Bow Wave Evaluation	Flight - HQ	USAF
A004	Simulated Emergency Separation	Flight – HQ	USAF
A005	Station Keeping - Uncoupled	Flight – HQ	USAF
A006	Station Keeping - Coupled	Flight – HQ	USAF
A007	Contact – Disconnect Envelope Expansion	Flight – Functional	USAF
A008	Boom Signal System Function	Flight - Functional	USAF
A009	Disconnect Delay Evaluation	Flight –Functional	USAF
A010	Slipway Assisted Contacts	Flight – Functional	USAF
A011	Fuel Transfer	Flight – Fuel	USAF
A012	Pressure Disconnect Evaluation	Flight – Fuel	USAF
A013	Pressure Refueling Evaluation	Flight – Fuel	USAF
A014	Independent Disconnect	Flight – Functional	USAF
A015	Tension Disconnect	Flight – Functional	USAF
A016	Lighting Evaluation – Day/Dusk/Night	Flight – Lighting	USAF
A017	Lighting Evaluation – Degraded Lighting	Flight – Lighting	USAF
…			

Table 1. Boom-Receptacle Aerial Refueling Testing Tasks

5.1 Ground Test

5.1.1 Tanker System Checks

System functional checks should be performed on the tanker prior to any test activity to ensure that the tanker systems are functioning, and operating within limits. This not only contributes to safe testing, but also verifies data quality and improves test efficiency by reducing the chance of needing to repeat testing due to a previously existing system issue that invalidates the collected data.

5.1.1.1 Fuel Regulator

Fuel regulator testing ensures that tanker and coupling regulators are operating normally prior to connecting to a receiver. This ensures that the receiver fuel system will not be over pressurized during transfer operations due to tanker faulty regulator system.

5.1.1.2 Fuel Pumps

On tanker aircraft not capable of monitoring fuel pressures, all fuel pumps should be checked for dead-head pressure generation prior to test. This can help identify any pumps that may not be operating sufficiently or may require maintenance actions prior to the start of testing.

5.1.2 Receiver System Checks

Receiver system checks should be performed to ensure that all receiver AR systems are functioning properly prior to test. This includes any BIT checks of fuel valves, fuel sensors, fuel management systems, vent lines, receptacle function, signal system, boom interphone, regulators/surge alleviation devices within the receiver, exterior lights used during AR.

5.1.3 Fuel Flow Tests

The objective of this testing is to ensure that fuel flows, valve closures, fuel level indicators, and fuel shutoff valves are operating normally. This test also provides an indication of flow rates that can be expected in flight to ensure that the receiver system is not over pressurized.

Various options exist to verify the proper operation of the receiver fuel system during ground tests. Most involve pumping fuel into the receiver aircraft from standard fuel trucks, sometimes using a pressure boosting system to achieve the desired “simulated tanker” pressures.

An ideal test would be to couple the tanker directly to the receiver aircraft without the use of additional fuel lines. However, this is extremely difficult for boom and receptacle aircraft, as the tanker must be placed above the receiver, with sufficient room below and behind to properly place the receiver and lower the tanker’s boom into place.

5.2 Flight Test

Flight test tasks should be performed at various flight conditions in order to collect data about the tanker / receiver configurations, Tanker auto pilot/auto throttle configurations, HQ assessments, functional checks, pilot/boom operator comments.

5.2.1 Handling Qualities

5.2.1.1 Boom Tracking

Boom Tracking is when the receiver aircraft tracks boom movement, including boom operator commands, throughout the refueling envelope. This should be accomplished to evaluate handling qualities of the receiver while maneuvering in the tanker wake environment during approach to the pre-contact position. Receiver evaluation should focus on aircraft response in the tanker wake, tanker/receiver visual cues, and identifying any unique or hazardous issues.

5.2.1.2 Emergency Separation

This event should be accomplished to ensure the capability of the two aircraft to safely separate during aerial refueling. Two items are evaluated during this event: tanker/receiver handling qualities during the event and receiver ability to see the indication on the tanker Pilot Director Lights (PDL) and other indicators (e.g. Beacons) from both pre-contact and contact-uncoupled positions. Any wake effects on the receiver from the tanker are understood; and receiver effects on the tanker are evaluated (i.e. bow wave effects).

5.2.1.3 Receptacle Tracking

Receptacle Tracking is when the boom tracks receiver movement throughout the refueling envelope. This event should be accomplished to evaluate the handling qualities of the boom while maneuvering in the boom envelope in the contact-uncoupled position by maintaining 1 to 3 feet separation between the nozzle and receptacle. Evaluations should focus on boom response to receiver flow disturbances, tanker response to receiver bow wave, visual cues, and identifying any unique or hazardous issues.

5.2.1.4 Station Keeping

This event should be accomplished to evaluate receiver workload including handling qualities, effects of wake, visual references, effects on tanker or effects on the Air Refueling Boom. Cooper-Harper evaluations are usually used to rate suitability during level flight and turning maneuvers in both contact-uncoupled and contact positions with and without fuel transfer.

5.2.2 System Functional Checks

5.2.2.1 Boom Controls

5.2.2.1.1 Boom Feedback

Modern boom systems are commanded through a fly-by-wire system, so they have flight control laws that can be tuned to improve handling qualities in each phase of aerial refueling. As the boom system performance requirements are different in each phase of the aerial refueling operation, boom control laws may have different modes for free air (before contact), contact and disconnect phases. In some modes, the flight control laws are using boom position feedback to modify the command inputs into the boom control surfaces. The boom flight control laws should demonstrate good handling qualities satisfactory in the contact envelope and acceptable handling qualities in the rest.

Particular attention should be given to the flight control laws modes transitions, to confirm no transients in boom position and to control laws indication to operator through the boom display (mode feedback).

5.2.2.1.2 Control Following

This feature (also called stick follow-up) consists of the boom stick being automatically driven to follow the boom position while in contact. In this mode, the stick follows the boom rather than the other way around, as in free air mode. It gives the operator a sensitive feedback of where the boom is, and also minimizes the transients after disconnect, since the boom stick will be in the same position as it would be if the operator was commanding it. This mode would normally be tested during each contact of the test campaign. It should be tested throughout the entire boom disconnect envelope.

5.2.2.1.3 Modes and implementation

Boom control modes should be tested in their relevant spatial envelope. Some examples of multiple modes used in boom operations are listed below.

- Free air mode is the mode for performing contacts. It should be tested in the whole boom spatial envelope and should provide satisfactory handling qualities within the boom system’s contact envelope and acceptable in the remaining disconnect envelope.
- Coupled mode is the mode where the receiver is driving the boom movement and the boom aerodynamic surfaces help alleviate the boom loads. The key control parameter in this mode is the boom load.
- Disconnect is the mode to avoid the receiver just after disconnect. It should allow the boom to move quickly away from receiver. Normally it does not require good handling, but boom movement should be predictable. It should be tested in the disconnect envelope. Evasive maneuvers away from receiver are the basic ones to test this mode. Worst case is normally where the disconnect envelope is closest to the control envelope, since the margin to move the boom is reduced.

5.2.2.1.4 Degraded / Emergency Modes

Some degraded modes should be tested in flight, which requires careful preparation to ensure safety is not in question. An analysis should be performed to evaluate possible consequences of each failure case. Some examples are:

- Control law mismatch: the boom is physically in one state but the mode is different (for instance, boom is connected to receiver but control law is uncoupled).
- Boom deployment backup mode
- Extension/retraction system and boom control surface actuator systems degraded. In these cases, boom operation is still possible but performances are degraded.

5.2.2.2 Signal Functional Checks

Signal functional checks are an important step in verifying signal system operation prior to commencing any contact testing between tanker and receiver pairing.

5.2.2.2.1 Signal Systems Modes

The tanker and receiver signal systems are tested in normal and override modes to ensure that the signal systems are operating correctly, and respond properly to all crew inputs.

5.2.2.2.2 Boom Interphone

This evaluation confirms the capability of the tanker and receiver to communicate through the air refueling electrical system and the talk through the boom system. All crew positions with this capability and all modes of the system should be evaluated.

5.2.2.2.3 Independent Disconnect (if applicable)

This functional test should be done to ensure that when the Tanker Boom Operator initiates an Independent Disconnect and the boom nozzle latch area collapses away from the receiver receptacle latches.

5.2.2.2.4 Rate Disconnect (if applicable)

This testing determines the time it takes for the receiver to disengage from the nozzle of the tanker boom while moving laterally and vertically and fore and aft at multiple speeds toward the limits of the boom envelope. The result of this testing is the determination of the tanker's Disconnect Delay setting for the specific receiver.

5.2.3 Physical Compatibility

5.2.3.1 Boom Envelope Expansion

Envelope expansion testing should be used to verify desired boom envelopes or define boom envelope limitations throughout the AR envelope.

5.2.3.1.1 Contact Envelope

Contacts should be repeated at various points inside the booms contact envelope, starting in the center, and building out to the edges and corners of the contact envelope to ensure no excessive loads, nozzle binding/cocking, or difficulties in making contact occur.

5.2.3.1.2 Disconnect Envelope

Disconnects should be repeated at various points inside the disconnect envelope, starting in the center, and building out to the edges and corners of the disconnect envelope to ensure no excessive loads, nozzle binding, or difficulties in achieving a disconnect.

5.2.3.2 Tension Disconnect

The evaluation ensures the tanker air refueling system can disengage from the receiver receptacle when the receiver's receptacle latches fail to disengage from the boom and the structural limits of the boom and receiver receptacle are not exceeded.

5.2.3.3 Towing

This evaluation determines the ability to tow the receiver when the receiver is unable to stay within the boom envelope due to flight control or power issues. The tanker deactivates the boom's extension limit, initiates a contact, and then the receiver pulls back very slowly to the full extension point. The tanker commences the receiver tow.

5.2.4 Fuel System

5.2.4.1 Fuel Transfer

This evaluation determines the ability of the receiver to receive fuel and manage its CG and fuel system configuration (tank and valve sequencing) without unacceptable fuel pressures or other system anomalies (e.g. excessive venting.) The capability to operate in all refueling modes is evaluated for tanker and receiver systems. The capability of the tanker to control the fuel offload should also be evaluated to include individual and all combinations of aerial refueling pump controls available to the aircrew. Evaluations should also consider flowing disconnects.

5.2.4.2 Pressure Disconnect

This evaluation, typically performed during receiver qualification, evaluates the suitability of the Pressure Disconnect Switch to disconnect when pressure at the switch exceeds the specified value.

5.2.4.3 Pressure Refueling

This test evaluates the ability of the tanker to refuel receiver aircraft when the receiver's receptacle toggles fail to latch onto the nozzle. This capability should be accomplished by the ARO applying slight boom extension/pressure to open the nozzle/receptacle poppet valves, maintaining contact with the receptacle, and transferring fuel to the receiver.

