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Air-to-Air Refuelling Flight Plan

An Assessment

Joint Air Power Competence Centre

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FROM:

The Executive Director of the Joint Air Power Competence Centre (JAPCC)

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Air-to-Air Refuelling Flight Plan – An Assessment

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Joint Air Power Competence Centre

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I am pleased to release the "Air-to-Air Refuelling Flight Plan" document, comprising an overall assessment of current Air-to-Air Refuelling (AAR) capabilities within NATO and building a joint perspective inside future requirements and development. This Flight Plan is part of a more ambitious project titled "Enhancing NATO AAR Interoperability," which has been in development since 2004 and aims to better utilise a limited resource – in this case AAR capability – providing formal guidance on interoperability and standardisation issues.

This document will also present a catalogue of current and future NATO AAR assets, examining a broad range of issues likely to impact future Alliance AAR planning and execution. It endeavours to increase awareness and, ultimately, standardisation and interoperability across the Alliance.

It cannot be ignored that AAR is a critical enabler for achieving the effects necessary to support NATO's stated Level of Ambition. For this reason, a clear understanding of AAR capability gaps and interoperability limitations is necessary before key NATO decision-makers can develop a strategy to provide the Alliance with the required AAR capability. This AAR Flight Plan provides NATO agencies and member Nations a means by which to stimulate constructive debate on critical issues, and contains advice to enhance strategic decision-making during AAR procurement.

The opinions and recommendations expressed in this document are the JAPCC's, and are not approved positions by NATO or its member nations. Any errors or omissions in this paper are the responsibility of the JAPCC. The JAPCC encourages reader comments and feedback in order to improve the document contents. For further information, please contact the JAPCC's AAR Project director, Air Commodore Jan van Hoof via e-mail at vanhoof@japcc.de, or through our Subject Matter Experts assigned to the AAR Coordination Cell at aar@japcc.de.

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Four Royal Danish Air Force F-16s in formation behind a 100th ARW KC-135 over Denmark 08 Dec 09.

CHAPTER 1

Introduction

1.1 Background

1.1.1 During the Cold War the requirement for AAR was limited to the support of long-range strategic forces as many NATO Nations, certainly the European members, worked under the assumption that their respective Armed Forces would operate very close to home. Post the end of the Cold War, NATO has been increasingly engaged in Expeditionary Operations (EO), and in training and exercises, beyond its traditional North Atlantic geographical domain. As a consequence there has been an increased requirement for AAR in order to satisfy a greater number of receivers at extended ranges. However as nations purchased new receiver-capable aircraft there was no corresponding increase in AAR assets. In 2002, this overall shortfall of AAR was recognised by NATO in the Prague Capabilities Commitment (PCC).

1.1.2 Current NATO policy holds individual nations ultimately responsible for the training, maintenance and deployment of their forces to and from an Area of Operations. AAR is critical to both the success of the deployment and any concurrent operations; to deploy the forces in a timely manner, in minimising both the logistical footprint and the chances of ground aborts during transits, and in maintaining a high tempo of operations. With the challenges associated with EO, AAR's role as a Force Multiplier has become increasingly important.

1.2 Aim

The AAR Flight Plan is a source document aimed at informing the wider NATO Alliance that establishes guidelines for improving AAR interoperability between nations. This Flight Plan reviews current NATO AAR capabilities, identifies problems in standardisation and discusses future considerations. This document will also present a catalogue of current and future NATO AAR assets, examining a broad range of issues likely to impact future Alliance AAR planning and execution. It endeavours to increase awareness and, ultimately, standardisation and interoperability across the Alliance.

1.3 Scope

The AAR Flight Plan combines studies previously carried out by the JAPCC, and updates the findings of those studies. The equipment, resources and systems covered include all AAR aircraft, and the systems that support them, including mission planning, basing and training. Issues are examined and discussed under the categories of effects, resources, future requirements, future employment concepts, additional roles and steps taken to enhance AAR Interoperability. However this document is by no means prescriptive and does not serve as a panacea to address all issues.

1.4 Assumptions and Limitations

1.4.1 This Flight Plan is based on the following assumptions:

1.4.1.1 Tanker Aircraft are national assets, under national command and control. This includes civilian tankers contracted by a nation or nations.

1.4.1.2 NATO has no AAR assets of its own, but national assets can be provided for the benefit of NATO upon national approval.

1.4.1.3 During crises and conflicts, Transfer of Authority (TOA) of AAR assets will follow the NATO generation of forces procedure.

1.4.1.4 Agreements between providers and receivers are driven by bilateral Memoranda of Understanding (MOU). Legal, financial, technical and operational specifics must be coordinated between nations for each combination of tankers and receivers, even when operating as NATO TOA assets.

1.4.1.5 NATO's capability to influence national policy and shape current and future AAR issues is limited. NATO influence is restricted to the NATO Defence Planning Process (NDPP), where NATO, through its mechanism for Defence Requirements Review (DRR), can influence (or encourage) nations to prioritise their investments. Alliance priorities and Standardisation Agreements (STANAGs) are considerations, but nations acquire and operate weapon systems on the basis of national interests and priorities.

1.5 Authority

The authors of this Flight Plan are AAR Subject Matter Experts (SMEs) working in the NATO AAR Coordination Cell (AARCC), Combat Support Branch, at the JAPCC. This AAR office was initially established in 2001 as a result of MCM 217(98)[1]. Manpower constraints within the NATO Commands resulted in the NATO AARCC being formed within the Reaction Force Air Staff (RFAS) at Kalkar. In 2004, the functions of RFAS were no longer relevant in the newly transforming NATO structure, and therefore, it was disestablished. In its place, the JAPCC was formed in 2005 with an office consisting of AAR SMEs, based on the model of the AARCC. Additionally, JAPCC confirmed that it would continue carrying out the functions of the AARCC and accordingly submitted to ACT a revision of MCM 217[2]. Furthermore, as the AAR SMEs were already in post, the JAPCC decided that one of its first transformation projects delivered to HQ Allied Command Transformation (ACT) would be "Enhancing NATO AAR Interoperability". This project is covered in detail in Chapter 7 of this Flight Plan, but in summary, it is a 10 year project improving NATO interoperability by developing Allied Tactical Publications (ATPs) and STANAGs. The JAPCC AAR SMEs continue to advise NATO on a wide range of AAR matters, and the office remains the only one in NATO dedicated to AAR issues and staffed by AAR SMEs.

1.6 Classification

This report is not classified. Information from classified sources and references are not cited or referenced in this report. Discussions, findings, and recommendations are not based on classified information. Reference to classified sources may be required to support more detailed discussions and recommendations that go beyond the information, discussion and recommendations presented here.

1. MCM 217(98) NATO AAR Strategic Concept recommended the setting up of an office in NATO that would be responsible for staffing all AAR issues. The office would be called the AAR Coordination Cell and would be manned by 3 AAR SMEs.
2. MCM 217(Revised 2006). Submitted to ACT, but as yet it has not been incorporated. See Chapter 7.

A KC-135 refuels a B-52 Stratofortress, extending the receiver's own capabilities.

CHAPTER II

The Objective of AAR

2.1 Purpose of AAR

The objective of AAR operations is to enhance combat effectiveness by extending the range, payload and endurance of receiver aircraft. It allows Air Power to be projected over greater distances or concentrated where and when it is needed most.[1]

2.2 AAR Effects

2.2.1 The primary effect of AAR is the spatial and temporal extension of air capabilities. This extension is accomplished simply by providing additional fuel to airborne aircraft and may prompt second order effects, specifically in enhancing flexibility, in reducing operating locations and in increasing payload capacity. Knowing how, when, and where this extension is to be employed are important factors that influence success and exploitation of the AAR capability. To ensure the effect is optimised, it is important that AAR does not substantially interfere with, or impact upon, receiving aircrafts' primary operations.

2.2.2 In order to optimise AAR capability a number of factors should be considered, including; offloading the requested amount of fuel, rendezvousing at the coordinated point in airspace at the correct time and trailing the assets during the deployment phase. AAR capability and effort is therefore expressed in terms of the numbers of tanker sorties generated, tanker hours flown, time on station, amount of fuel offloaded, number of booms or hoses in the air, and the number of receivers supported. However it should be noted that AAR is an enabling or supporting capability instrumental in accomplishing ultimate air effects. Therefore the overall efficiency of AAR support is derived from the ratio between the aforementioned efforts and, most important, the achieved mission results of the receiving aircraft

2.2.3 It can be reasonably expected that extension will remain the primary AAR effect for the foreseeable future. New technologies and techniques will continue to emerge and will, in combination with improvements in basing, planning, and employment, have the potential to maximise AAR supporting capabilities and efficiency. Future technologies are discussed in NATO Future AAR Requirements in Chapter 4, and emergent concepts are discussed in the Future AAR Employment Concepts within Chapter 5.

2.3 AAR – Force Multiplier

AAR is a very significant Air Power force multiplier. In considering the additional costs of lifting and delivering fuel in the air, AAR still provides an invaluable capability that increases the range, endurance, payload and flexibility of all capable receiver aircraft, and is especially important when forward basing is limited or unavailable, or when limitations on air base operations impose constraints. AAR increases a receiver's flight time, releases aircraft for reassignment to other tasks, allows aircraft to be based beyond the effective range of enemy weapons and reduces intermediate fuel stops during deployment, redeployment or sustainment flights. AAR allows Air Power to increase levels of versatility, surprise, flexibility, and mobility, and can concentrate more assets for operations. The overall effect of these applications is a force enabler and force multiplier in Air Power employment.

2.4 AAR – Asset Protection

AAR platforms are considered to be High Valuable Airborne Assets (HVAA) and therefore special consideration must be given by air planners and tasking authorities in order to minimise exposure to enemy threats. AAR procedures are both complex and vulnerable. The dangers inherent to both the tankers and receivers whilst on task require a high degree of Air Superiority to be achieved.

1. Reference AJP-3.3. Joint Air and Space Operations Doctrine dated May 2002.

The KC-135 fleet has formed the backbone of NATO AAR capability during the last four decades.

CHAPTER III

AAR Resources

3.1 Tanker Aircraft Inventory

3.1.1 National tanker inventories are very much a legacy from the Cold War era. However, subsequent to the Cold War ending, the number of types of aircraft and the number of missions requiring AAR has increased. National Procurement strategies have considered AAR as a fundamental capability in modern aircraft design, not just in fighters and bombers, but across the full spectrum of air platforms. Unfortunately, this increase in the AAR requirement has not been matched by a corresponding purchase of tanker aircraft. In 2002, the overall shortfall of AAR was recognised by NATO in the PCC, and by the European Union (EU) in the European Capabilities Action Plan (ECAP). The PCC and ECAP are discussed in more detail in Section 3.4 below.

3.1.2 An unclassified list of National AAR capabilities and future intent is at Annex A[1]. It should be noted that Annex A merely contains a list of each country's AAR assets, which are declared, but not necessarily assigned to NATO, as they may be assigned to national duties only. Absent from Annex A are non-traditional platforms, such as buddy-buddy[2] systems; details of which can be found in Annex B – Tanker Aircraft Characteristics. The final observation to note is that most tankers will be multi-role (Air Transport (AT) and/or AAR) and declared numbers may be double-hatted to multiple roles.