5.2.5 Visual Cues/References

5.2.5.1 Tanker Visual Cues

This test evaluates receptacle markings, paint schemes, lights, and other visual cues found on the receiver aircraft to assist the tanker Aerial Refueling/Boom Operator during all phases of boom refueling operations.

5.2.5.2 Receiver Visual Cues

This test evaluates tanker lighting, PDLs, and other visual cues found on the tanker aircraft to assist the receiver crew throughout the air refueling operations.

5.2.5.3 Night Operations

Tanker and receiver optimal lighting configuration should be determined and evaluated in dusk, twilight and full dark lunar illumination periods. Degraded tanker or receiver aerial refueling lighting conditions should be evaluated and minimal lighting configurations should be established. Operational lighting configurations and scenarios should also be evaluated and optimal tactical lighting configurations should be established. If applicable, lighting evaluations should also include assessment of compatibility with NVGs.

6. Probe-Drogue System Tasks

Probe-Drogue testing tasks are listed in the table below. The detailed description of the task is provided in Appendix B – Boom Flight Test Tasks. As new tasks are added to this document, they will be listed in this table, and then attached in Appendix B.

Ref No.	Name	Type	Source
B001	Drogue Fit and Function Check	Ground	USAF
B002	Drogue Stability – Receiver Influences	Flight -	USN
B003	Wake Survey	Flight – HQ	USAF
B004	HQ Evaluation – Observation/Astern/Contact	Flight – HQ	USAF
B005	Operational Contact	Flight - HQ	USAF
B006	Probe Loads	Flight – Loads	USAF
B007	Fuel Transfer	Flight – Fuel	USAF
B008	Lighting Evaluation – Day/Dusk/Night	Flight – Lighting	USAF
B009	Lighting Evaluation – Degraded Lighting	Flight – Lighting	USAF
B010	Refuel Start / Stop	Flight – Fuel	USAF
B011	Refueling Zone Transition	Flight – Fuel	USAF
…			

Table 2. Probe-Drogue Aerial Refueling Testing Tasks

6.1 Ground Test

6.1.1 Tanker System Checks

System functional checks should be performed on the tanker prior to any test activity to ensure that the tanker systems are functioning, and operating within limits. This not only contributes to safe testing, but also verifies data quality and improves test efficiency by reducing the chance of needing to repeat testing due to previously existing system issue that invalidates data.

6.1.1.1 Fuel Regulator

Fuel regulator testing is accomplished to ensure that tanker and coupling regulators are operating normally prior to connecting to a receiver. This ensures that the receiver fuel system will not be over pressurized during transfer operations due to tanker faulty regulator system.

6.1.1.2 Fuel Pumps

On aircraft not capable of monitoring or self-checking fuel pressures, all fuel pumps should be checked for dead-head pressure generation, at a minimum, prior to test. This can help identify any pumps that may not be operating sufficiently for test, and will need to be serviced prior to test, or not used for testing, if capable.

6.1.1.3 Drogue Fit/Function Check

TBD

6.1.2 Receiver System Checks

Receiver system checks should be performed to ensure that all receiver AR systems are functioning properly prior to test. This includes any BIT checks of fuel valves, fuel sensors, fuel management systems, vent lines, regulators/surge alleviation devices within the receiver, exterior lights used during AR, and interior lights.

6.1.3 Fuel Flow Tests

The objective of this testing is to ensure that fuel flows, valve closures, fuel level indicators, fuel shutoff valves are operating normally. Additionally maximum flow rates acceptable in flight are established by evaluating surge characteristics for a variety of worst case shutoff conditions.

Various options exist to verify the proper operation of the receiver fuel system during ground tests. Most involve pumping fuel into the receiver aircraft from standard fuel trucks, sometimes using a pressure boosting system to achieve the desired “simulated tanker” pressures.

An ideal test would be to couple the tanker directly to the receiver aircraft without the use of additional fuel lines.

6.2 Flight Test

Flight test tasks should be performed at various flight conditions in order to collect data about the tanker / receiver configurations, including HQ assessments, functional checks, and pilot comments.

6.2.1 Handling Qualities

6.2.1.1 Wake Survey

Wake surveys and HQ evaluations should be performed behind the tanker throughout the refuel envelope, building up from a trail position, and stepping closer to the tanker until the receiver is in the fuel transfer zone region. This test evaluates formation maneuvering for higher gain tasks in the presence of the tanker wake and drogue movement. Larger receivers typically begin the buildup process farther aft than a fighter-class receiver due to wake effects on different sized receivers. This assessment should also be performed for a receiver with degraded modes conditions such as single engine for two engine aircraft and gear down configuration.

6.2.1.2 Emergency Separation

The aim of this task is to verify that the emergency separation is always possible in the considered flight condition and aircraft configuration. This evaluation should be performed from pre-contact and contact/uncoupled positions.

6.2.1.3 Formation Keeping

The aim of this task is to evaluate the handling qualities throughout the desired receiver's aerial refueling envelope while performing aerial refueling tasks. The receiver HQs should be evaluated in station keeping and during turns. This objective addresses aerodynamic compatibility of the tanker and receiver aircraft and visual cues required to accomplish the AR task. Hose stability should also be assessed to ensure there is no unpredictable/sudden movement or unacceptable oscillations. Drogue tracking evaluations should also be assessed with a dry/drained hose to assess higher drogue trail position and reduced hose stability.

6.2.1.4 Contacts

The aim of this task is to evaluate the handling qualities of the receiver while performing contacts and moving into the Fuel Transfer Zone. Evaluation should focus on visual cues, bow wave effects on drogue, any receiver oscillations tendencies, and identifying any unique or hazardous issues. Engagements should be conducted in both straight and level flight and during stabilized turns.

6.2.1.5 Disconnects

The aim of this task is to evaluate the handling qualities of the receiver while performing disconnects. Evaluation should focus on visual cues, bow wave effects on drogue after disconnect, any receiver oscillations tendencies, and identifying any unique or hazardous issues. Disconnects should be conducted in both straight and level flight and during stabilized turns.

6.2.1.6 Station Keeping

The aim of this task is to evaluate receiver workload including handling qualities, effects of wake, visual references, and hose response. Subjective pilot evaluations (e.g. Cooper-Harper Ratings) should be used to rate suitability during level flight and turning maneuvers with the receiver in contact with and without fuel transfer.

6.2.2 System Compatibility

6.2.2.1 Hose Response and Probe Loads

The aim of this task is to evaluate receiver AR probe loads during both contact and disconnect events. The objective is to ensure that a receiver can perform all phases of a refueling operation and that probe loads associated with hose response do not exceed design strength to include slow, nominal, medium, and fast closure rate contacts.

6.2.3 Fuel Transfer

The aim of this task is to verify the capability of the receiver to receive fuel, manage CG and fuel system configuration (tank and valve sequencing) without unacceptable fuel pressures or other system anomalies (e.g., excessive venting) The capability to operate in all refueling modes should be evaluated for tanker and receiver systems. The capability of the tanker to control the fuel offload should also be evaluated to include individual and all combinations of air refueling pump controls available to the aircrew.

The fuel pressure delivered to the receiver should be verified in different conditions (number of AR pumps, pump transients, opening and closing of valves, simultaneous receiver refueling, etc.) The optimum AR pump configuration for the considered receiver should be defined at this point.

During this phase, the ability to disconnect with fuel pressure and fuel flowing in the hose should be verified.

6.2.4 Visual Cues/References

6.2.4.1 Receiver Visual References

This task consists of defining visual cues that helps the receiver pilot to capture and maintain the refueling position (e.g. visual cues, tunnel lighting and hose markings). These visual references should include both day and night conditions.

6.2.4.2 Signal Light Functional Checks

This task evaluates that the signal lights are functioning correctly and is accomplished by the receiver moving the hose forward and backward with or without fuel flowing. The receiver pilot should verify function of the signal lights. During this phase, the tanker aircrew should also check the indicators, signal system status feedback, and emergency separation commands on the tanker, if available.

6.2.4.3 Night Operations

The aim of this task is to evaluate night lighting compatibility between the tanker and receiver. The objective is to determine AR compatibility with regard to pilot/ARO visual cues, tanker and receiver aircraft lighting, system status lighting, optimum lighting settings, and acceptable degraded lighting configurations. During this phase, the optimum lighting settings should be defined for the considered receiver. Refueling in degraded lighting conditions or with OPS lighting (e.g. with NVG) should be assessed.

6.2.4.4 Tanker Visual References

This task consists of evaluating the visual references used by the tanker ARO/flight crew to monitor the refueling position (e.g. visual cues, drogue, and hose markings). These visual references should include day, night, and multi-point refueling systems.

7. Additional Test Considerations

7.1 Vision Systems

While legacy tankers have typically used direct vision systems to see the receiver, modern tankers feature camera systems that are part of the refueling equipment and must be evaluated for adequacy to ensure safe aerial refueling operations. Some particular items of interest are: field of view, image processing, and camera capabilities.

7.1.1 Cameras

There could be different camera systems for the different phases of AR operation on tankers, each camera system needs to be evaluated to determine adequacy for aerial refueling operations. The evaluation should include all phases of the AR operation between the tanker and specific receiver: join, observation, astern, contact, refueling, astern, disconnect and reform for effects on cameras during the tanker/receiver certification. When qualifying the camera systems, they should be evaluated under different illumination conditions:

- Daylight conditions should consist of both high and low sun positions, different backgrounds (clouds, sea and terrain), and situations with the sun entering into the field of view.
- Dusk conditions should consist of sunset to nautical twilight. These conditions provide poor illumination for visible cameras, but high for IR ones.
- Night conditions should consist of different night illumination levels and should consider lunar illuminations and urban lighting.

Tanker/receiver certification should include daylight, dusk and night conditions, but a subset of recommended tests for each condition may be performed.

7.1.2 Displays

7.1.2.1 Tanker Displays

Remote vision systems should provide similar visual cues to those of direct view systems. Particular test attention should be given to visual system failure modes, which could result on operator losing view of receiver or having image degraded.

Modern boom camera systems provide 3D displays via a stereoscopic system that overlaps the images received from two different cameras, to provide the operator with depth perception. This 3D system should be evaluated during the test campaign throughout the different phases of AR from astern to contact and back to astern. This 3D display could have key symbology overlaid in the display that should also be evaluated during the test campaign to confirm that all key safety information is readily available and fit for purpose.

7.1.2.2 Receiver Displays

If utilized during aerial refueling operations, Heads Up Displays (HUDs) or Helmet Mounted Displays (HMDs) should be evaluated during flight testing to ensure correct operation. Testing should include impact to visual cues, various lighting scenarios and degraded operating modes (if applicable).

7.1.3 Recording

Recording systems may be part of the modern tanker camera systems. The video recorders may require their own testing. They provide good information for analysis and are quite useful during the flight test program especially if they record symbology overlaid on the operator displays.

7.2 Electromagnetic Interference (EMI)/Electromagnetic Compatibility (EMC)

EMI/EMC testing is generally performed on the ground with tanker and receiver aircraft in close proximity. Testing is performed to ensure no system anomalies occur due to EMI/EMC during aerial refueling operations.

7.3 Fuel Spray Effects/Impingement & Venting

Depending on receiver geometry and AR system location, specific test requirements may be used to assess fuel spray and/or venting on the receiver during aerial refueling operations. Considerations include potential fuel ingestion during fuel transfer or after disconnect on engine inlets, pitot-static systems, or other system ram air intakes. Pilot visibility may also be affected by fuel spray and/or venting onto the receiver canopy. Some methods used for this testing are Pilot/ARO comments and visual data analysis.

7.4 Chase Considerations

The use of a chase aircraft has sometimes been considered required for first AR flights. It is clear that a chase aircraft can provide feedback in terms of lateral positioning that can help the receiver find its position in the absence of other cues (drogue, boom, visual aids). This case can be relevant during the development stages of a tanker, where all the systems are not fully available. The technical value of the chase should be weighed against the cost and schedule risk.

Chase aircraft also provide an excellent profile view of hose reel response and assist in post flight assessment of hose reel performance.

In terms of safety, a chase aircraft can perform damage assessment on tanker and receiver and can assist in the recovery. But normally tanker and receiver can also inspect each other in case of damage and can also provide assistance mutually. Additionally, some flight test programs count with extensive means of data and video monitoring on board the tanker/receiver and even with real time telemetry data. In these cases, the chase aircraft can be considered nice-to-have, rather than a hard requirement for testing.

8. Instrumentation

The instrumentation required for aerial refueling test can vary greatly depending on the particular testing required. Some testing (particularly HQ) can sometimes be performed with no instrumentation or just video. Other testing, such as contact-disconnect envelope expansion, and fuel transfer, usually require both tanker and receiver instrumentation. Qualification testing generally requires more instrumentation than certification testing. Impacts of not instrumenting are listed below.

8.1 General

8.1.1 Hot Mike

Audio transcript allows tanker and receiver pilots and AROs to provide real-time observations without keying the Mike. It also provides narration for onboard video documentation.

IMPACT: Nice to have, minimizes pilot workload to key the Mike.

8.1.2 Chase Video with audio

Video transcript of all flight test operations (Side view):

- Documents tanker/receiver movement
- Documents hose/drogue stability
- Documents span wise view of hose response (contact through disconnect, hose whips)
- Backup for determination of receiver closure
- Supports technical/safety anomaly investigations

IMPACT: No backup for closure rate assessment. No documentation of engagement technique and hose response from the "whole picture" perspective.

8.2 Boom-Receptacle Instrumentation

8.2.1 Tanker Instrumentation

8.2.1.1 Fuel Pressure

Used to document tanker fuel pressures during fuel transfers to receiver aircraft (reference the ARSAG Pressure Definitions and Terms document for more information on surge instrumentation), defining;

- Fuel pressure during pump startup or when flow begins.
- Receiver shutoff surge pressures.
- Automatic or manual fuel flow shutoff (if applicable) due to:
  - Moving outside the Fuel Transfer Zone (FTZ), either too far in (inner limit) or backing out to disconnect.
  - Offloading a scheduled fuel amount.

IMPACT: Pressure data for system analysis and correlating pressure anomalies during testing of the receiver/tanker pair may not be available. The level of instrumentation should be determined by the individual organizations involved in the test program.

8.2.1.2 Boom Loads

Used to support physical compatibility testing and should include:

- Axial load monitoring at the nozzle
- Lateral, vertical or bending loads at the nozzle

IMPACT: Nozzle binding leading to inability to immediately disconnect may occur leading to severe nozzle and/or receptacle damage.

8.2.1.3 Boom Position

Used to support physical compatibility testing and should include:

- Elevation
- Extension
- Azimuth/roll

IMPACT: Inability to determine receiver specific boom envelope limits.

8.2.2 Receiver Instrumentation

8.2.2.1 Fuel System

Receiver individual tank fuel quantities used with fuel pressure to determine on-load fuel flow. Refuel manifold and fuel line pressures used to monitor surge pressures and identify what tanks create high surge pressures.

IMPACT: Lack of fuel system fuel quantity data prevents accurate on-load fuel flow assessment and identifying the specific fuel tank which may induce high shutoff pressure surges.

IMPACT: Pressure data for system analysis and correlating pressure anomalies during testing of the receiver/tanker pair may not be available.

8.2.2.2 Receiver Engine(s)

Used to monitor engine health and evaluate operability during aerial refueling operations. Engine load measurements (e.g. propeller loads, prop shaft loads, inlet distortion) can also be assessed with the receiver in the wake of the tanker.

IMPACT: Pilot can sufficiently monitor critical engine operation.

8.3 Probe-Drogue Instrumentation

8.3.1 Tanker Instrumentation

8.3.1.1 Fuel Pressure

Used to document the receiver's fuel system response to tanker fuel delivery, defining;

- Fuel pressure when tanker pumps kick on or receiver flow begins.

- Receiver shutoff surge pressures.
- Automatic or manual fuel flow shutoff due to:
  - Moving outside the Fuel Transfer Zone (FTZ), either too far in (inner limit) or backing out to disconnect.
  - Offloading a scheduled fuel amount.

IMPACT: If receiver refueling pressure is not measured, damaging pressure surges can exist in the refueling manifold and components which exceed structural strength. Damage sustained may not manifest itself immediately, but rather remain latent until failure ultimately occurs after repeated exposure. Risk mitigation can be provided by on-aircraft ground tests.

8.3.1.2 On-Board Video

Video transcript of all engagements (pilot view).

- Verifies on-center / off-center engagements
- Documents receiver movement, hose stability (free trail), hose response (contact through disconnect, hose whips) and fuel spray (contact, during fuel transfer and at disconnect)
- Helps support or explain instrumentation (loads) observations.

Real-time capability provides test team additional situational awareness of receiver position and movement and assessment of hose response.

IMPACT: Must rely on pilot observations. Chase footage will not capture receiver lateral corrections or targeting accuracy (e.g. on-center, off center hits), or any lateral hose movement. Fuel spray (should it occur) cannot be quantified.

8.3.2 Receiver Instrumentation

8.3.2.1 Aerial Refueling Probe Loads

Used to document radial and axial loads transferred to the aerial refueling probe and supporting structure by the tanker drogue system, during the following operations:

- Contact
- Fuel initiation and transfer
- Receiver movement
- Disconnect

Used to ensure applied loads do not exceed structural design limits. Should be required to (1) provide a safe buildup approach for high closure engagements and subsequent hose response as risk mitigation to probe failure and (2) to assess the acceptability of hose response or any questionable events (e.g., hose whips.)

IMPACT: If probe loads are not measured, loads can unknowingly exceed limit load strength without visual indications.

8.3.2.2 Receiver Closure Rate

Closure rates are required to provide a safe buildup to high closure rate engagements. They are used to ensure receiver speed at contact, during movement while engaged, and at disconnect falls within the tanker system's design criteria. It is Used in conjunction with probe load instrumentation to synchronize exact time of contact and receiver movement while engaged showing high probe loads. Examples include TSPI, ARDS, or photogrammetrics.

IMPACT: If closure rate is not measured, the test team must rely on highly subjective estimates of closure (pilot assessment, chase video) which do not provide the accuracy needed to show engagements did not go beyond the tanker's drogue system design capabilities.

8.3.2.3 Fuel System

Receiver individual tank fuel quantities used with fuel pressure to determine on-load fuel flow. Refuel manifold and fuel line pressures used to monitor surge pressures and identify what tanks create high surge pressures.

IMPACT: Lack of fuel system fuel quantity data prevents accurate on-load fuel flow assessment and identifying the specific fuel tank which may induce high shutoff pressure surges. The level of instrumentation should be determined by the individual organizations involved in the test program.

8.3.2.4 Receiver Engine(s)

Used to monitor engine health and evaluate operability following:

- Probe failure
- FOD from a drogue slap.
- FOD from tanker hardware separation (basket, canopy, drogue, hose).
- Fuel ingestion
- Tanker wake effects

IMPACT: Pilot can sufficiently monitor critical engine operation.

8.3.2.5 On-Board Video

Video transcript of all engagements (pilot view).

- Verifies on-center / off-center engagements
- Documents receiver movement, hose stability (free trail), hose response (contact through disconnect, hose whips) and fuel spray (contact, during fuel transfer and at disconnect)
- Helps support or explain instrumentation (loads) observations.

Real-time capability provides test team additional situational awareness of receiver position and movement and assessment of hose response.

IMPACT: Must rely on pilot observations. Chase footage will not capture receiver lateral corrections or targeting accuracy (on-center, off center hits), or any lateral hose movement. Fuel spray (should it occur) cannot be quantified.

9. Data Reduction Techniques and Methods

This section is reserved for future use. (See Appendix C for examples of test data.)

10. Safety Planning

This section is reserved for future use.

11. Support Equipment

This section is reserved for future use.

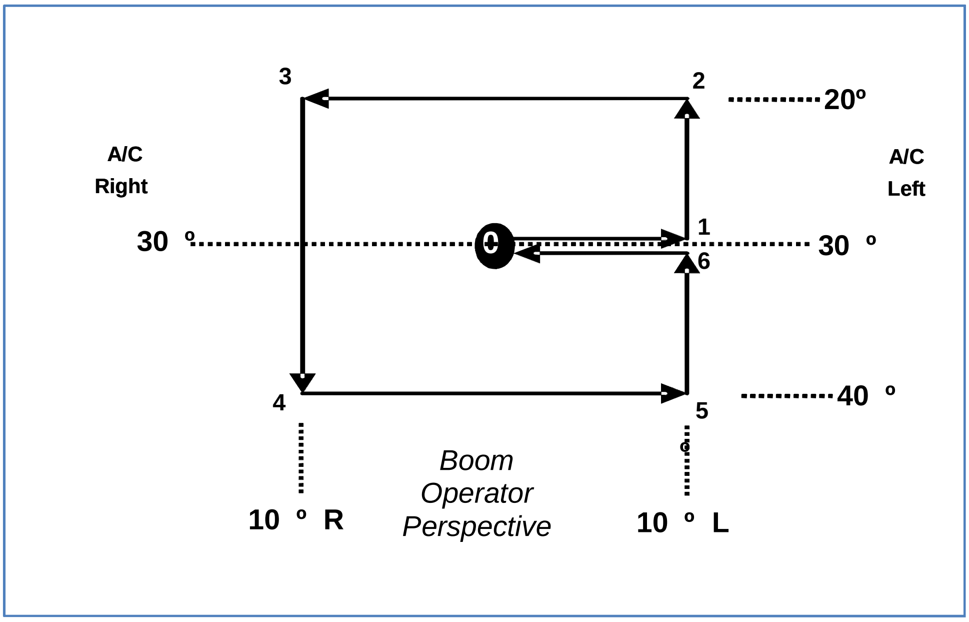
Appendix A
Boom Receptacle AR Task Sheets
(Detailed Methods)

AR Task Description Sheet

Title	A001 - Boom Tracking 300/100/50 Ft
Originator	
Type	Flight
Purpose/ Utilization	Objective: The flying qualities of the tanker and receiver will be qualitatively evaluated during aerial refueling operations.
Instrumentation	None – Pilot and boom operator comments / Cooper-Harper Evaluation

Task Description:

1. The receiver will stabilize 300 feet aft of the refueling boom, and activate his AR system, opening the UARRSI slipway and activating any AR specific flight control laws.
2. The boom operator will move the boom around the boom flight envelope at slow (1-2 deg/sec) speed in a box pattern.
3. The receiver will track the end of the boom (using a HUD pipper, or other visual reference) as it is moved.
4. The receiver pilot will comment on the difficulty of the task (tracking and stabilizing at each new boom position), and assign a Cooper-Harper rating.
5. Steps 2-4 will be repeated at fast (3+ deg /sec).
6. Steps 2-5 will be repeated at 100 feet aft of the boom.
7. Steps 2-5 will be repeated at the pre-contact position.