3.1.3 The information contained in Annex A suggests that national tankers will be sufficient to meet national needs, but not NATO needs. Several nations (France, Germany, Italy, the Netherlands, Spain, and the UK) have been sharing AAR capacity to support each other's requirements through the Movement Coordination Centre Europe (MCCE), based at Eindhoven in the Netherlands. One of the MCCE's objectives is to coordinate and optimise the use of AAR capabilities between its participants, thereby improving their overall efficiency and effectiveness. The Air Transport and Air-to-Air Refuelling and other Exchange of Services Technical Arrangement (ATARES TA)[3] enable MCCE members to employ a flexible and non-bureaucratic exchange of flying hours without the need for direct monetary payment. This arrangement has proved an effective and efficient peacetime cooperation; however, it does not meet the needs of NATO-led combat operations.

3.1.4 Tankers are declared by nations to NATO for defence planning. Resource requirements are identified in the DRR process, and nations respond to the NATO

Capability Survey (NCS) by declaring forces available for NATO planning. These forces may be some, all, or none of the forces possessed.

3.1.5 NATO Reaction Forces (NRF) tanker requirements are identified and filled by nations under the Combined Joint Statement of Requirements (CJSOR) process for six-month periods. Since NRF tanker requirements are relatively small, and each NRF series contains different receiver aircraft packages, NRF tanker contributions must be tailored to ensure compatibility.

3.1.6 Alliance plans rely on AAR as a critical enabling capability, and shortages in declared AAR capability would impact adversely on alliance effectiveness. AAR resources declared to NATO for war planning, and analysis of their sufficiency, are classified and will not be discussed in this AAR Flight Plan. As mentioned above, however, NATO must be cognisant of double-counting Multi Role Tanker Transport (MRTT)[4] assets.

3.2 Tanker Aircraft Characteristics

3.2.1 Aircraft Types. Annex B lists detailed tanker aircraft information for NATO Nations and Organisations which provide an AAR service. Several NATO Nations are now looking to obtain or improve AAR capabilities, while industry is developing new platforms and leading-edge technology. More tanker aircraft are being produced and developed by member nations (B767 – Italy, A330 – UK, KC130J – U.S., and A400M – France/Germany/Spain, KC-X for the U.S. and an MRTT for France).

3.2.2 Fuel Transfer Technology. There are currently 2 different AAR transfer systems in use; Probe and Drogue and the Flyable Boom. These two systems are not compatible, however, some booms can be adapted (on the ground only) using a Boom Drogue Adapter (BDA); this makes the boom compatible with probe equipped receivers. Some tankers are equipped with both boom and probe/drogue systems and either may be used on the same flight. A full description of AAR transfer systems is in Annex C.

3.2.2.1 The boom and probe/drogue hardware technology are currently in use and will remain the standard for AAR equipment. Both systems have been in use by NATO for decades and are generally, but not universally and formally, standardised. In order to formalise equipment standardisation within NATO, specifications and STANAGs have been developed. New tanker aircraft could be equipped with new technologies in addition to current systems. However, no Alliance Air Forces have identified requirements that the current systems do not meet.

3.2.3 Dual-Capable Tankers. A small minority of tankers are able to refuel boom and drogue capable receivers on the same sortie and present a clear advantage to drogue-only tankers and to most KC-135s (which can refuel both types of receivers, although not on the same sortie). Interoperability and flexibility are greatly enhanced by dual-capable tankers and all new tankers scheduled to enter the NATO inventory should be dual-capable. However, nations procure tankers based on their own requirements and a nation with only probed receivers is unlikely to equip their tankers with an expensive boom system. Furthermore, the A400M and KC130-J tankers are planned only to have the drogue system, as installing a boom would make the rear cargo ramp unusable. On the other hand, the future USA KC-X tanker is planned to be dual-capable. Boom and drogue requirements are discussed in Chapter 4 – Future AAR Requirements.

3.2.4 Currently some tankers are capable of receiving fuel via AAR, and this technique has been shown to further enhance flexibility and keep the maximum fuel in the air, where it is required. This capability is considered a requirement for future tankers, and the fuel consolidation employment concept is discussed in Chapter 5 – Future AAR Employment Concepts.

3.2.5 Multi-Mission Tankers. The current tanker inventory is predominantly limited to AAR and AT roles however procurement strategies may, in future, consider, employing these assets for other roles including Intelligence, Surveillance and Reconnaissance (ISR) and limited Airborne Command, Control and Communications (C3). Potential roles are discussed in Chapter 6 – Tanker Roles.

3.2.6 Size and Capacity of Tankers. The KC-135, currently the standard tanker for NATO planning, can be termed as a medium sized tanker with a max gross weight of just over 300,000 pounds. Most of the other tankers scheduled for acquisition, including the KC-135 replacement, will be in the medium to large category with max. weights between 350,000 and 500,000 pounds; A400M is a notable exception at 285,000 pounds. A number of KC-130 tankers will also continue in service, and Air Forces will continue to use buddy-buddy or fighter-to-fighter AAR in very limited circumstances. These exceptions notwithstanding, the clear trend is toward medium to large tankers.

3.3 Increasing Effect and Efficiency from Existing Tankers and Aircrews

3.3.1 Apart from increasing the number of tankers, there are other ways to produce greater effect from a given number of tankers. These methods involve generating more sorties and/or flying hours per aircraft and employing more efficient working practices.

3.3.2 Increasing Crew Ratio. Crew ratios (number of crews available per aircraft) vary with national air forces and aircraft type. USAF Air Mobility Command (AMC) crew ratios are likely to increase from 1.36 to 1.75 for KC-135s and approximately 2.0 for KC-10s. Increasing the crew ratio will increase the number of available sorties per aircraft, assuming aircraft utilisation (maintenance reliability) rates and fuel availability permit flying crews at maximum monthly rates. Crew ratios are only one factor in determining individual and collective tanker sorties available.[5] Increasing the number of crews can enable an increase in number of hours or sorties available, and may be achieved at a lower cost than increasing numbers of aircraft. It should be noted, however, that increasing crew ratios entails significant costs beyond the cost of additional personnel. Increases in flying hours, fuel, maintenance, and airspace capacity may be required to maintain the additional crews' peacetime training and currency.

3.3.3 Improve Reliability Rates. The cost-benefit ratio of increased investment-improved reliability, and the optimum package of maintenance resources, is dependent on many factors, such as manning, geography, economics, age of the fleet and so on. This involves engineering, modifying, or reengineering aircraft components, and/or providing more robust maintenance capacity, including spare parts, at operating locations.

A U.S. Air Force Airman lifts the boom of a U.S. Air Force KC-135 Stratotanker. Reliability rate improvement and turn time reduction are measures to increase existing tankers' efficiency.

3.3.4 Reduced Turn Time. Turn time is the amount of time a tanker spends on the ground between sorties. Turn time is impacted by the quantity, location and characteristics of support resources such as fuel and maintenance. Air forces typically use standardised planning factor turn times which assume typical support arrangements and average task times. Reduction of turn times may incur costs in terms of personnel and equipment.

3.3.5 Basing Close to the Area of Operations. The number of sorties that can be flown and the amount of offload fuel available per tanker are inversely proportional to the flying distance from base to the operating area. Traditional planning considered tankers a HVAA and prescribed basing tankers in areas of minimum risk, resulting in long transits to the refuelling areas. The reality is that shorter-range platforms (Rotary Wing (RW), fighters, tactical Unmanned Air Systems) are normally based close to, or inside, the Area of Operations and consume all the available real estate. Longer-range platforms, including AAR assets, are obliged to base further afield where there is available space and relative safety. In the majority of planning cases the availability of parking space, logistics footprint and force protection (potentially including counter-IDF) must also be considered in basing decisions. See 5.5 – Basing and Deployment Concepts.

3.3.6 Advanced Planning and Assessment Techniques. Advances in automated operational-level mission planning systems have improved the efficient distribution of AAR tasking amongst tankers. The number of potential AAR pairings expands exponentially as receivers, tankers, aircrews, operating bases, airspace and control times increase in moderate to large scale air operations. Even the most skilled and experienced planners, working within a 72 hour Air Tasking Order (ATO) cycle, cannot assure the most efficient and effective plan. The USAF Air Refuelling Tool Kit (ARTK) and NATO's Integrated Command and Control (ICC) systems are being fielded in order to provide improved interfaces, functionality and automated mission matching capabilities, and thus improve overall efficiency. These improvements can be best demonstrated in generic large scale operations, and therefore, used in war planning and in crisis response operations. NATO also expects to replace ICC with the Air Command and Control System (ACCS) in the future, incorporating ICC functionalities.

3.3.7 AAR Planner Training. AAR planners require experience in AAR training and operations. As an example, the U.S. mandates that before commencing an assignment to a U.S. Air Operations Centre (AOC), all AAR planners shall have completed formal training in all aspects of AAR planning within AOC operations. With constant feedback between the training school and the Combined Air Operations Centres (CAOCs), this training is continuously evolving to suit the change in tactics. As yet, NATO has no formal training course for its AAR planners. AAR planner training will be discussed in Chapter 7 – Enhancing NATO Interoperability.

3.3.8 Fuel Consolidation. A Fuel Consolidation employment concept can provide efficiencies during mission planning and execution. Under this concept, tankers provide AAR to other tankers to enable the most efficient combinations of tankers and to take advantage of excess capacity, thus, avoiding returning to base with unused fuel. Planners can then maximise efficiency when scheduling tankers. The execution staff monitor operations hour-by-hour, and can redirect tanker missions and redistribute fuel amongst tankers to consolidate savings realised when receivers take less fuel than programmed. The capability to consolidate fuel will be enhanced by the receiver capable tankers currently being acquired or programmed by some Alliance nations.

3.3.9 AAR Mission Execution. The dynamic flow of information during the execution phase from individual tankers and formations to all players offers similar potential for improvements in efficiency and effectiveness in response to tactical developments. Real-time management in execution has always existed but should be addressed in and standardised in all AOCs. A thorough analysis of variables and potential courses of action, however, is restricted by the time available for replanning. Introduction of net-enabled Command, Control, Communications and Computers, Intelligence Surveillance and Reconaissance (C4ISR) connectivity and dynamic planning software into the tanker cockpit can improve information sharing, situation awareness and comparison of alternatives within the cockpit and in collaboration with other aircraft and Command and Control (C2) nodes. These empowering technologies will be included in acquisitions and upgrades, and enable better decision-making for efficiency and effectiveness.

3.3.10 Limitations to Potential Efficiency Improvements. Some of the potential efficiencies from the techniques listed above can be realised most effectively in sustained operations once a battle rhythm and routine have been established that provide predictable and reliable opportunities for efficiencies. They are also most effective with large numbers of tankers, where savings from individual sorties can be consolidated to reduce sortie, aircraft, and crew requirements. War planning and crisis response operations, such as NRF, will still require conservative assumptions, especially where assured effectiveness and flexibility are critical but detailed requirements are unknown. Assured effectiveness may be assigned a higher priority than efficiency in planning during the early phases of an operation.