Lessons Learned:

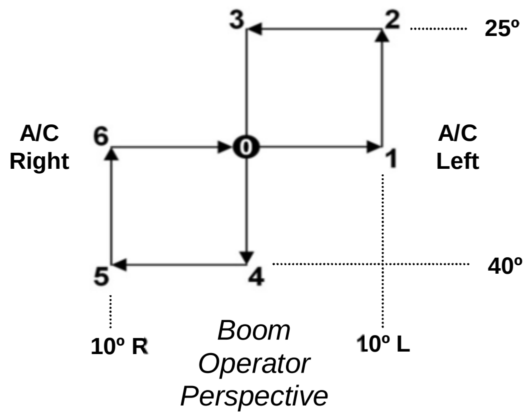
- None identified

AR Task Description Sheet

Title	A002 - Boom HQ
Originator	USAF
Type	Flight
Purpose/ Utilization	The flying qualities of the tanker and receiver will be qualitatively evaluated during aerial refueling operations. Boom flying qualities and the impact of the receiver bow wave will be evaluated.
Instrumentation	None – Pilot and boom operator comments / Cooper-Harper Evaluation

Task Description:

1. The receiver will stabilize in the contact uncoupled position.
2. The boom operator will direct the receiver to specific locations in the boom flight envelope, keeping the end of the boom nozzle within 2 feet of the receptacle. [See illustration below for suggested boom pattern]
3. The receiver pilot will comment on the difficulty of the task (responding to boom operator directions and stabilizing at each new boom position), and assign a Cooper-Harper rating.



Lessons Learned:

- None identified

AR Task Description Sheet

Title	A003 - Heavy Receiver Bow Wave Evaluation
Originator	USAF
Type	Flight
Purpose/ Utilization	Evaluate the effects of a large receiver aircraft bow wave on the tanker aircraft, to include auto-pilot effects, tanker HQ changes, and boom effects. Determine the maximum closure rate to the contact position for large bow wave receivers.
Instrumentation	Optional

Task Description:

1. The receiver will stabilize in the pre-contact position (astern position per to ATP 3.3.4.2).
2. The boom operator will clear the receiver to the contact position at the first (slowest) closure rate.
3. The receiver will move to the contact position at the desired closure rate.
4. The tanker pilot/co-pilot will closely monitor auto-pilot trim change inputs while guarding the controls.
5. The boom operator will monitor boom position changes due to receiver bow wave.
6. Once stabilized in the contact position, the receiver will be cleared back to the pre-contact position.
7. Steps 1-6 are repeated at increasing closure rates, up to maximum for the given tanker/receiver combination.

Lessons Learned:

- Large bow-wave receivers with fast closure rates can cause pitch changes in the tanker aircraft that cannot be compensated for quickly enough by the tanker auto-pilot. This results in the auto-pilot automatically disconnecting, and the tanker no longer maintaining a stable altitude, likely diving in front of the receiver aircraft.
- Instrumentation that provides closure rates, distance between aircraft, and auto-pilot pitch trim changes will allow for a detailed analysis. However, the evaluation can be performed without instrumentation, with qualitative comments only, and by estimating closure rates. This does result in a higher risk of incorrectly identifying the maximum closure rates, and more uncertainty about when the auto-pilot will disconnect.
- Safety: The tanker must be ready to instantly take control of the flight controls in the event of an auto-pilot disconnect, and initiate a breakaway maneuver. All flight crews in both aircraft should be prepared to quickly initiate a breakaway to avoid a mid-air collision.

AR Task Description Sheet

Title	A004 - Simulated Emergency Separation
Originator	USAF
Type	Flight
Purpose/ Utilization	The flying qualities of the tanker and receiver will be qualitatively and/or quantitatively evaluated during a simulated emergency separation.
Instrumentation	None Required – Position Information may be desired or useful.

Task Description:

1. The receiver will stabilize in the contact uncoupled position.
2. After approximately 10 seconds, the boom operator will initiate a simulated emergency separation by broadcasting "[Call sign of tanker] Breakaway, Breakaway, Breakaway" on the radio.
3. Upon hearing "Breakaway" the tanker pilot will advance the throttle to increase speed.
4. Upon hearing "Breakaway", the receiver pilot will use a combination of power reduction, speed brakes, and flight controls to maintain visual separation from the tanker, and maintain a safe position clear of the AR equipment.
5. Test is complete when the boom operator calls "Terminate simulated emergency separation".

Lessons Learned:

- Under some conditions, the tanker may also initiate a climb if excess thrust is available, and acceleration can be maintained.
- If testing is being performed at maximum airspeeds, the tanker may not be able to accelerate without exceeding structural airspeed limits. In this case, the tanker will climb as able.
- The ability of the tanker to accelerate to perform an emergency disconnect may limit its maximum aerial refueling speed.

AR Task Description Sheet

Title	A005 - Station Keeping - Uncoupled
Originator	USAF
Type	Flight
Purpose/ Utilization	The flying qualities of the tanker and receiver will be qualitatively and/or quantitatively evaluated during aerial refueling operations involving turns.
Instrumentation	None Required – Position Information may be desired or useful.

Task Description:

1. The receiver will stabilize in the contact-uncoupled position.
2. The receiver will verify he can see the PDI lights, and has adequate visual references to hold position.
3. The receiver will attempt to hold position as close to the center of the boom envelope as possible for two (2) minutes straight and level.
4. The tanker will initiate a turn and stabilize at a shallow (10-15 degrees) bank angle. The receiver will maintain position, and comment on HQ, excess thrust available, and difficulty of the task.
5. The tanker bank angle will be incrementally increased, up to the maximum bank angle, and the evaluation in step 4 repeated. Once the maximum sustainable bank angle is determined, perform that turn for at least 180 degrees, then return to straight and level flight.
6. After the turns and straight and level evaluation is complete, tanker and receiver will return to pre-contact position (astern position per ATP 3.3.4.2).
7. The receiver pilot will comment on the difficulty of the task, and assign a Cooper-Harper rating if desired.

Lessons Learned:

- None identified

AR Task Description Sheet

Title	A006 - Station Keeping - Coupled
Originator	USAF
Type	Flight
Purpose/ Utilization	The flying qualities of the tanker and receiver will be qualitatively and/or quantitatively evaluated during aerial refueling operations involving turns.
Instrumentation	None Required – Position Information may be desired or useful.

Task Description:

1. The receiver will stabilize in the contact position.
2. The boom operator will initiate a contact.
3. The receiver will verify he can see the PDI lights, and has adequate visual references to hold position.
4. The receiver will attempt to hold position as close to the center of the boom envelope as possible for two (2) minutes straight and level.
5. The tanker will initiate a turn and stabilize at a shallow (10-15 deg) bank angle. The receiver will maintain position, and comment on HQ, excess thrust available, and difficulty of the task.
6. The tanker bank angle will be incrementally increased, up to the maximum bank angle, and the evaluation in step 4 repeated. Once the maximum sustainable bank angle is determine, perform that turn for at least 180 degrees, then return to straight and level flight.
7. After the turns and straight and level evaluation is complete, tanker and receiver will disconnect.
8. The receiver/tanker pilots will comment on the difficulty of the task, and assign a Cooper-Harper rating if desired.

Lessons Learned:

- None identified

AR Task Description Sheet

Title	A007 - Contact – Disconnect Envelope Expansion
Originator	USAF
Type	Flight
Purpose/ Utilization	Determine/verify the boom contact and disconnect envelope.
Instrumentation	Boom Instrumentation • Boom Position (Elevation, Roll, Telescope) • Boom nozzle loads (Axial, Torsional, Lateral, vertical) • IRIG or GPS Time • Contact and Disconnect Status • Video

Task Description:

1. The receiver will stabilize in the contact position, middle of the boom envelope. (example: 30 elevation, 0 azimuth)
2. The boom operator will attempt a contact, followed by a disconnect. Observe that there is no binding of the boom nozzle, and boom loads are acceptable.
3. The boom operator will then direct the receiver to a new point in accordance with the safety build-up and test plan, and step 2 will be repeated. (An example list of point and sequence is listed below).
4. Working in a build-up manner, the contact and disconnect envelopes will be expanded to the maximum envelopes possible without nozzle cocking, binding, or unacceptable boom loading.

Example Test Point matrix for Contact and Disconnect (KC-10 Example)

Test Point	Roll (degrees)	Elevation (degrees)	Extension (feet)
1	5 Left	30	11-16
2	10 Left	30	11-16
3	15 Left	30	11-16
4	20 Left	30	11-16
5	25 Left	30	11-16
6	20 Right	35	11-16
7	25 Right	35	11-16
8	0	40	11-16
9	5 Left	40	11-16
10	10 Left	40	11-16
11	15 Left	40	11-16
12	20 Left	40	11-16
13	25 Left	40	11-16
14	25 Right	40	11-16
15	15 Right	25	11-16
16	20 Right	25	11-16
17	25 Right	25	11-16
18	0	20	11-16
19	5 Left	20	11-16
20	10 Left	20	11-16
21	15 Left	20	11-16
22	20 Left	20	11-16

AR Task Description Sheet

Test Point	Roll (degrees)	Elevation (degrees)	Extension (feet)
23	25 Left	20	11-16
24	25 right	20	11-16

- Repeat Positions 1 through 24 with Long Boom Extension (14 to 18 feet) and Short Boom Extension (6 to 10 feet).
- For the above example, contacts and disconnects are attempted at up to 10 degrees roll, while disconnects only are attempted above 10 degrees roll.