3.3.11 In summary, tanker planners and commanders will enjoy small efficiency improvements in the immediate future, resulting from improved automation. Large scale operations may require up to 5% fewer tankers in best-case scenarios. This is an educated savings estimate only; no data is available to demonstrate the cumulative effects of proposed efficiency techniques. Additional efficiencies may be realised through improved analysis and management during sustained operations. Even relatively small planning considerations can represent substantial savings in sorties, tankers, and fuel, making efficiency techniques worthy of consideration in planning and execution. Efficiencies are also important where there are sufficient resources for operations, as resources saved can be redirected toward other operational requirements or for reserve and reconstitution.

3.4 Increasing the Number of Tankers Available to NATO

In addition to more traditional acquisition, NATO and individual nations have been exploring alternative means of increasing the number of tankers. These include; collective acquisition, leasing and commercial supply of AAR services.

3.4.1 Collectively Owned Fleet. In 2002, the shortfall in AAR provision was recognised by NATO in the PCC, and by the EU in the ECAP. Work on the PCC AAR shortfall commenced, with Spain leading a group of nations which examined the potential to collectively acquire and commonly operate a squadron-size fleet of tankers to increase the number of tankers available to NATO. In the Prague Summit Declaration, the nations recognised AAR as a capability requiring improvement and development, and pledged to implement the PCC.[6] The PCC-AAR Working Group considered purchase, lease-to-buy, and leasing arrangements. The resulting AAR capability, as agreed to in Prague, would have been available for NATO-led operations and the EU, in addition to national tasking.

3.4.1.1 The work conducted as a result of the PCC AAR Initiative concluded in February 2005. Although the Working Group conducted valuable research and analysis of potential acquisition, management and implementation solutions for a collectively held and operated fleet, it concluded that the financial commitment required was beyond that which the participating nations found to be feasible. The European Defence Agency (EDA) began a similar study into identifying ways to provide additional AAR capability. Whilst the study is on-going, there are currently no plans for additional tankers, other than those that are currently committed or in procurement by individual nations. In the end, it has been a case of National necessity versus NATO requirement.

3.4.2 Aircraft Leasing. The UK's Future Strategic Tanker Aircraft (FSTA) program demonstrates a practical example of a long-term leasing arrangement albeit on a national level. In this case, the UK determined the maximum number of tankers (the Airbus 330) required to meet its operational commitments. However, during peacetime the demand for AAR is expected to be lower and therefore fewer aircraft are required. The aircraft will be civilian owned, military operated and when not required for operations, the aircraft will revert to the civil register and be operated by the civil company for commercial flights. The process of reverting a tanker from the military register to the civil register requires the removal of all military equipment, including the

AAR system. This leasing method is a way of deferring the initial high cost of defence procurement by spreading the costs over the life of the aircraft/contract. The life cost of leasing, however, is expected to be higher than the costs of buying the asset from the onset.

3.4.3 Commercial Air-to-Air Refuelling Interim Solution (CAARIS) The operation of civil aircraft is governed by International Civil Aviation Organisation (ICAO) regulations. Current ICAO regulations do not permit AAR activity for civil aircraft. Additionally, there is no certification process for military-specified equipment installed on tankers (Boom, Hose Reels, Pods etc.), to meet Civil ICAO standards. The US military is, however, able to utilise CAARIS under a specific clause agreed with the ICAO which permits the use of civil registered Aircraft operated by a civilian company fulfilling a US Government contract. The US is the only NATO Nation that has this clause with the ICAO. Other nations and/or NATO would have to approach ICAO for a similar waiver.

3.4.3.1 The principle of CAARIS is relatively new and the potential for growth, particularly for AAR currency and training requirements, is clear. The EDA Nations are currently assessing a proposal to provide Commercial AAR as a way to overcome the AAR shortfall.

1. Information is based on National assets declared to the NATO Air Force Armaments Group (NAFAG) Aerospace Capability Group 5 (ACG 5) on Global Mobility.
2. Buddy-buddy AAR: In-flight refuelling from one suitably modified combat aircraft to another combat aircraft.
3. ATARES TA. This TA provides a compensation system to achieve a balance of exchanged services in such a way as to avoid compensatory financial payments. It enables the exchange of flying hours, based on the C130 Flying Hour as an agreed equivalent value unit of exchange. More information can be found at www.mcce-mil.com.
4. MRTTs usually take the form of a civilian platform converted to a military requirement for tanker and strategic/tactical cargo.
5. Number of sorties available per aircraft depends on crew ratio, number of hours crews may fly per 30-day and 90-day periods, average duration of AAR sorties, and situational support constraints (fuel availability, airfield operating hours, etc)
6. Summary of PCC commitments available on NATO website: http://www.nato.int/issues/prague_capabilities_commitment/index.html.

Sgt. Thomas E. Bahr, student loadmaster, watches from the rear ramp of a KC-130J Hercules as an MV-22 Osprey refuels in flight. Receiver characteristics, such as Tilt Rotor, will determine future NATO AAR requirements.

CHAPTER IV

NATO Future AAR Requirements

4.1 Introduction

4.1.1 Future NATO AAR requirements will be driven by the numbers and characteristics of future receiver aircraft. The NATO DRR process identifies operational requirement based on planning scenarios derived from the Alliance's stated Level of Ambition. DRR-driven requirement figures address minimum capabilities requirements for war planning. These figures are classified, and will not be discussed in this Flight Plan. The requirement discussion and findings described within do not replace the DRR process and requirements, and should not be confused with Minimum Capabilities Requirements (MCR).

4.1.2 With the exception of potential developments in specialised equipment for Unmanned Aerial Systems (UAS) rendezvous and AAR, the most likely changes in the AAR requirement will be in numbers of aircraft, and characteristics other than refuelling hardware.

4.2 Future Tanker Numbers

4.2.1 It is difficult to forecast the exact number of future tankers. However, current projections indicate fewer tankers, with increased individual capability. Nevertheless, with this reduction in numbers, concerns might arise especially during times of large scale conflict or when concurrent minor operations require higher concentrations of Air Power; scenarios which should not be quickly discounted. With the U.S. KC-135s comprising the greatest numbers of NATO tankers, their uncertain replacement rate may mean

A US Marine Corps CH-53E Super Stallion helicopter makes contact with a C-130 during an in-flight refuelling off the coast of Djibouti 28 Jul 10.

that the total, number of tankers could be smaller than today. It is anticipated that fewer 'KC-X' tankers will enter service than the retiring KC-135 fleet, and despite the KC-X being a more capable platform, it is possible that the overall AAR output may be reduced. The USAF is expected to award a contract for a KC-135 replacement tanker in 2011. The RAND Analysis of Alternatives (AoA) Executive Summary provides a useful discussion of requirements and recapitalisation strategy.[1]

4.3 Future Receiver Numbers

4.3.1 Five AAR-capable NATO fighter platforms are expected to operate in the near to mid-term future; Eurofighter (Typhoon), Rafale, Grippen, F-22 and F-35/Joint Strike Fighter (JSF). Overall the number of AAR-capable fighters will decrease when compared with the number currently flying, as older fighters are retired and with the introduction of new platforms. The new fighters will be more efficient in fuel consumption, although planners anticipate utilising them on longer-range/endurance missions requiring more fuel, and therefore potentially requiring more AAR support. Furthermore improved reliability and utilisation of the newer aircraft imply a higher sortie rate per aircraft, which may also further multiply the AAR requirement. Similarly the number of nations providing fighters, but not tankers, will increase; it is also anticipated that numbers of AAR-capable helicopters, AT and ISR aircraft numbers will increase thus creating greater

demand for AAR platforms. Unless other nations provide more tankers than receiver aircraft (which is unlikely to be the case), the result will be an increasing imbalance between the number of receivers versus the number of tankers. With this in mind, the tanker shortfall identified in the PCC could be even larger.

4.3.2 In addition to the operational requirement, it is worth noting that an increase in training and currency should be anticipated.

4.4 Receiver AAR Characteristics

4.4.1 The boom and probe/drogue hardware technology currently in use will remain the standard AAR equipment. Both systems have been in use by NATO for decades. STANAGs, defining the technical interface requirements of both systems, are being developed to formalise the equipment within NATO. New receiver and/or new tanker aircraft may be equipped with more modern AAR systems; however, these will be based on the current boom and probe/drogue design. No requirement beyond the current systems has been expressed.

4.4.2 It is forecast that the current ratio of boom capable receivers to drogue equipped receivers will remain static in the near future. Dual-capable tankers would obviously provide greater flexibility; however, based on national requirements, future tanker procurement may not incorporate this dual capability.

4.4.3 Future technologies will drive an increase in AAR requirements and may potentially change current equipment and procedures. Developments in UAS may enter the AAR remit including tanker UAS; considerations for refuelling UAS involving automated AAR to guide UAS as receiver aircraft are further discussed in Section 4.6. Section 4.7 discusses issues regarding potential UAS tankers.

4.4.4 In addition, the demand for Rotary Wing (RW) and Tilt Rotor AAR is likely to increase. Current procedures exist within Allied Tactical Publication ATP-56(B) for Rotary platforms. However, as their characteristics suggests, Tilt Rotor platforms fall somewhere between Fixed Wing (FW) and RW procedures. The decision as to where Tilt Rotor sits will depend upon the user community and their respective safety concerns; US Air Force Special Operations Command (AFSOC) Tilt Rotor platforms work predominantly alongside RW assets and so would prefer common Rotary procedures; the US Navy and Marines however refuel Tilt Rotor alongside FW aircraft and may wish to adopt common FW procedures. The critical factor will be the type of tanker from which the Tilt Rotor aircraft refuel; refuelling from a 'strategic tanker' would perhaps suggest a FW procedure whilst refuelling from a 'tactical' tanker, at lower speeds and altitudes, may suggest a RW procedure. Work on standardisation continues.

4.5 Types and Characteristics of Tankers

4.5.1 There is a clear direction amongst nations toward utilising tanker aircraft as MRTT platforms, which will drive a trend likely to result in an increase in aircraft size. The footprint therefore, or required pavement strength, parking, and runway dimensions will also potentially increase and so in order to increase flexibility and minimise support, smaller tankers (operating at the tactical level) capable of refuelling both helicopters and Fixed Wing receivers may provide a more optimal solution. For tankers at the larger end of the spectrum, footprint requirements will restrict basing options.

4.5.2 These considerations have led to discussion of heterogeneous tanker fleets, with combinations of small, medium, and large tankers to mitigate restrictions and to leverage relative advantages to optimise effects in a variety of condition sets. Such a fleet could operate effectively in operations where a mixture of austere Forward Operating Bases and fixed Main Operating Bases is required. While there is a supportable rationale for a heterogeneous fleet, and the A400M will provide good austere base capabilities, the future inventory of NATO tankers will consist mostly of medium – to-large tankers that require permanent, well-supplied airfields. This is especially true as nations invest the limited resources available in tankers optimised for large amounts of fuel available and for efficiency.