Lessons Learned:

- None identified

AR Task Description Sheet

Title	A008 - Boom Signal System Function
Originator	USAF
Type	Flight
Purpose/ Utilization	Verify the boom signal system functions properly in contact with a receiver, in all modes, and disconnects can be accomplished at all stations as expected.
Instrumentation	Boom Instrumentation • IRIG or GPS Time • Contact and Disconnect Status – (Including Ready/Free Flight/etc.) • Audio/Video

Task Description:

1. The receiver will stabilize in the contact position, middle of the boom envelope. (example: 30 elevation, 0 azimuth)
2. The boom operator will perform a contact, followed by a boom operator initiated disconnect.
   a. This step is repeated for each tanker crew position and method available to initiate a disconnect
3. The Boom operator will perform a contact, followed by a receiver pilot initiated disconnect.
   a. This step is repeated for each receiver crew position and method the receiver has to initiate a disconnect
4. Repeat steps 1-3 for all combinations of tanker and receiver override modes
5. Verify proper indications of the signal systems of both the tanker and receiver, as well as disconnects either working or not working as expected depending on tanker/receiver override configuration.

Lessons Learned:

- None identified

AR Task Description Sheet

Title	A009 - Disconnect Delay Evaluation
Originator	USAF
Type	Flight
Purpose/ Utilization	This testing is used to determine the system delay between the disconnect command and when the toggles actually release the boom nozzle. Some tanker systems, such as the KC-10, utilize a predictive system in the auto-disconnect system. This system needs to know how much delay is in the receiver system to accurately auto-disconnect at the correct time.
Instrumentation	Boom Instrumentation • Boom loads (Axial, Lateral, Vertical) • IRIG or GPS Time • Contact and Disconnect Status – (Including Ready/Free Flight/etc.) • Audio/Video

Task Description:

1. The receiver will stabilize in the contact position, middle of the boom envelope. (example: 30 elevation, 0 azimuth).
2. The boom operator will perform a contact.
3. The boom operator will pre-load the nozzle with 400-600 pounds of force.
    a. Boom loads can be in axial (retract), or a combination of axial and radial force.
4. The boom operator initiates a disconnect.

Lessons Learned:

- Disconnect delay is determined by comparing the time the disconnect was commanded with the time the pre-load on the nozzle was relieved.

AR Task Description Sheet

Title	A010 - Slipway Assisted Contacts
Originator	USAF
Type	Flight
Purpose/ Utilization	This testing ensures the slipway properly aligns the nozzle when attempting to make a contact.
Instrumentation	Boom Instrumentation • Boom loads (Axial, Lateral, Vertical) • IRIG or GPS Time • Contact and Disconnect Status – (Including Ready/Free Flight/etc.) • Audio/Video

Task Description:

1. The receiver will stabilize in the contact position, middle of the boom envelope. (example: 30 elevation, 0 azimuth).
2. The boom operator will place the boom nozzle near the leading edge of the slipway, and apply down force sufficient to tilt the nozzle at the ball joint.
3. The boom operator will then extend the boom while maintaining down pressure, allowing the slipway to guide the boom into the receptacle.

This test can also be completed with lateral pressure, or a combination of lateral and vertical pressure on the boom nozzle. The boom operator will observe the boom nozzle path to the receptacle, and make note of any slipway characteristics that cause the boom nozzle to hang on any part of the slipway, or not properly align with the receptacle bore.

Lessons Learned:

- None identified

AR Task Description Sheet

Title	A011 - Fuel Transfer
Originator	USAF
Type	Flight
Purpose/ Utilization	This testing is used to evaluate the fuel transfer characteristics of the receiver.
Instrumentation	Boom Instrumentation • Boom loads (Axial, Lateral, Vertical) • Fuel Flow Through Nozzle • Fuel Pressure at Nozzle • Fuel Pressure at Pump Outlets • Receiver Fuel Pressure (AR Manifold as minimum, possibly more) • IRIG or GPS Time • Contact and Disconnect Status – (Including Ready/Free Flight/Etc) • Audio/Video

Task Description:

1. The tanker will make contact with the receiver.
2. The tanker will activate one or more pumps to begin transferring fuel to the receiver, stopping when the receiver is full, or the desired test parameters are reached.
3. Repeat as required to increase the number of pumps, evaluate different fuel system configurations, and different refueling modes.
4. The receiver fuel system is also monitored to verify there are no surges, pressure spikes, or abnormal behaviors, and that all valves sequence as expected during refueling to include Top-Off.

Lessons Learned:

- Some aircraft have different refueling modes that sequence the valves on the fuel tanks differently. Each of these modes should be evaluated.
- Several fuel system configurations are normally evaluated (for systems with external stores or expandable fuel systems). The base system (no externals), and the configuration that has been identified as the worst case (normally multiple external fuel tanks).
- Starting fuel conditions must be chosen to allow the full range of valve sequencing without operating below safe fuel limits.
- Pressure transducer sampling rates should be adequate to capture anticipated transient events. A sampling rate of 400 Hz has been shown to adequately capture high pressure surge spikes resulting from pump startups, valve closures, and flowing disconnects.

AR Task Description Sheet

Title	A012 - Pressure Disconnect Evaluation
Originator	USAF
Type	Flight
Purpose/ Utilization	This testing is used to evaluate the behavior of the receiver fuel system as the system approaches a full state, and evaluates the behavior of the pressure disconnect system.
Instrumentation	Boom Instrumentation • Fuel Flow Through Nozzle • Fuel Pressure at Nozzle • Fuel Pressure at Pump Outlets • Receiver Fuel Pressure (AR Manifold as minimum, possibly more) • IRIG or GPS Time • Contact and Disconnect Status – (Including Ready/Free Flight/etc.) • Audio/Video

Task Description:

1. The tanker will make contact with the receiver.
2. The tanker will activate one or more AR pumps to begin transferring fuel to the receiver, continuing to refuel until a pressure disconnect occurs, or a "no flow" state has been reached, and the receiver is taking fuel at the rate it is being burned.
3. Repeat as required to increase the number of AR pumps, evaluate different fuel system configurations, and different refueling modes.

Lessons Learned:

- Some aircraft have different refueling modes that sequence the valves on the fuel tanks differently. Each of these modes should be evaluated.
- Several fuel system configurations are normally evaluated (for systems with external stores or expandable fuel systems). The base system (no externals), and the configuration that has been identified as the worst case (normally multiple external fuel tanks).
- If a pressure disconnect occurs, receiver fuel pressure data can be analyzed to determine that the pressure disconnect occurred at predicted values and response time delay.
- If a pressure disconnect does not occur, the receiver fuel pressure data can be analyzed to show that the receiver pressure did not meet the criteria (tip pressure and time delay) to initiate a pressure disconnect.

AR Task Description Sheet

Title	A013 - Pressure Refueling Evaluation (Stiff Boom Refueling)
Originator	USAF
Type	Flight
Purpose/ Utilization	Demonstrate that the receiver is capable of pressure refueling when the receiver and tanker are unable to achieve a normal contact and engage the receptacle toggles to the boom nozzle.
Instrumentation	Boom Instrumentation • Fuel Flow Through Nozzle • Fuel Pressure at Nozzle • Fuel Pressure at Pump Outlets • Receiver Fuel Pressure (AR Manifold as minimum, possibly more) • IRIG or GPS Time • Contact and Disconnect Status – (Including Ready/Free Flight/Etc) • Audio/Video

Task Description:

1. Tanker signal system: OVERRIDE.
2. The receiver will disable its ability to latch upon contact, and place the AR system into OVERRIDE.
3. The receiver will move to the contact position and stabilize.
4. The boom operator will place the boom nozzle in the receptacle. Observe that there is no CONTACT indication.
5. The boom operator will use the boom extension control to maintain positive pressure (pressure seal) on the nozzle and receptacle while the tanker AR pumps are energized via the emergency contact made switch, and fuel is transferred.
6. Maintain fuel flow until specified amount of fuel has been transferred (several thousand pounds, nominal).
7. The boom operator will initiate a disconnect (de-energizing the AR pumps), then retract the boom from the receptacle, and clear the receiver back to pre-contact.

Lessons Learned:

- None identified

AR Task Description Sheet

Title	A014 - Independent Disconnect
Originator	USAF
Type	Flight
Purpose/ Utilization	Demonstrate that the boom nozzle releases the receptacle when the tanker boom operator initiates an independent disconnect, and the boom stresses are inside allowable limits.
Instrumentation	Boom Instrumentation • IRIG or GPS Time • Contact and Disconnect Status – (Including Ready/Free Flight/etc.) • Audio/Video

Task Description:

1. The boom operator will verify that the Independent Disconnect System is fully functional.
2. The receiver aircraft will place the signal coil in OVERRIDE mode.
3. The receiver will establish a normal contact with the tanker.
4. The aerial refueling/boom operator will perform an independent disconnect. Observe that the boom nozzle is released from the receiver receptacle.

Alternate procedures for receivers without OVERRIDE capability:

1. Establish contact.
2. Receiver: Pull AR Signal Amplifier C/B.
3. Initiate normal disconnect from tanker. Observe no disconnect.
4. Initiate IDS disconnect from tanker. Observe disconnect and boom free of receptacle.

Alternate procedures for receivers without OVERRIDE capability:

1. Establish contact.
2. Tanker: Pull Signal Amp Circuit Breaker (Inhibits disconnect signal being sent).
3. Initiate IDS disconnect from tanker (within 3 sec of C/B pulled).
4. Observe disconnect and boom free of receptacle.

Lessons Learned:

- None identified

AR Task Description Sheet

Title	A015 - Tension Disconnect
Originator	USAF
Type	Flight
Purpose/ Utilization	Demonstrate that the receiver receptacle releases the boom nozzle when the tanker boom length is exceeded, and the boom stresses are inside allowable limits.
Instrumentation	Boom Instrumentation • IRIG or GPS Time • Contact and Disconnect Status – (Including Ready/Free Flight/etc.) • Audio/Video

Task Description:

1. The tanker and receiver will establish a normal contact.
2. Once stabilized, the receiver will reduce power to pull away from the tanker at approximately 1 ft/sec.
3. Once the boom has been fully extended, the toggles in the receptacle should release the boom nozzle.
4. Boom loads will be monitored on the tanker to evaluate tension disconnect loads on the boom and nozzle. (Loads at disconnect for in-spec systems should be 4800-9411 pounds)
5. Steps 1-4 will be repeated until loads at disconnect are consistent.

Lessons Learned:

- The desired outcome is for the receiver to slowly pull free from the tanker nozzle at a minimum rate, eliminating impact loads, and almost “settling” at the maximum boom extension prior to disconnecting. This closely matches the criteria for lab/ground testing of the receptacle system. Some smaller receivers may need to use speedbrakes or faster rates separation rates in order to avoid settling on the end of the boom and ending up in a towing condition.
- Satisfactory results have been obtained using a criterion of at least 3 consistent tension disconnect loads using nominal fall back rates while maintaining 30 degrees elevation, 0 degrees azimuth.
- If marginal data is observed or appears temperatures could influence capabilities, cold soaking may be required.

AR Task Description Sheet

Title	A016 - Lighting Evaluation – Day/Dusk/Night
Originator	USAF
Type	Flight
Purpose/ Utilization	Evaluate the ability of the receiver to view visual references and PDI lighting on the tanker, and optimum tanker lighting settings.
Instrumentation	Boom Instrumentation • IRIG or GPS Time • Contact and Disconnect Status – (Including Ready/Free Flight/etc.) • Audio/Video

Task Description:

1. During day evaluations, the performance of the lights when viewing into the sun or on top of an overcast deck should be tested.
2. Dusk evaluations will be performed as a build-up to night evaluations, and to familiarize the receiver pilot with all lighting and visual references.
3. The receiver aircraft and tanker will configure for night AR, including opening the receptacle and setting lights for any “AR” settings. During dusk, this may include setting all lighting to 100% intensity, and adjusting as lighting conditions transition into night.
4. The receiver will approach the tanker and stabilize aft of pre-contact (roughly ¼ mile). Receiver pilot will observe the tanker lighting, noting any areas of concern, and asking the tanker to adjust any lights as required.
5. The receiver will repeat step 3 at the pre-contact position.
6. The receiver will then move into the contact position, uncoupled, and evaluate the tanker lighting. Before making any changes to the lighting configuration, the boom operator will direct the receiver to move back to the pre-contact position to avoid any light adjustments while the receiver is in contact position.
7. Receiver pilot will direct boom operator to adjust tanker lighting to determine optimum settings.
8. NVG testing, if applicable, would be conducted in the same flow as items 3-7 with lights configured appropriately.

Lessons Learned:

- None identified

AR Task Description Sheet

Title	A017 - Lighting Evaluation – Degraded Lighting
Originator	USAF
Type	Flight
Purpose/ Utilization	Evaluate various degraded lighting configurations on the tanker and receiver to determine which are acceptable, which are emergency only, and which are unacceptable.
Instrumentation	Boom Instrumentation • IRIG or GPS Time • Contact and Disconnect Status – (Including Ready/Free Flight/etc.) • Audio/Video

Task Description:

1. Beginning with the optimum lighting settings determined in initial night testing, a matrix containing each possible combination of tanker and receiver lighting failures will be constructed.
2. The tanker and receiver will configure for one of the degraded lighting modes.
3. The receiver will approach the tanker and stabilize at pre-contact. Boom operator will observe the receiver lighting, noting any areas of concern, and asking the receiver to adjust any remaining lights as required.
4. The receiver will then move into the contact position, uncoupled, and the boom operator will evaluate the receiver lighting. Observe visibility of the receiver leading edges or fuselage, receptacle and slipway illumination, lead-in lines, and perception of surface contours.
5. Before making any changes to the lighting configuration, the boom operator will have the receiver move back to the per-contact position.
6. Receiver pilot will direct boom operator to adjust tanker lighting to determine optimum settings for each degraded lighting condition.

Repeat steps 2-6 for each degraded lighting configuration.

Lessons Learned:

- The inclusion of degraded lighting testing will allow clearances to include degraded lighting configurations that are still acceptable for normal use. This reduces the impact of a failed light on training and routine operational refueling.
- While it is up to the crew to determine if they wish to attempt refueling in an emergency situation, having previously tested degraded lighting to determine the feasibility of different lighting configurations can allow the crew to better balance the risk of attempting degraded lighting refueling with other possible options.

Appendix B
Probe Drogue AR Task Sheets
(Detailed Methods)

AR Task Description Sheet

Title	B001 - Drogue Fit and Function Check
Originator	USAF
Type	Ground
Purpose/ Utilization	To verify compatibility of the Receiver probe with the Tanker coupling and basket
Instrumentation	

Task Description:

1. Receiver aircraft is located behind the tanker aircraft at a distance commensurate with the length of the Drogue system hose.
2. Multiple AGE Stands and restraint for the hose are required to minimize hose movement during pressurization
3. Perform an operationally representative ground connection of the tanker drogue system and a receiver probe systems to validate latching, basket clearances, and safe fuel flow when the drogue system is pressurized with fuel.
4. When Tanker is flowing fuel record pressures and any leakage

Lessons Learned:

- None identified

AR Task Description Sheet

Title	B002 - Drogue Stability – Receiver Influences
Originator	USN
Type	Flight
Purpose/ Utilization	
Instrumentation	• Video/Audio from Tanker • Video/Audio from Receiver

Task Description:

1. Fully extend the tanker refueling hose. (Note: Drogue stability during hose extension and retraction should be assessed during tanker qualification tests, and is not necessarily assessed at this time.)
2. Receiver slowly moves from the pre-contact to the contact position to assess bow wave effects on the drogue stability.
3. Repeat steps at various combinations of airspeed and altitude to assess the entire refueling envelope.

Lessons Learned:

- None identified

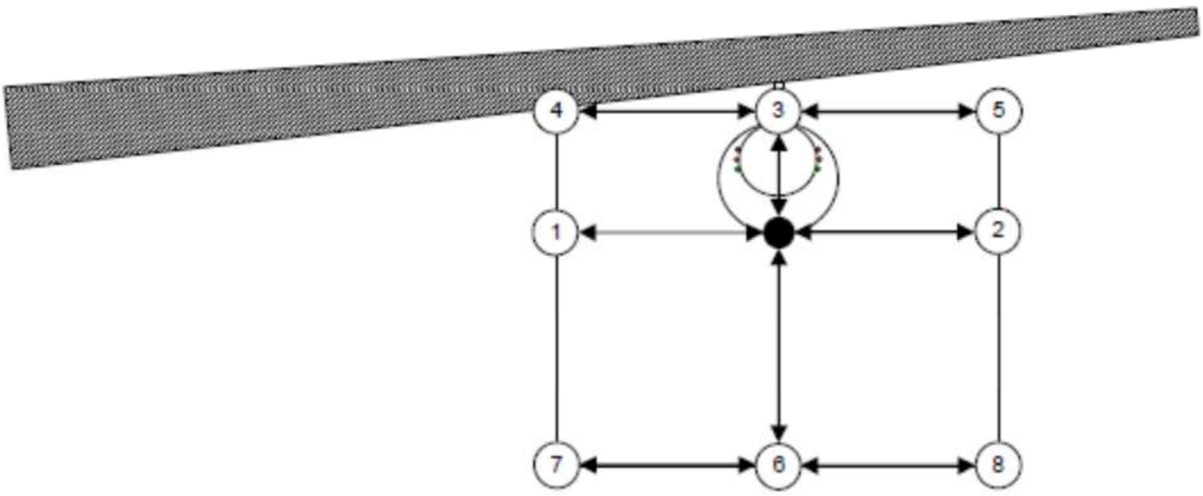
AR Task Description Sheet

Title	B003 - Wake Survey
Originator	USAF
Type	Flight
Purpose/ Utilization	Establish the extent of the safe refueling area behind each station, evaluating the flow field of the tanker and any possible interactions that would negatively impact safety, or the ability to refuel.
Instrumentation	• Video/Audio from Tanker • Video/Audio from Receiver

Task Description:

1. Perform the initial wake survey box assessment with the hose extended and the receiver in the pre-contact position (astern positions per ATP 3.3.4.2). The pilot should cautiously explore the refueling volume in the pre-contact and in the contact position.

This Box Assessment Sequence is illustrated in the figure below (for a typical Wing Station) and described in the table that follows.



Step	Wing Stations	Centerline Station
1	From the pre-contact position, cautiously move inboard until significant disturbances (Level III) are encountered.	From the pre-contact positions, cautiously move left until significant disturbances (Level III) are encountered. If significant disturbances are not encountered, stop once well outside the refueling box.
2	Return to the pre-contact position and cautiously move outboard until significant disturbances (Level III) are encountered. If significant disturbances are not encountered, stop once clear of the wingtip.	Return to the pre-contact position and cautiously move right until significant disturbances (Level III) are encountered. If significant disturbances are not encountered, stop once well outside the refueling box.
3	Return to the pre-contact position and cautiously move up until significant disturbances (Level III) are encountered.	Return to the pre-contact position and cautiously move up until significant disturbances (Level III) are encountered.

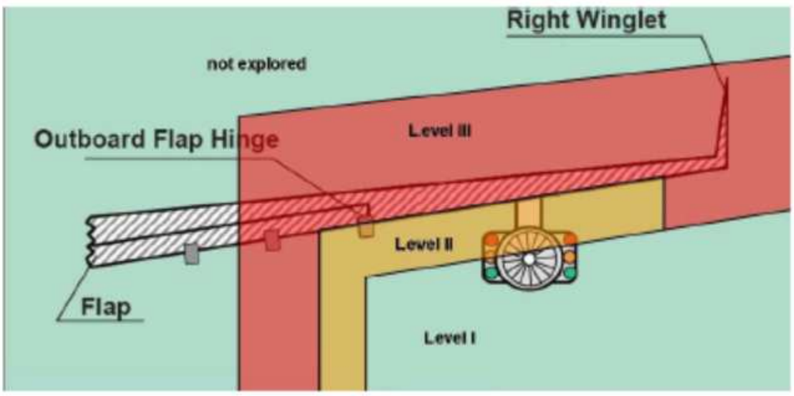
AR Task Description Sheet

Step	Wing Stations	Centerline Station
4	Move down until the aerodynamic disturbances cease (still above the pre-contact position) and cautiously move inboard until significant (Level III) are encountered.	Move down until the aerodynamic disturbances cease (still above the pre-contact position) and cautiously move left until significant (Level III) are encountered. If significant disturbances are not encountered, stop once well outside the refueling box.
5	Return to the centerline of the pod (remaining above the pre-contact position) and cautiously move outboard until significant disturbances (Level III) are encountered. If significant disturbances are not encountered, stop once clear of the wingtip.	Return to the centerline of the fuselage (remaining above the pre-contact position) and cautiously move right until significant disturbances (Level III) are encountered. If significant disturbances are not encountered, stop once well outside the refueling box.
6	Return to the pre-contact position and move down to the bottom of the refueling box.	Return to the pre-contact position and move down to the bottom of the refueling box.
7	Cautiously move inboard until significant disturbances (Level III) are encountered.	Cautiously move left until significant disturbances (Level III) are encountered. If significant disturbances are not encountered, stop once well outside the refueling box.
8	Return to the centerline of the pod (remaining below the pre-contact position) and cautiously move outboard until significant disturbances (Level III) are encountered. If significant disturbances are not encountered, stop once clear of the wingtip.	Return to the centerline of the fuselage (remaining below the pre-contact position) and cautiously move right until significant disturbances (Level III) are encountered. If significant disturbances are not encountered, stop once well outside the refueling box.

The above sequence should be repeated from the approximate contact position and the maximum forward refueling position.

Lessons Learned:

- Post flight, the pilot can provide an illustration of the various regions explored using the following definitions (see figure below for an example).
  - Level I – No aerodynamic disturbances noticeable.
  - Level II – Light aerodynamic disturbances including vibrations in the fin and/or wing tip.
  - Level III – Significant disturbances including heavy vibration, drift forward or sideways or induced roll.