4.5.3 There may be future scenarios where stealth tankers, and/or tankers with robust self-defence capabilities, will be a requirement. One proposed concept is for tankers to operate in the same speed and altitude envelopes as strike aircraft and be capable of penetrating enemy defences in order to accompany the strikers into hostile airspace. With the current demands of asymmetric warfare, AAR platforms are increasingly being located in more hostile environments and future procurement will reflect this.

4.5.4 One existing capability that provides the potential for increased range, time duration and flexibility is in-flight refuelling of AAR platforms from another tanker. This capability should be emphasised, allowing planners and operators to increase both efficiency and to respond to changing situations by redistributing fuel amongst tankers whilst airborne.

4.5.5 Command, Control, Communications, Computers and Information (C4I). Innovative technologies will provide future tankers with greater situational awareness in the tanker cockpit, and greater real-time visibility of each tanker's capabilities at the operational level of command. Future tankers will therefore be more seamlessly integrated into network enabled operations.

4.6 UAS Receivers

4.6.1 UAS development, including experimental refuelling capability, is proceeding rapidly. Many nations, services, and commercial interests are pursuing AAR development. Several organisations are involved in UAS AAR research and development, concentrating on Autonomous AAR technology (to formate and guide the receiver the final few meters to the tanker). The majority of this work focuses on this capability due to the time delay in transmitting and receiving remote guidance inputs for the fine adjustments that must be made instantaneously with two aircraft in close proximity. Laser, Global Positioning System (GPS), Optical and Infrared (IR) technologies have been considered for this purpose, and trials have proven Automated AAR feasible. Two potential requirements exist for UAS AAR; refuelling current UAS (Predator or Global Hawk); and the future generation of UAS.

4.6.2 Currently, there are no definitive requirements for refuellable Unmanned Combat Air Systems (UCAS); however, some nations have researched the potential within future combat aircraft systems concepts and developments.

4.7 UAS Tankers

4.7.1 National air forces and industry are using technology demonstrations to explore the potential of unmanned tankers using boom and drogue delivery systems, which has so far been limited to very small tankers refuelling other small UAS. This is a logical first step because it minimises the challenges from refuelling a light UAS with a large tanker, and operating manned and unmanned aircraft in close proximity. A UAS tanker, as currently conceived, enjoys a compatibility with current UAS based on shared characteristics of light weight and low cost, while permitting operations without risk to human operators.

4.7.2 There may be a future requirement for larger, unmanned tankers that operate similarly to current tankers, providing fuel to a variety of receivers. A major challenge to operating larger UAS tankers, which would be interchangeable with other manned medium-to-large aircraft, is a lack of research and development in this area. This puts such possibilities into a distant future timeframe.

4.7.3 Probe and drogue AAR may prove the most practical system for UAS tankers. The probe and drogue system permits a more passive operation for tanker systems than boom AAR. With probe and drogue the receiver must be self-guided to the tanker drogue, and the tanker is not required to direct the drogue as precisely as the boom nozzle must be guided by the tanker with boom AAR.

1. Analysis of Alternatives for KC-135 Recapitalisation, Executive Summary, RAND Project Air Force, 2006 RAND Corporation. Executive Summary available at http://www.rand.org/pubs/monographs/MG495/#.

CHAPTER V

Future AAR Employment Concepts

5.1 General Employment Concepts

The NATO AAR Employment Concept is as yet unapproved; it will, however, be defined in Allied Joint Publication (AJP) 3.3.4.[1] In the absence of a current NATO approved Employment Concept, individual nations have developed their own AAR Concep of Operations (CONOPs). AAR will continue to be employed in support of; tactical and strategic operations, NATO EO, in addition to national inter-theatre fighter movements, global strike, and air transport operations. With the exception of Air Policing, existing CONOPs will be driven by the requirement to enhance flexibility and efficiency, the operating environment, and the basing and deployment considerations.

5.2 Employment of Concepts to Enhance Flexibility and Efficiency

5.2.1 As NATO Nations acquire more receiver-capable tankers, employment concepts that take advantage of tanker receiver capability will be used more to improve efficiency and effectiveness across fleets and on individual sorties. This section examines the AAR terms 'Force Extension' and 'Consolidation', and explains their advantages and how receiver-capable tankers will make these concepts more widely available. While the concepts are closely related, it is helpful to discriminate between the relatively narrow purpose of Force Extension as a planned fighter deployment AAR, and Fuel Consolidation as a broader concept applicable to any AAR mission.

5.2.2 Force Extension. Force Extension has been used for tanker-to-tanker AAR, usually in the context of long-range offensive air capability deployment[2], whereby tankers refuel primary receiver-capable tankers associated with the Trail/Coronet from fighter departure base to fighter destination. Force Extension provides the benefit of extending the deployment range of receiver packages by ensuring the supporting tankers do not have to make en route fuel stops. Opportunities to employ this concept have been limited by the relatively few receiver-capable tankers available in the past, but will multiply as the number of receiver-capable tankers that can act as the primary departure to destination tankers increases.

5.2.3 Fuel Consolidation. Fuel Consolidation involves Tanker-to-Tanker AAR in order to; enable the most efficient combination of tankers, take advantage of excess capacity and avoid returning to base with unused fuel. This process enables the release of tankers off-station to return to base and refuel, without reducing the amount of available fuel in the operating area. Planners can maximise efficiency when scheduling, and Current Operations Staff can redirect tanker missions in real-time to redistribute fuel among tankers for tactical advantage.

5.3 Air Policing

5.3.1 As the NATO Air Policing mission has evolved, so has the requirement for AAR support. However, the AAR requirement is not addressed in the Force Planning or NRF CJSOR processes. The Air Policing mission should be included as a future requirement with baseline CONOPs including AAR orbit coverage, ground alert tankers and possible deployed tanker operations.

5.4 Operating Environment

5.4.1 Threats and Defensive Capability. Tankers are considered HVAA and are particularly vulnerable to air and ground threats. The majority of tankers are not fitted with threat warning or defensive systems. For this reason, tankers are not normally based close to the immediate battle space, and they usually operate within 'safe' airspace, in which a high degree of air control is required. Both Threat Warning and Defensive Aids Systems would enable AAR closer to the actual or potential threats, and potentially enable greater support to receiver missions.

5.4.1.1 The asymmetric threats to air bases, even those within relatively secure or friendly areas, must also be considered in planning and employment of tankers, both for the Force Protection of bases and aircraft defences. Man Portable Air Defence (MANPAD) system proliferation, together with the potential threat presented by other weapon systems, will require greater attention being given to departure and approach phases.

5.5 Basing and Deployment Concepts

5.5.1 Current NATO planning includes provisions for forward basing within the borders of Alliance Nations. The number of bed-down spots are calculated based on planning scenarios, and operational concepts. Pri-

A French C-135 refuels a Royal Australian Air Force A330 MRTT Aircraft (KC-30A). The Fuel Consolidation concept enhances flexibility.

mary bases, and less capable contingency bases, are identified to accommodate the required numbers. The identification process includes analysis and verification of capabilities and agreements with host and user nations to ensure access. This process is expected to continue for the foreseeable future.

5.5.2 The primary considerations for tanker basing are; adequate runway and taxiway dimensions to permit heavy tanker operations; adequate parking; and sufficient fuel storage and delivery capacity. Fewer bases with greater capacities are generally preferable to more bases with smaller capacities to permit economies of scale, optimise the logistics footprint and reduce risk associated with more locations. Proximity to operating areas, Force Protection and security are also important basing criteria. Base Operating Support common to all air operations is also a consideration, and embodies, ATC, security, fire protection, accommodation, and so on. NATO anticipates and addresses the need for adequate AAR basing with the Capability Package process that identifies airfields within NATO territory that can support AAR operations and funds airfield infrastructure improvements where appropriate, to ensure airfields are capable if required. Decisions on inclusion of airfields in a Capability Package are based on operational utility and location; however the packages are financially constrained, agreed by Alliance consensus, and exclude bases outside NATO territory.

5.5.3 Long Range Deployment operations and Out-of-Area operations may require tanker basing locations well outside NATO territory. However, there is currently no formal planning effort to identify potential locations and their support capability. This eventuality is left for crisis action planning, so real capabilities and prospects for host nation permission are unknown, and Alliance planning does not identify this possibility to the nations (outside the limited scope of NRF planning). Operations from austere deployment sites will require deployable support packages of equipment and personnel, from the tanker units and/or from a bare base support capability. Tanker and support units will also require preparation in the form of training, and exercises to ensure a rapid deployment capability, and capability to sustain operations in forward locations.

1. AJP 3.3.4 Study Draft 4 developed under chairmanship of JAPCC. Current status – pending ratification and published as ATP-3.3.4.
2. Generally referred to as Trails or Coronets – ATP56 (B) NATO AAR Manual.

CHAPTER VI

Tanker Roles – More Capabilities, Same Platform

6.1 Interchangeable and Dual Role AAR/AT

6.1.1 Interchangeable AAR and AT roles will become an increasingly important consideration for NATO AAR. Tanker aircraft currently support the deployment of air assets, delivering receiver aircraft to operating locations using AAR to minimise en route support while transporting the receiver aircraft support personnel and equipment on the same tankers. Until now this aircraft delivery mission has typified the 'dual role' mission. Tanker aircraft have also been used in specific AT missions. Aircraft deployment dual role missions will continue to be important, but future tanker aircraft will also be called on to perform a variety of additional roles. Additionally, the same platform could be used for Aeromedical Evacuation (AE) or ISR.

6.1.2 The purchase of MRTT aircraft, from a national perspective, tries to address not only the shortfall in AAR but also the shortfall in strategic AT. Air Power flexibility allows the possibility to task the same platform for different roles, often executed concurrently. With fleets of tankers specifically designed for interchangeable and dual role (AAR/AT) operations, future operations could include tanker aircraft and units transitioning from one role to another in accordance with operation phases and also transitioning dynamically in response to unexpected requirements and priorities. However during concurrent operations, the number of available tankers and fuel offload capacity may decrease if AT is deemed a higher priority for MRTT platforms.

6.2 Other Secondary Roles

6.2.1 The tankers' internal payload capacity, endurance, and range present a platform with the potential to perform additional missions. These characteristics coupled with a growing requirement for network enabled communications, and technologies enabling autonomous, efficient, transportable line-of-sight and satellite communications, could lead to incorporation of C4ISR equipment and missions on tankers.

6.2.2 An example of this can be seen from the U.S. which has begun utilising Multi-Mission capabilities that can be loaded in tankers modified for electrical power and antenna fittings. This enables the tanker to perform a C4ISR role simultaneous with, or in addition to, the AAR mission. This additional role can be as simple as automated radio relay, which could require only minor aircraft modifications, but can include establishment of an 'IP address in the air' network component. Surveillance and reconnaissance equipment and roles may also be incorporated with greater aircraft modifications; however, requirements for coordinating roles, missions, C2 and training will also increase.