AR Task Description Sheet

Title	B004 - HQ Evaluation – Observation/Astern/Contact
Originator	USAF
Type	Flight
Purpose/ Utilization	Handling qualities assessments will be performed to establish HQ ratings, for the various phases that make up an AR operation. These assessments will also provide a controlled work-up to the first drogue engagement at each flight condition.
Instrumentation	• Video/Audio from Tanker • Video/Audio from Receiver

Task Description:

1. Begin at the observation position and evaluate HQ ratings
    - Maintain tanker echelon left position laterally, vertically and longitudinally within ±5ft / ±1.5m (Desired) or ±10ft / ±3m (Adequate).
2. Starting from the observation position (on tanker's wing), assume the pre-contact/astern position (approximately 5ft / 1.5m behind basket) and evaluate HQ ratings.
    - Maintain position laterally and vertically within half a drogue radius (Desired) or one drogue radius (Adequate).
    - Maintain position longitudinally within ±2ft / ±0.6m (Desired) or ±5ft / ±1.5m (Adequate).
3. Starting from the pre-contact position (5ft / 1.5m behind basket) perform a contact at operationally representative rates. Make contact having maintained the aircraft position relative to the drogue center. Assess HQ qualitatively and note number of successful and unsuccessful contacts.
    - Maintain position laterally and vertically within half a drogue radius (Desired) or one drogue radius (Adequate).
    - Maintain position longitudinally within ±5ft / ±1.5m (Desired) or ±10ft / ±3m (Adequate) of the nominal, hose refueling range, mid-position.
4. Maintaining contact position relative to the nominal hose position in Straight and Level flight and in turns, evaluate HQ ratings.
    - Maintain position laterally and vertically within ±2ft / ±0.6m (Desired) or ±5ft / ±1.5m (Adequate);
    - Maintain position longitudinally within ±5ft / ±1.5m (Desired) or ±10ft / ±3m (Adequate) of the nominal, hose refueling range, mid-position.

Lessons Learned:

- None identified

AR Task Description Sheet

Title	B005 - Operational Contact
Originator	USAF
Type	Flight
Purpose/ Utilization	Starting from the Observation Position, the pilot should attempt to engage the drogue within the desired time.
Instrumentation	• Video/Audio from Tanker • Video/Audio from Receiver

Task Description:

1. Perform an operationally representative transition from the observation position to contact and fuel transfer.
2. Evaluate contacts at slow (1-3 ft/s), medium (3-5 ft/s), and firm (5-9 ft/s) closure rates.

The pilot should give notice when he leaves the observation position as well as when he achieves a successful hook-up. This will allow the time taken for the hook-up to be determined.

Lessons Learned:

- None identified

AR Task Description Sheet

Title	B006 - Probe Loads
Originator	USAF
Type	Flight
Purpose/ Utilization	Determine the loads experienced by the receiver probe during contact at various closure rates.
Instrumentation	• Instrumented probe • Closure rate (GPS, video analysis, etc.) • Video/Audio from Tanker, Receiver or chase aircraft

Task Description:

1. Perform an operationally representative transition from the observation position to contact and fuel transfer.
2. Evaluate probe loads at slow (1-3 ft/s), medium (3-5 ft/s), and firm (5-9 ft/s) closure rates.

The pilot should give notice when he leaves the observation position as well as when he achieves a successful hook-up. This will allow the time taken for the hook-up to be determined.

Lessons Learned:

- None identified

AR Task Description Sheet

Title	B007 - Fuel Transfer
Originator	USAF
Type	Flight
Purpose/ Utilization	Evaluate the fuel pressures and valve sequencing on the receiver during aerial refueling.
Instrumentation	• Fuel Pressure and Flow Rates (Receiver) • Fuel Pressure and Flow Rates (Tanker) • Valve positions (Receiver) • IRIG Time • Video/Audio from Tanker • Video/Audio from Receiver

Task Description:

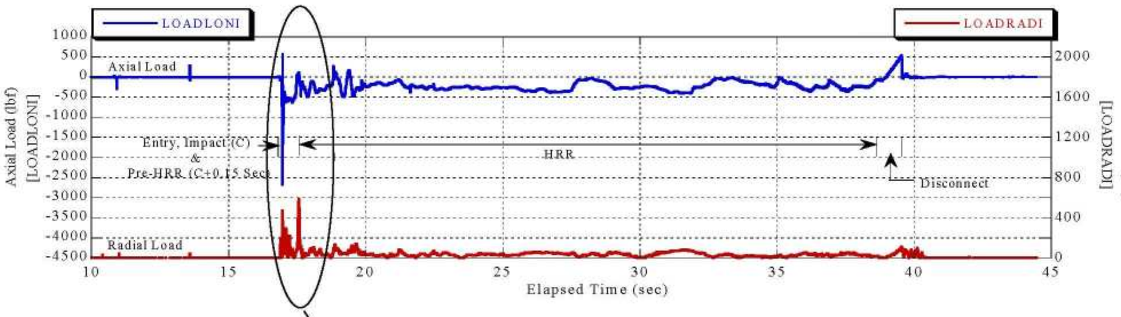
1. The receiver will make contact with the tanker.
2. The tanker will activate one or more pumps to begin transferring fuel to the receiver, stopping when the receiver is full, or the desired test parameters are reached.
3. Repeat as required to increase the number of pumps, evaluate different fuel system configurations, and different refueling modes.
4. The receiver fuel system is also monitored to verify there are no surges, pressure spikes, or abnormal behaviors, and that all valves sequence as expected during refueling to include Top-Off.

Lessons Learned:

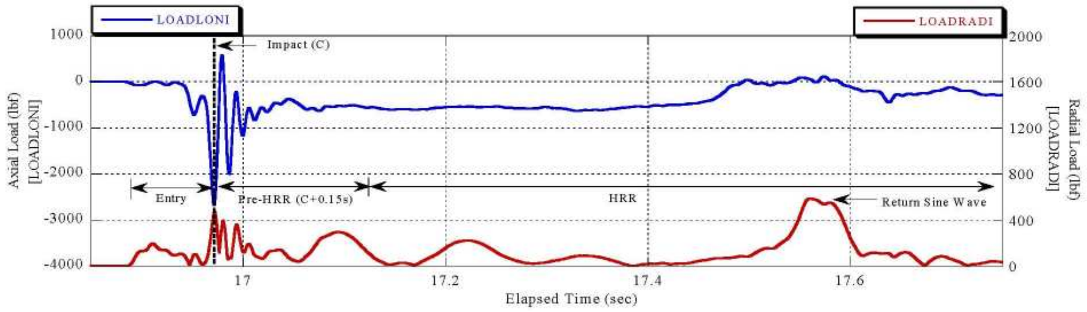
- Pressure transducer sampling rates should be adequate to capture anticipated transient events. A sampling rate of 400 Hz has been shown to adequately capture high pressure surge spikes resulting from pump startups, valve closures, and flowing disconnects.

Appendix C
Examples (Data, Methods, Case Studies)