6.3 Managing All Roles. Risks and Opportunities

6.3.1 In utilising tankers in the MRTT role, there will be consequences. Commanders and planners must be cognisant of both the advantages and constraints of each dual-hatted aircraft type and its respective aircrews.

6.3.2 Multirole assets, while avoiding double counting during declaration, always provide a plus in flexibility, permitting dynamic transition from one role to another while adapting to changing situations and operational requirements.

6.3.3 When dealing with multirole assets, a correct apportionment and task prioritisation, in accordance with the operational situation, is extremely important. Assessment failure could drive a departure from the resourcing of enabling roles, such as AAR, leading to consequential cascading effects.

6.3.4 There has to be a balance struck between the basing of AT aircraft at their Aerial Ports Of

A Royal Australian Air Force A330 MRTT refuels two Spanish EF-18s. MRTT concept might challenge the management of future AAR assets.

Disembarkation (APOD) versus the requirement to base AAR aircraft close to their customers. The basing issue has yet to be examined, but as an example, it may play an important role in the design of future NATO Capability Packages and their approval processes.

6.3.5 Managing Dual role aircrews' proficiency and currency could also present a challenge due to the existing trade-off between training efforts versus force readiness levels.

6.4 Doctrine for Interchangeable, Dual and Secondary Role Employment

6.4.1 Currently, the (draft) AJP 3.3.4 is intended to provide guidance to NATO Nations on AAR terminology, definitions and concepts of employment. Subordinate to this AJP is ATP-56(B), which encompasses standardised AAR procedures at the operational and tactical levels. However, when using the same platform in different roles, we also need to refer to the corresponding AT publication, ATP-3.3.4.3(A) and ISR publication.

CHAPTER VII

JAPCC Project on Enhancing NATO AAR Interoperability

7.1 Background

7.1.1 In 2004, ACT tasked the RFAS to produce a list of projects which would highlight the transformational aspect of the newly established JAPCC, one of which was "Enhancing NATO AAR Interoperability". Subsequent work carried out on this project, the conceptual framework, the methodology, products delivered, and future areas for possible standardisation, are contained within.

7.1.2 Historically, the vast majority of AAR capability rested in the hands of only a few nations. With an expected increase in the number of tanker platform types, provided by a greater number of nations and industry partners, the requirement for standardisation becomes ever more critical. In order to achieve standardisation, a transformational approach to AAR operations is required.

7.1.3 The NATO AAR process was constrained in several ways; the AAR Concept lacked true doctrinal guidance, procedures (contained in ATP-56(A)) were out-dated, and tanker tactics and employment were developed at the national level. Figure 1 below describes the 2004 AAR process, which provided direction and guidance for NATO AAR operations. However, as the diagram shows, there was little or no input from a Strategic or Operational context with respect to AAR tactics.

7.2 Project Aim

7.2.1 The aim of this project is to develop and implement a 10 Year Vision to enhance Alliance Air-to-Air Refuelling interoperability through improved formal guidance, including updated and accurate

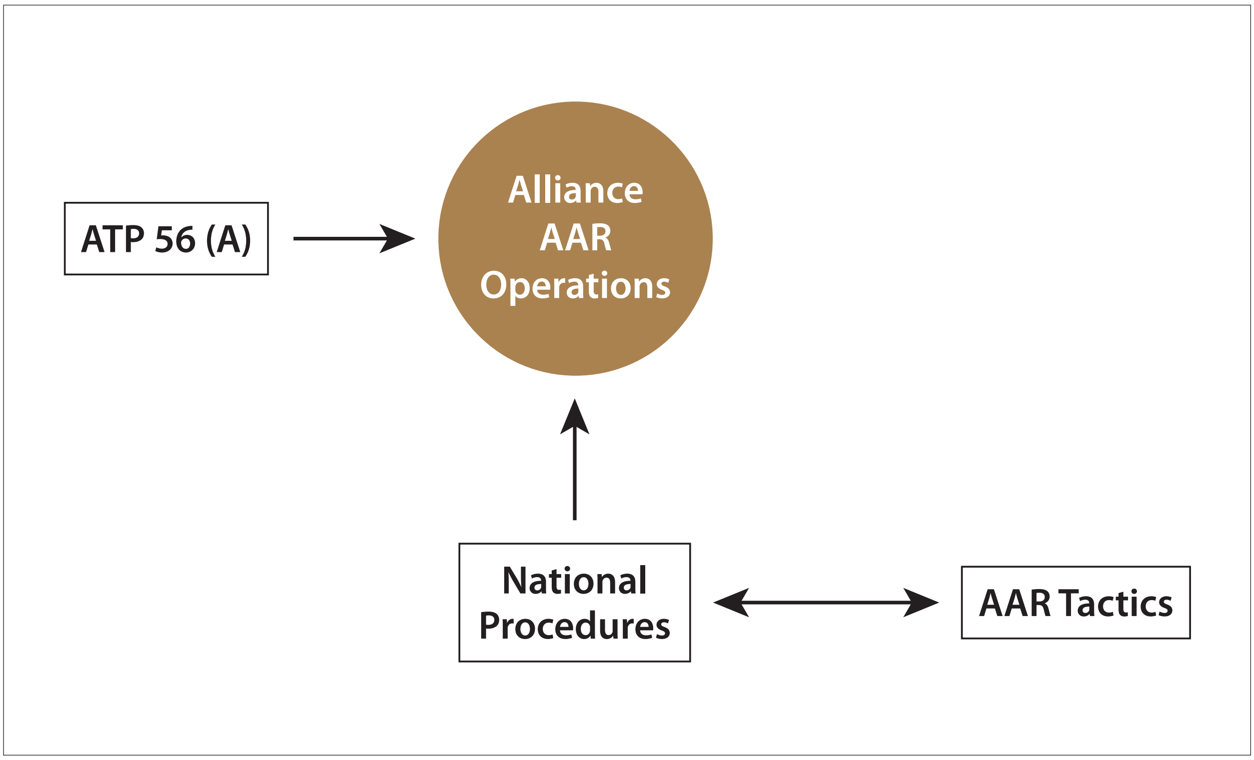

Figure 1: 2004 AAR Process for providing direction and guidance for NATO AAR operations.

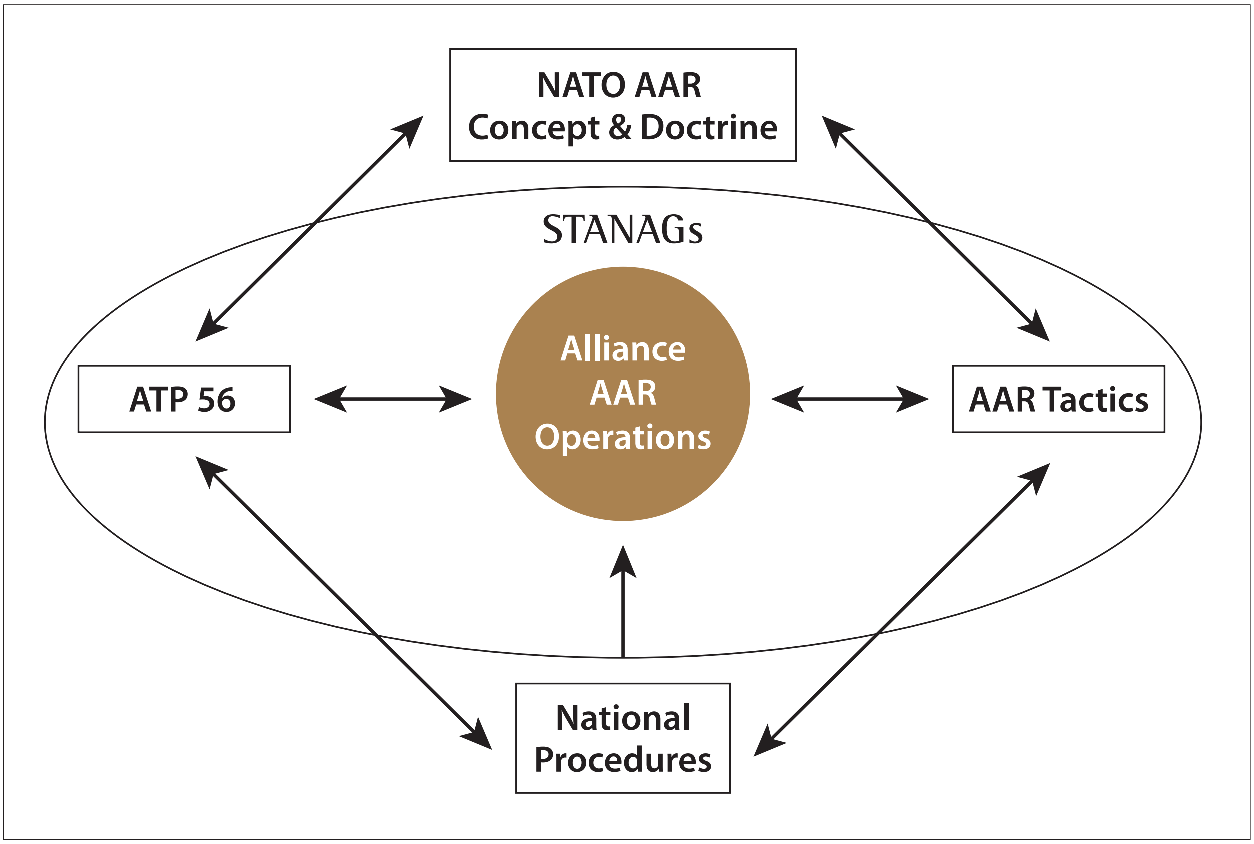

Figure 2: Proposed AAR Process for providing direction and guidance for NATO AAR operations.

documentation. This project is producing NATO AAR procedures to improve NATO AAR interoperability, at the strategic, operational, and tactical levels (Figure 2).

7.3 Conceptual Framework and Methodology

The following methodology has been applied:

- Draft and seek ratification of *NATO AAR Doctrine;*
- Assess, develop and update *AAR STANAGs;*
- Develop a NATO AAR Manual *AAR Procedural Manual ATP-56(B):*
  - Continually assess the status of Alliance AAR interoperability (including the clearance process[1]) and standardisation, and incorporate lessons learnt into products;
  - Standardise AAR clearances and aircrew receiver training and currency.
- Draft and seek ratification of a *NATO Tanker Tactics/ Employment Manual;*
- Develop a Tanker Planner Training program for Alliance tanker planners.

7.4 AAR Affiliated Agencies

7.4.1 The effectiveness of the JAPCC project is based on involvement with decision-making AAR agencies. The agencies that are solely dedicated to AAR are described in the following paragraphs.

7.4.2 NATO Standardisation Agency (NSA) AAR Panel. The NSA AAR Panel, chaired by the JAPCC, is responsible for improving the operational effectiveness of NATO forces by developing operational standards and exchanging information that enhance AAR effective employment and interoperability. The Panel's principle activity is the identification, proposal and development of STANAGs and Allied Publications that embrace doctrine, tactics, techniques and procedures.

7.4.3 Aerial Refuelling System Advisory Group (ARSAG). The ARSAG is an independent, non-profit organisation that is solely interested in pursuing AAR issues. Its members comprise the Armed Forces of more than fifteen nations, in addition to representatives from airframe manufacturers, aerial refuelling hardware manufacturers, study groups and aerospace consultants. The members meet to discuss all facets of AAR technology, procedures, interoperability, safety, design, training, operations, reliability and maintainability, research and development, advanced concepts and studies and analysis.

7.5 Concepts, Doctrine and Procedures Progress

7.5.1 NATO AAR Concept. MCM 217 (1998) is the current, approved NATO AAR Strategic Concept. However, as the date suggests, it is somewhat out-dated and has been superseded by the past decade of EO. A revised version of MCM 217 was signed off by the JAPCC and handed over to ACT in 2006. Upon request from ACT, the JAPCC added further updates to this document in 2008. This revised version has yet to be approved and promulgated.

7.5.2 NATO AAR Doctrine. As in the case of the NATO AAR Concept, the respective doctrine was also outdated, with a distinct gap between the higher level AJP-3.3 Air Operations Doctrine and the ATP-3.3.4.2 AAR Procedures manual. In 2008, the NSA Air Operations Support Working Group (AOSpWG) tasked the NSA AAR Panels with developing ATP-3.3.4 AAR Doctrine. The final drafts were submitted to the AOSpWG in 2009. Subsequently, the NATO Military Committee Air Standardisation Board (MCASB) decided that the doctrine should proceed as a joint document and requested the NATO Military Committee Joint Standardisation Board (MCJSB) incorporate it within AJP-3.3.4. The Air Operations Working Group is currently[2] evaluating this doctrine.

7.5.3 NATO AAR Procedures – ATP-56 (ATP-3.3.4.2). Until 2005, despite NATO published AAR procedures, ATP-56(A) was not adopted and utilised across the Alliance. Most importantly, the US, despite being the largest single contributor to AAR force elements, followed their own National procedures. The disparity between national and Alliance procedures was further highlighted by EO in the Middle East. It was agreed between Alliance nations that one Procedures Manual was required and the new ATP-56(B) was ratified in February 2007. Initially, FW procedures were addressed with RW procedures following in February 2010. Work has commenced on Tilt Rotor and UAS procedures; however, a majority of nations has agreed that Tilt Rotor and UAS procedures should conform where possible to the existing Fixed Wind or Rotary procedures, as noted in paragraph 4.4. National procedures are still promulgated as an annex to ATP-56(B) Part 5. ATP-56(B) is increasingly recognized as the global standard for AAR Procedures with many non-NATO Nations now referencing the document and submitting details for inclusion in Part 5 of ATP-56. The JAPCC remains the custodian of ATP-56(B).

7.6 Standardising AAR Equipment

7.6.1 Improved interoperability amongst all nations with AAR capabilities is a necessity if we are to fully realise the potential of a global tanker force for EO. In the Cold War years, there were a few manufacturers of AAR equipment, and for some pieces of equipment like the Boom, there was only one manufacturer. One manufacturer meant that there was no need to have a standard. However, with the increasing demand for tankers, there emerged an increase in the number of manufacturers willing to provide the equipment. Therefore, in order to enhance NATO AAR interoperability, the standardisation of the primary equipment used to conduct AAR is paramount.

7.6.2 The last few years have seen the following STANAGs developed:

- STANAG 3447 – Probe and Drogue (Promulgated)[3];
- STANAG 7191 – Boom and Receptacle (Under ratification process);
- STANAG 7215 – Signal Lights in the Drogue System (pendant of ratification);
- STANAG 7218 – Hose colour and markings (pendant of ratification).

These STANAGs represent a push by NATO Nations to not only standardise their equipment (STANAG 3447 and 7191) on future tankers, but also to simplify AAR procedures by standardising receiver pilots' site picture[4] (STANAG 7215 and 7218). A standard site picture for all tankers would lead to a safer AAR environment as receiver pilots would be more familiar with the equipment. In this respect, the Signal Lights[5] STANAG represents a step forward in the influence of tanker design in order to standardise AAR procedures. The standardisation of equipment is likely to continue as even more manufacturers emerge within the market place.

USAF SSgt Justin Brundage, a KC-10 boom operator with the 908th Expeditionary Air Refuelling Squadron, refuels a Royal Netherlands Air Force F-16.

7.7 Tanker Employment

7.7.1 Manning constraints and limited budgets have created shortfalls in the number of trained AAR personnel and equipment available to manage AAR planning during Joint Air Operations. This capability would be enhanced by addressing the following factors:

7.7.1.1 Tactics Employment Manual. The development of a NATO Tactics Employment Manual would satisfy the requirement for guiding AAR planners through the AAR planning process when building the ATO, particularly when using ICC to accomplish this task. The shortfall of AAR planners during NATO exercises has highlighted this problem, and this manual would provide a basic understanding of AAR concepts and tools for a planner with little-to-no experience in AAR operations.

7.7.1.2 CAOC Planner Training. The lack of an education and training standard for AAR planners has been identified as a problem for NATO-led air operations. This issue is currently left to the individual CAOC's initiative to be resolved. As an example, CAOC Uedem has developed an AAR track for the Air Operations Training Course (AO&TC), which will provide greater situational awareness for AAR planners, especially if it were used in conjunction with the Tactics

Employment Manual. The basic framework for this courseware could be provided by the HQ USAF Mobility Operations School Detachment 1, which certifies all US AAR CAOC planners.

7.7.1.3 Tanker Planning Toolkit. The integration of tanker planning toolkit software with current and future CAOC C2 systems could provide the necessary tools to make AAR planning quicker and easier. The AAR toolkit could assist CAOC planners with an enhanced picture and eliminate many of the extraneous steps required during AAR planning.

7.8 AAR Clearances and Currencies

7.8.1 In the past, the clearance process was simple because both the tanker and receiver aircraft were either developed by the same company or belonged to the same nation. As the possible number of tanker and receiver combinations grow, the AAR clearance process is becoming more important. The AAR community is faced with the challenge of how to accomplish these clearances in the most economical manner. The development of standardised and streamlined processes that are agreed upon by all nations involved is, therefore, critical.

7.8.2 An AAR Clearance comprises many different functional areas, all of which must be in place before two platforms can execute AAR. The functional areas include legal, financial, technical (engineering), aircrew training, minimum maintenance standards and political clearances. Currently, the ARSAG AAR Clearance Focus Group is aimed at standardising the Technical Clearance process to ensure that all aircraft data and test points are common. If this can be achieved, it will reduce the time taken to carry out a technical clearance, and may result in read-across clearances being given for nations operating the same or similar aircraft. Standardising the data requirements and sharing this data will speed up the AAR Clearance process and save money by reducing testing requirements.

7.8.3 Currency Requirement and Aircrew Training. Once a technical AAR clearance has been obtained, a common NATO definition of minimum requirements, in terms of time, sorties and hook-ups, is necessary to maintain currencies for receiver aircrews. Until now, this issue had been handled nationally or bilaterally between nations because the number of tanker and receiver combinations was fewer and easier to manage. In the near future, there will be three factors which could drive the need for a standardised NATO currency approach; the increasing number of tanker types, emerging interests of commercial providers and finally, due to NATO enlargement, the greater imbalance between both countries owning tankers and countries with only receivers. To guarantee interoperability in an operational environment, NATO will need to look for the maximum numbers of aircrew current in AAR procedures in the maximum numbers of tanker types. A currency read-across between tanker aircraft types and nations is necessary to counter the increasing impact on training effort and cost due to increased tanker and receiver combinations. An aircrew qualification and currency would therefore be based on tanker type rather than tanker flag.

1. The international clearance process is currently limited to ensuring AAR compatibility of tanker and receiver aircraft. The reference for this process is ATP-56 (B).
2. Last decision taken in January 2011 is to publish the document as ATP-3.3.4 to cover the gap between AJP-3.3 and ATP-3.3.4.2.
3. Edition 5 of STANAG 3447 is expected to be submitted for ratification during 2011.
4. The site picture is the view from the receiver's cockpit of the AAR system on the back of the tanker.
5. Signal Lights are discussed in Annex C to this Flight Plan.

CHAPTER VIII

Areas of Concern and Recommendations for Future Work

8.1 Revitalisation of the PCC

8.1.1 In 2002, NATO recognised an AAR shortfall through the PCC. Although the operational need was identified, financial considerations discouraged development of the capability, and the PCC remains unfulfilled and ignored in this area.

8.1.2 The AAR shortfall identified could increase in the future. On one hand, the overall number of tankers in NATO Nations is going to decrease, although these aircraft will be more capable. On the other, the total AAR requirement may increase. Fighter aircraft, with shrinking numbers, must not provide the only consideration when determining this requirement, but other aircraft types must also be added to the receiver list (UAS, AT, Rotary Wing, Tilt Rotor, and so on).

8.1.3 Recommendation: NATO Strategic Commanders should re-introduce discussion on the identified AAR shortfall at the corresponding national level, and press for solutions to develop more AAR capability available to NATO. Different approaches can be looked at to develop increased AAR capability, ranging from traditional procurement, to more innovative solutions, such as CAARIS or those similar to the multinational Strategic Airlift Capability.

8.2 Emphasise Basing Close to Operations

8.2.1 Historically, war and contingency planning highlighted AAR aircraft as HVAA, and recommended minimal safe distances from the area of operations for basing AAR aircraft. In the future, the basing concept of AAR assets may change due to new considerations, such as improved threat awareness, defensive suites and extended Force Protection techniques. Furthermore, NATO-led EO should drive the necessity to produce a global database with tanker-suitable potential Forward Operation Bases (FOB) to minimise reaction time when deploying.

8.2.2 Recommendation: New Basing distance guidelines should be revaluated to include the aforementioned factors. Defence and operational planning should therefore be based on these new requirements.

8.3 UAS AAR

8.3.1 In the near future, AAR will be conducted from UAS to UAS or between manned and UAS aircraft. It remains to be seen what technologies and systems will be adopted, but operational utility, safety, cost, and interoperability will be the key considerations.

8.3.2 Recommendation: To the extent that NATO (especially the NATO Standardisation Organisation (NSO) and the Conference of National Armaments Directors (CNAD)) can influence national UAS AAR development, the Alliance should emphasise the practical benefits of interoperability with other AAR and C2 systems to avoid developing and requiring specialised resources, procedures and airspace. UAS AAR will bring a new age of development of concepts and how NATO should understand UAS AAR.

8.4 Efficient AAR Planning

8.4.1 Improvements in AAR planning automation and dynamic replanning have led to greater efficiency in AAR planning. Additional efficiencies may be realised through improved analysis and AAR management in sustainment operations. Small-scale efficiencies cannot offset significant shortfalls in numbers of aircraft or aircrews, but the resources saved can be redirected toward other operational requirements or for reserve and reconstitution.