SAMPLE AIR REFUELING TEST DATA

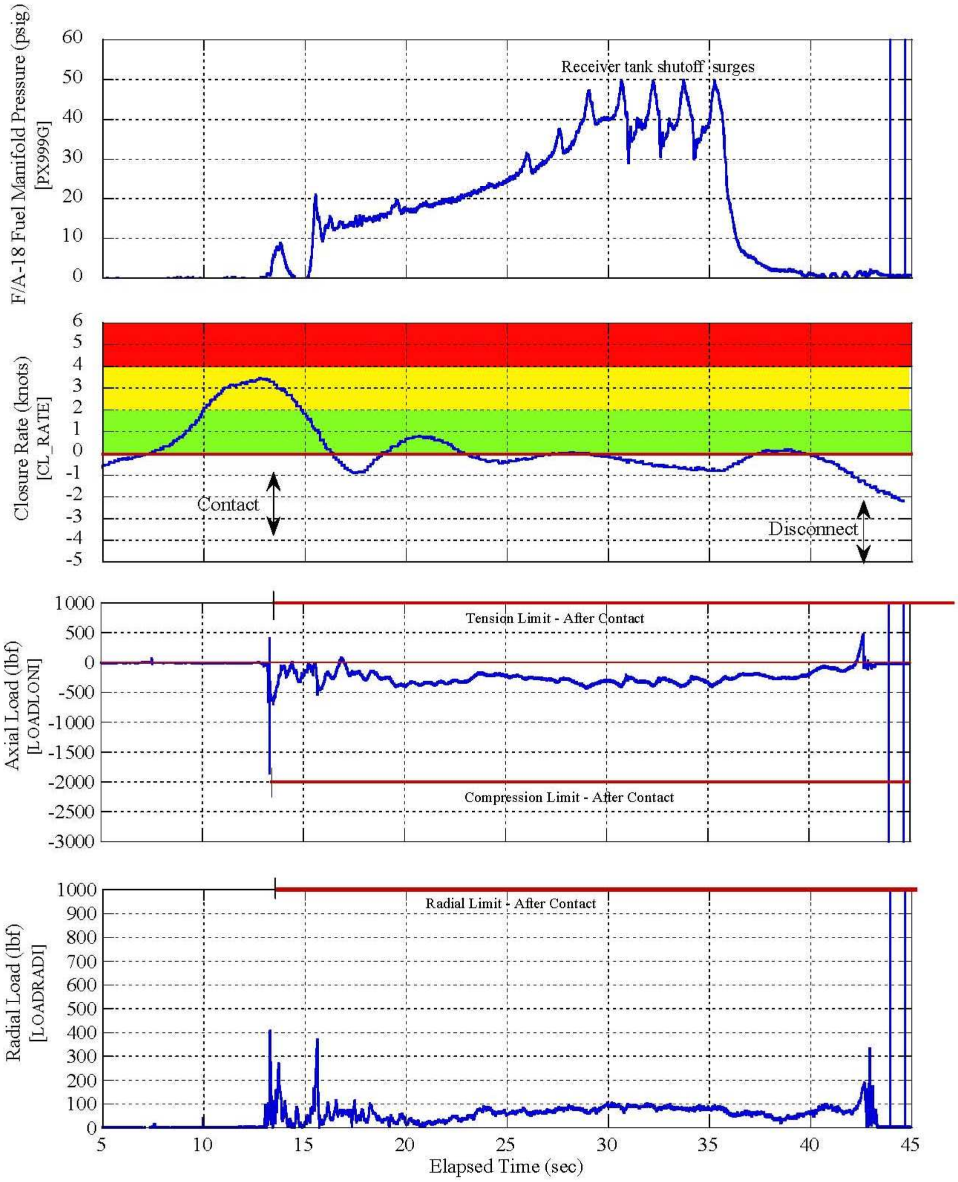


Engagement Characteristics / Definitions

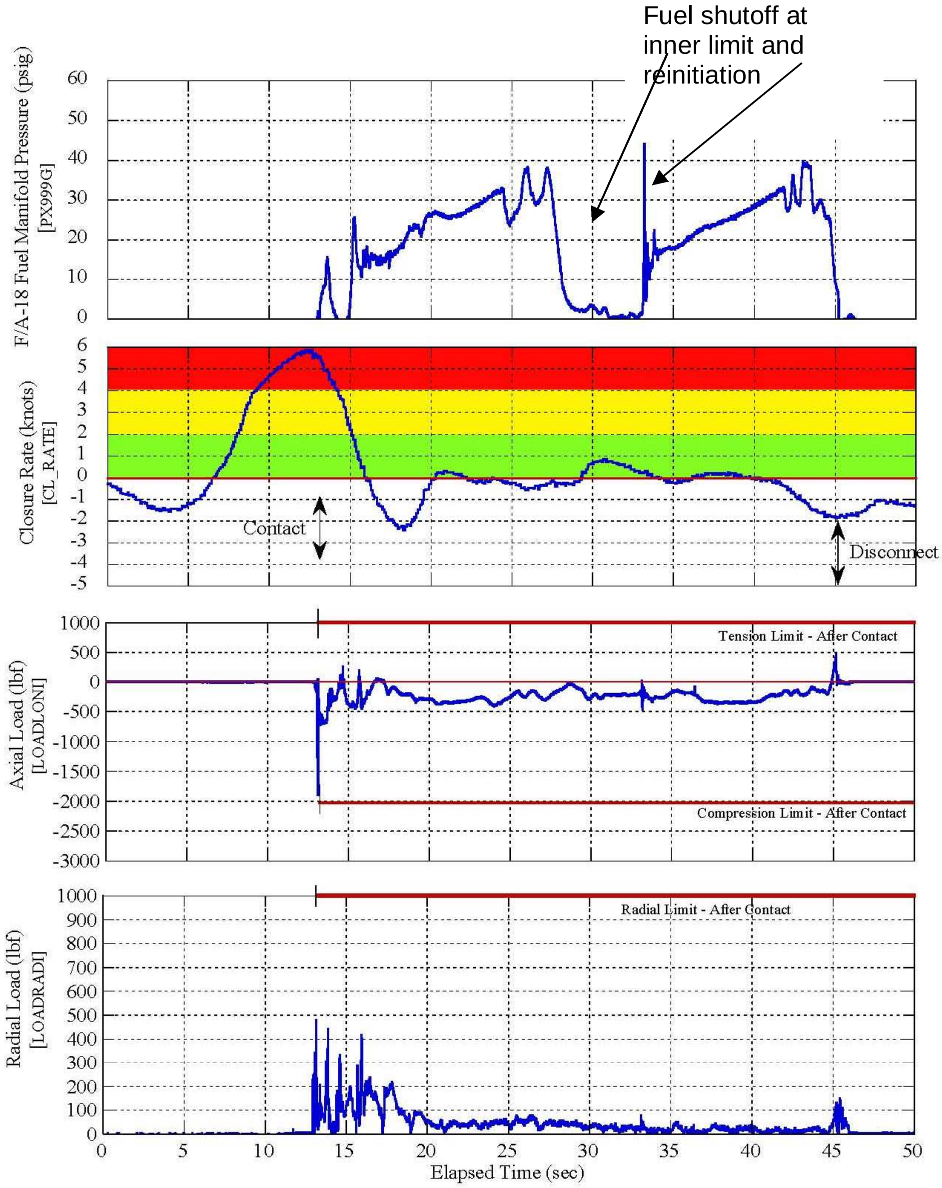


Engagement Characteristics / Definitions (Expanded View)

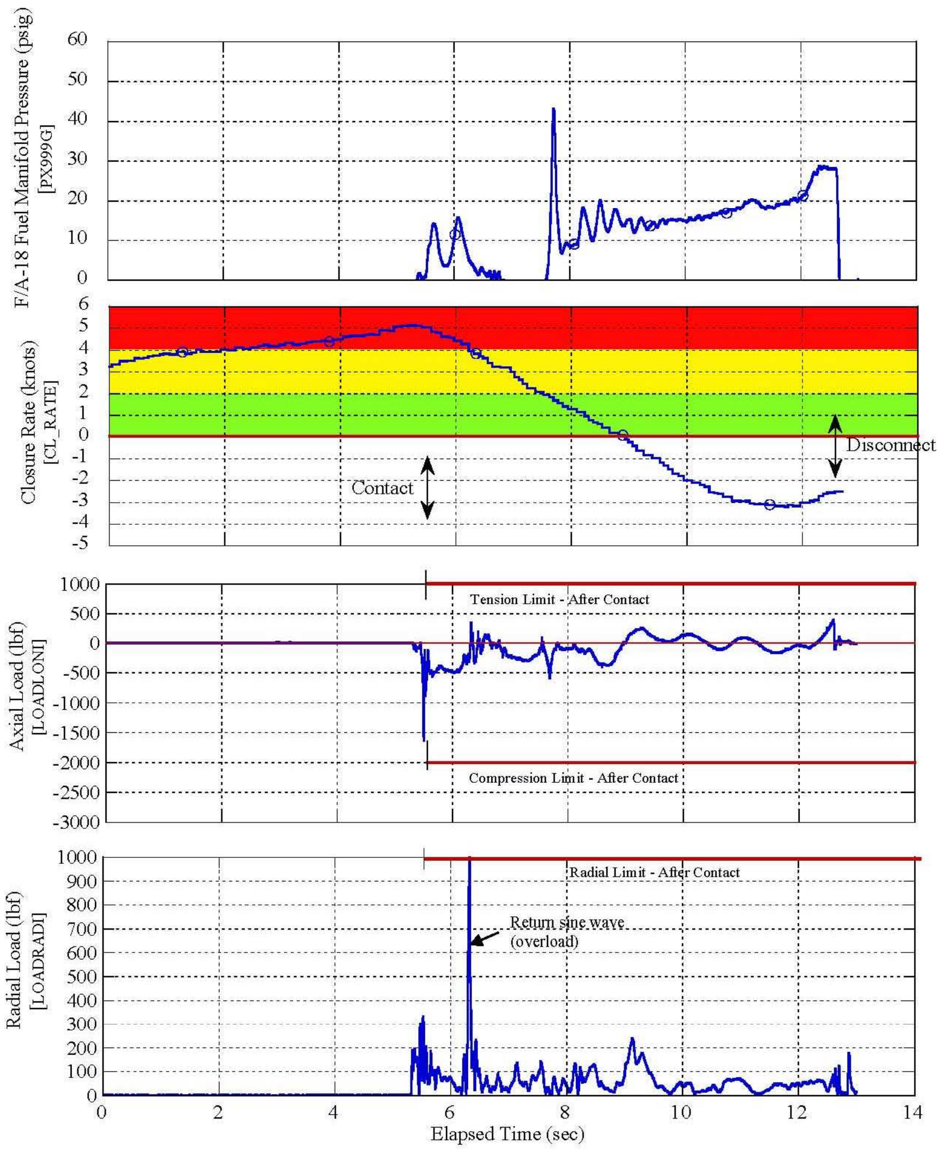
SAMPLE AIR REFUELING TEST DATA



SAMPLE AIR REFUELING TEST DATA

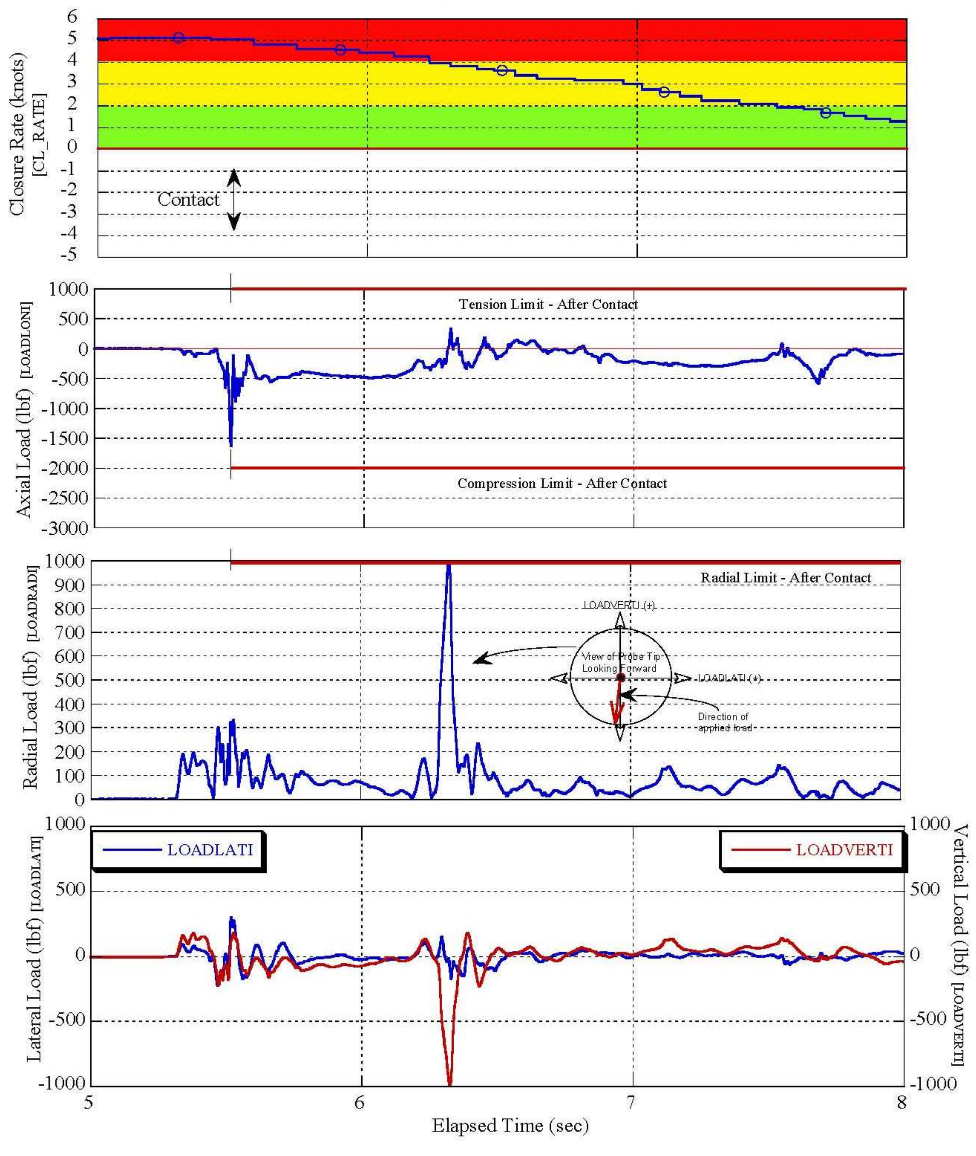


SAMPLE AIR REFUELING TEST DATA



OVERLOAD

SAMPLE AIR REFUELING TEST DATA



OVERLOAD EXPANDED VIEW