8.4.2 Recommendation: Technologies and techniques, to include efficiency as a basing consideration, current operations analysis and assessment, and fuel consolidation, should be institutionalised and incorporated into all Alliance AAR planning and execution. New concepts, such as Consolidation and Force Extension, should be used by NATO planners. These methods can; improve efficiency, even where operations are not constrained by AAR resources, identify reserve capacity and facilitate or accelerate reallocation.

8.5 Policy and Doctrine

8.5.1 The current AAR Policy at the strategic level, MCM 217, is in the review stage at the International Military Staff (IMS). There is also no Alliance promulgated operational AAR doctrine. The only NATO approved terminology, from the ATP-56(B) AAR Manual, is at the tactical level and therefore addresses techniques and procedures, not employment concepts, roles or doctrine at the higher levels of command. Only Study Draft 4, AJP 3.3.4 includes Alliance operational doctrine for AAR. This document was built through a combination of Allied thinking on a capability and its employment, defining concepts, and providing a common foundation for Alliance planners, operators, and commanders. As interchangeable roles, receiver capable tankers, and network-enabled AAR provide more options for efficient, effective execution across tanker fleets and on individual sorties, Alliance doctrine development can identify and develop optimal employment concepts. Thus Operational Doctrine and Policies should be the first step toward NATO EO.

8.5.2 Recommendation: NATO should promulgate AAR operational doctrine and update the MCM 217 Policy. Both documents are completed. If NATO has to apply AAR within EO, Policy and Common Doctrine will be mandatory.

8.6 Interchangeable and Secondary Roles for Planning

8.6.1 Additional capabilities for AAR platforms, such as AT and C4ISTAR, offer greater benefits in flexibility to Air Operations at a relatively low developmental and acquisition cost. Caution will need to be exercised to manage these dual capabilities effectively in EO, where mission prioritisation must be clearly defined during the planning process.

8.6.2 Recommendation: Force planners and Defence planners should recognise that aircraft can only be identified for one role during the declaration process. During the operational planning process, Joint Force Commanders will need to provide clear direction on prioritising with operational planners the mission requirements for AAR aircraft with interchangeable roles.

8.7 Procedural Interoperability

8.7.1 Ratification and Implementation of ATP-56(B) as the single AAR Manual for NATO has been a significant step forward. Continued interoperability and effectiveness require balance between attaining the widest possible acceptance of changes, and timely implementation of changes to meet operational requirements. STANAGs dealing with technical and operative AAR issues are emerging; 7215 and 7218 (STUDY phase) will give a good degree of interoperability for the new tankers.

8.7.2 Recommendation: Maintaining an agreed and effective manual will require careful attention, good staff coordination and considerable effort to achieve workable compromises. Refuelling nations should pay careful attention to initiate change proposals as soon as a requirement is identified. National AAR Panel representatives must work diligently with other nations, and within their national forces, to achieve mutually agreeable solutions so that changes can be implemented quickly. NATO promulgation of new STANAGs is necessary with the entry into service of new AAR platforms.

8.8 Training and Exercises

8.8.1 National training programs meet AAR procedural training requirements, but there is no realistic, challenging AAR exercise activity reflecting an operational environment. Operational deployment, interoperability and C2 challenges are not addressed during these exercises.

8.8.2 Recommendation: Joint Force Commanders emphasise realistic and challenging AAR activity in NATO exercises to address the same challenges that would be encountered during conflict or crisis operations, such as; operations from forward operating bases, AAR between aircraft without the traditional tanker-receiver relationship, and dynamic tasking and retasking.

8.9 Clearance Process

8.9.1 An AAR clearance is not only about technical compatibility between receiver and tanker aircraft, but also concerns financial, legal, political and currency/training issues. In the future, a clearance mechanism could be developed if nations establish a common means by which to communicate amongst each other. Transparency amongst individual nation's clearance processes is a necessity before a common approach can be identified.

8.9.2 Recommendation: The National Annexes within ATP-56 (B) provide a means by which NATO Nations can publish their AAR clearance standards. If a common clearance and currency mechanism can be developed for nations to share a standardised process, greater interoperability would exist amongst nations.

[M] © Aeronautica Italiana

KC-130J refuelling an Italian EF-2000 Typhoon.

CHAPTER IX

Closing Remarks

AAR has been, and will be, a critical enabling capability for Joint Air Power employment and deployment. This Flight Plan has discussed core concerns and challenges affecting AAR. It is of the utmost importance that NATO, at all levels, faces these issues and encourages nations, industry and other AAR agencies, to provide the necessary means to maintain this capability.

Building AAR capability requires both time and money. An AAR comprehensive plan needs to focus on the right concerns, which, if ignored, could severely hamper this capability. These include; number of tankers available, updated policy and doctrine development, AAR clearances and aircrew currencies. If NATO Nations are not committed to solving these issues, NATO might lose its ability to respond to operational challenges in a timely manner, and interoperability in AAR operations might also be compromised.

NATO's Level of Ambition cannot be achieved, or maintained, by decreasing AAR availability. NATO deployment for EO might be slower, more complex and expensive. AAR effects, such as range, persistence and concentration of force, would also be reduced, precluding Air Power's ability to fully respond in an operational environment.

NATO has taken the first steps toward standardising AAR equipment through the development of STANAGs. In the future, a failure to develop and implement a common NATO policy on AAR clearances and aircrew currency requirements, which would need to be flexible enough to avoid overloading National training efforts, will endanger interoperability during the most critical moment, when Air Power is exploited during combat operations.

Finally, NATO faces other challenges which will shape efforts to maintain and develop current and future AAR capabilities. These include; UAS AAR, efficient AAR planning, basing options and interchangeable/secondary roles for tankers. These challenges and the aforementioned concerns must drive NATO efforts to maintain and develop this key enabling capability.

AAR may not be very visible in peacetime, is expensive to acquire and therefore difficult to build; however, it is absolutely necessary while engaged in combat operations, especially during both major conflicts and those of an expeditionary nature.

ANNEX A

NATO Nations' AAR Capabilities

The following information is unclassified and has been obtained by JAPCC members as a result of participation in different meetings, forums and workshops regarding Air-to-Air Refuelling. This list is current as of Feb 11 and is liable to changes or future updates.

Nation	AAR Receivers	Current Tanker Capability	Future Tanker Plans
ALBANIA	NO		
BELGIUM	YES		MRTT > 2012. No Decision.
BULGARIA	NO		
CANADA	YES	CC150 CC130	CC150 CC130
CROATIA	NO		
CZECH REPUBLIC	YES		
DENMARK	YES		
ESTONIA	NO		
FRANCE	YES	C-135FR KC-135R C-160NG	A-400M (Wing AAR Kit) A-400M (HDU Kit) MRTT
GERMANY	YES	A310MRTT	A-400M (Wing AAR Kit) A310MRTT
GREECE	YES		Possible MRTT. No Decision.
HUNGARY	YES		
ICELAND	NO		
ITALY	YES	KC-767A KC-130J	KC-767A KC-130J
LATVIA	NO		
LITHUANIA	NO		
LUXEMBOURG	NO		

Nation	AAR Receivers	Current Tanker Capability	Future Tanker Plans
NETHERLANDS	YES	KDC-10	KDC-10
NORWAY	YES		
POLAND	YES		
PORTUGAL	YES		
ROMANIA	NO		
SLOVAKIA	NO		
SLOVENIA	NO		
SPAIN	YES	B-707 KC-130H	A-400M (Wing AAR Kit) A-400M (HDU Kit)
TURKEY	YES	KC-135	KC-135
UNITED KINGDOM	YES	TriStar VC-10	A-330MRTT (FSTA)
UNITED STATES	YES	KC-135R KC-10A MC-130P HC-130P/N	KC-X KC-135R KC-10A MC-130P/W MC-130J

ANNEX B

NATO Tanker Aircraft Characteristics

Introduction

This Annex is a catalogue of current and future AAR assets of NATO Nations. The Annex not only displays the current status of AAR capabilities, listing details for each asset, but also highlights new AAR aircraft coming online within NATO Nations, such as the A330 (United Kingdom) or B767 (Italy).

Given the evolving nature of the topic, more updates or changes may be expected after the publication of this document.

Each entry contains four tables. The first table provides general aircraft information. The second table contains basic AAR information: AAR system, AAR equipment, AAR Fuel System Pressure rate, and the AAR altitude and speed envelopes at which AAR can be conducted. The third table provides aircraft fuel load, fuel burn and fuel type, which can be used to calculate overall capability. Fuel load and burn are important planning factors used to determine fuel offload requirements. Additional information is provided as 'Features' in the final table.

The information and photos contained within this Annex come from open Sources.

B-707

Manufacturer
Boeing Company

Variants
B-707 T/T

Quantity in NATO Nations
Spain: 2 (Air Force)

Spanish B-707 refuelling a EF-18 Hornet.

General Aircraft Information

Wingspan	Length	Weight MTOW
145 ft 9 in (44,42 m)	145 ft 6 in (44.35 m)	333,600 lb (151,320 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Probe and drogue	Two (2) Pods	< 3.5 bars (50 psi)	3,300 lb/min (1,500 kg/min)	1500 ft to FL 350	200–350 KIAS

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Primary Fuel Type
156,200 lb (71,000 kg)	16,300 lb/hr (7,400 kg/hr)	F34 (JP8)

Features

The B-707 is a dual role aircraft for AT and AAR. It has 2 drogue-equipped refuelling stations, one mounted on each wing, outboard of the engines.

- One B-707 can be configured for passengers (173 maximum) or freight (11 pallets) or a combination of both. The other can carry only passengers (163 maximum).

KC-130

Manufacturer
Lockheed Martin

Variants
KC-130H, KC-130T, CC130T

Quantity in NATO Nations
Canada: 5 CC130T (Air Force)
Spain: 5 KC-130H (Air Force)
USA: 28 KC-130T (US Marine Corps);
as of April 2010, the US KC-130 recapitalisation program was changing T models into J models.

Spanish C-295 in pre-contact position to refuel from a KC-130.

General Aircraft Information

Wingspan	Length	Weight MTOW
132 ft 7 in (40.4 m)	97 ft 9 in (29.8 m)	155,000 lb (70,300 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope (KIAS)
Probe and drogue	Two (2) Pods	50 +/– 5 psi (CC130T/KC-130T) 45 +/– 5 psi (KC-130)	1,000–2,000 lb/min (450–900 kg/min)	1000 ft – FL250 (CC130T) 1500 ft – FL250 (KC-130H) 500 ft – maximum service ceiling (KC-130T)	200–250 (CC130T), 195–250 (KC-130H), 105–120 (low speed drogue) 185–250 (high speed drogue) (KC-130T)

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
45,000 lb (20,140 kg)	6,000 lb/hr (2,727 kg/h)	F34, F35, F40, F44 (CC130T/KC-130T); F34 (KC-130T)

Features

KC-130 is a multi-role tactical tanker/transport. It has two removable pods under wing located halfway between each wing-tip and the outboard engine.
CC130T – during overweight conditions, Maximum Fuel Load is 83,100 lb (37,770 kg). The C-130J will replace the current aging C-130 fleet; first aircraft due in 2010, no AAR capability in replacement.
KC-130H – with an internal auxiliary tank, total fuel loads are normally up to 72,000 lb (32,662 kg), with an overload weight capacity of 84,900 lb (38,500 kg).
KC-130T – provides in-flight refuelling to tactical aircraft and helicopters, as well as rapid ground refuelling when required. US Marine Reserve operates the T model.

KC-130J

Manufacturer
Lockheed Martin

Variants
KC-130J

Quantity in NATO Nations
Italy: 5 Kits and total of
11 C-130J (Air Force)
USA: 36 KC-130J (US Marine Corps);
as of April 10, US Marine KC-130 recapitalisation program goal is 79 KC-130Js.

Italian KC-130J refuelling a French EC725 Caracal.

General Aircraft Information

Wingspan	Length	Weight MTOW
132 ft 7 in (40.4 m)	97 ft 9 in (29.8 m) 112 feet, 9 inches (34.69 meters) C130J-30	155,000 lb (70,300 kg) 164,000 lb (74,393 kg) C130J-30

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Probe and drogue	Two (2) Pods	–	300 Gal/min	MSL – FL290	105–130 KIAS (low speed drogue) 185–250 KIAS (high speed drogue)

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Primary Fuel Type
57,500 lb (8,455 US Gal)	–	–

Features

The KC-130J is a transport and tanker capable of tactical airlift and AAR operations. It also retains the capability for worldwide delivery of combat troops, personnel, and cargo via airdrops or air-land operations to austere sites with limited resources.
• It has two removable pods underwing, located halfway between each wing-tip and the outboard engine;
• The J-model tanker is capable of refuelling both Fixed Wing and Rotary Wing aircraft;
• An additional fuselage tank can carry 24,392 lb (3,600 US Gallons).

HC/MC-130

Manufacturer
Lockheed Martin

Variants
HC-130, MC-130 E/H/P/W

Quantity in NATO Nations
USA: 69 HC/MC-130 (AFSOC);
20 MC-130Hs, 12 MC-130Ws,
14 MC-130Es, MC-130Ps (USAF)

A USAF MC-130P about to refuel a MH-53 PAVE LOW.

General Aircraft Information

Wingspan	Length	Weight MTOW
132 ft 7 in (40.4 m)	97 ft 9 in (29.8 m)	155,000 lb (70,300 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure[1]	AAR Fuel System Transfer Rate[2]	AAR Altitude Envelope	AAR Speed Envelope
Probe and drogue	Two Pods – Sargent Fletcher System (SFS) or Integrated Air Refuelling System (IARS)	5–28 psi (Tankers with SFS) Up to 120 psi[3] kg/min (Tankers with IARS)	462.7 kg/min or 1,020 lb/min; 150 GAL (SFS) or up to 879 kg/min or 1,937 lb/min (IARS)	1000 ft to maximum service ceiling	105–120 KIAS (low speed drogue) 185–215 KIAS (high speed drogue) 110–180 KIAS (variable drag drogue)

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
50,000 lb (22,680 kg) E model; 63,000 lb (28,576 kg) W model	6,000 lb/hr (2,720 kg/hr or 960 GAL) MC-130P/W and HC-130; 7,000 lb/hr (3,175 kg/hr 1120 GAL) MC-130H	F34, F40, F44, F35, Jet A, Jet B

Features

The HC/MC-130 is a specially modified C-130 series airframe designed to support personal recovery (PR) and Special Operations Forces (SOF) missions. It is AAR-capable as a receiver and tanker.
• HC-130 and MC-130P have an additional internal fuselage tank that can carry 81,120 lb (36,795 kg);
• MC-130H 'Talon II' secondary mission is SOF AAR;
• MC-130E 'Combat Talon I' secondary Mission is SOF AAR;
• MC-130P 'Combat Shadow' primary mission is SOF AAR;
• MC-130W 'Combat Spear' secondary mission is SOF AAR;
• Tanker Recapitalisation program projects 37 MC-130J converted to modified KC-130J (as of Apr '10).

1. Pressure for one receiver; for two receiver simultaneous AAR – pressure rates should be divided by two.
2. Rates for one receiver; for two receiver simultaneous AAR, pressure rates should be divided by two.
3. At the delivery pressure, the helicopter tanks may be filled to top off with no valve close restriction at 35 psi (MH-53J/M, MH-60K/L; HH-60G and MH-47E) and 20 psi (MH-47D).

VC 10 CMk1K

Manufacturer
Vickers-Armstrongs Limited

Variants
–

Quantity in NATO Nations
UK: 8 VC 10 CMk1K (RAF)

RAF VC-10 refuelling two F3s.

General Aircraft Information

Wingspan	Length	Weight MTOW
146 ft 2 in (44.55 m)	158 ft 8 in (48.36 m)	334,878 lb (151,900 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Probe and drogue	Two (2) Pods	3.5 bars (50 psi)	3,000 lb/min (1,360 kg/min)	MSL to 35000 ft	235–310 KIAS

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
154,000 lb (70,200 kg)	16,000 lb/hr (7,000 kg/hr)	F34, F35, F40, F43, F44

Features

The VC10 CM1k1K is a long-range AAR and air transport aircraft modified from the civilian VC10 by the RAF. It is AAR capable as receiver and tanker.
• It has two wings pod mounted;
• It can carry 136 Passengers, 8 Pallets, or a combination thereof.

VC 10 K

Manufacturer
Vickers-Armstrongs Limited

Variants
VC 10KMk3 and VC 10KMk4

Quantity in NATO Nations
UK: 4 VC 10KMk3 and 1 VC 10KMk4 (RAF)

VC 10 K.

General Aircraft Information

Wingspan	Length	Weight MTOW
146 ft 2 in (44.55 m)	158 ft 8 in (48.36 m)	334,878 lb (151,900 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Probe and drogue	Two (2) Pods and Centreline drogue	3.5 bars (50 psi)	Pods: 3,000 lb/min (1,360 kg/min) Centreline: 4,800 lb/min (2,280 kg/min)	MSL to 35000 ft	235–310 KIAS

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
185,000 lb (83,500 kg)	16,000 lb/hr (7,000 kg/hr)	F34, F35, F40, F43, F44

Features

The VC 10 K is a long-range tanker modified from the civilian VC 10 by the RAF. It is AAR capable as receiver and tanker.
• VC 10KMk3 has a permanent fuselage tank.

C-160NG

Manufacturer
Aerospatiale, Messerschmitt-Bolkow and VFM-Fokker.

Variants
–

Quantity in NATO Nations
France: 14 (Air Force)

French C-160 refuelling a M-2000.

General Aircraft Information

Wingspan	Length	Weight MTOW
40.00 m	32.40 m	112,435 lb (51,000 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Probe and drogue	1 Centreline hose	3.5 bars (50 +/- 5 psi)	Maximum: 2,650 lb/min (1,200 kg/min) Minimum: 880 lb/min (400 kg/min)	Surface to 18000 ft	160–220 KIAS

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
30,870 lb (14,000 kg)	–	F34

Features

The Transall C-160 is a military transport aircraft built through a consortium of French and German aircraft manufacturers for the Air Forces of these Nations and that of South Africa. The C-160 Nouvelle Generation (NG/New Generation) is a modification for AAR. From the total number of 22 NG's, 14 are tankers (if equipped with the left side of Hose Drum Unit (HDU) AAR pod). All of them are receiver-capable.

- AAR below 1500 ft AGL has to be approved first by French authorities. Below 5,000ft, weather conditions may influence hose stability.

KC-135

Manufacturer
Boeing Company

Variants
KC-135R/E

Quantity in NATO Nations
France: 3 KC-135R (Air Force)
Turkey: 7 KC-135R (Air Force)
USA: 419 (Air Force)

USAF KC-135.

General Aircraft Information

Wingspan	Length	Weight MTOW
41 ft 8 in (12.70 m)	136 ft 3 in (41.53 m)	322,500 lb (146,000 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Boom; Probe and drogue	Centreline boom; BDA &/or 2 Pods (Multi-Point Refuelling System (MPRS) – USA only)	3.5 +/- 0.35 bars (50 +/- 5 psi) for both systems	Boom: 6,000 lb/min (2,722 kg/min) BDA: 2,800 lb/min (1,270 kg/min) Pods (MPRS): 2,680 lb/min (1,216 kg/min)	Boom & BDA: MSL – greater than 30000 ft Pods (MPRS): 5000 ft–35000 ft	Boom & BDA: 200–320 KIAS Pods: 220–300 KIAS

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
KC-135E: 187,000 lb (84,870 kg) KC-135R: 203,000 lb (92,060 kg)	10,000 lb/h	F34, F35, F40, F44

Features

The KC-135 is derived from the original Boeing 367–80 (it was the basic design for the commercial Boeing 707). As such, it has a narrower fuselage and is shorter than the Boeing 707 jetliner.

- There is one centreline mounted flyable boom for boom-type refuelling. The boom can be modified to refuel probe-equipped aircraft by fitting a Boom Drogue Adapter; the BDA can only be fitted or removed on the ground;
- French and Turkish KC-135R aircraft are equipped only with Boom or BDA;
- The USAF has a large fleet of KC-135, with several variants in service; the main differences are in fuel capacity and engine fitting. A small number of KC-135s are fitted with a receptacle to receive fuel from boom-equipped tankers. Approximately twenty (20) aircraft can be fitted with two wingtip-mounted MPRS pods.

C-135FR

Manufacturer
Boeing Company

Variants
KC-135

Quantity in NATO Nations
France: 11 (Air Force)

French C-135FR refuelling M-2000.

General Aircraft Information

Wingspan	Length	Weight MTOW
130 ft 10 in (39.88 m)	136 ft 3 in (41.53 m)	322,500 lb (146,000 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Boom; Probe and drogue	Centreline boom; BDA & 2 Pods	3.5 +/- 0.35 bar (50 +/- 5 psi)	Boom: 6,000 lb/min (2,725 kg/min) BDA: 2,800 lb/min (1,275 kg/min) Pods: 2,640 lb/min (1,200 kg/min)	Boom & BDA: MSL – 45000 ft Pods: MSL – 35000 ft	Boom & BDA: 200–350 KIAS Pods: 240–325 KIAS

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
Without Pods: 185,000 lb (83,900 kg) With Pods: 192,000 lb (87,100 kg)	12,000 lb/hr (5,500 kg/hr)	F34, F35, F40, F44

Features

The French AF has two variants of KC-135s in service: C135FR and KC135R. Both are equipped with one centreline-mounted flyable boom. A BDA can be installed for probe-equipped aircraft. Only C-135FR aircraft are fitted with 2 wingtip AAR pods.

A-310 MRTT

Manufacturer
Airbus

Variants
CC150T Polaris (CAN AF)

Quantity in NATO Nations
Canada: 2 (Air Force)
Germany: 4 (Air Force)


© Luftwaffe/Marc Thöne

Luftwaffe A-310 MRTT refuelling EF-2000 Eurofighters.

General Aircraft Information

Wingspan	Length	Weight MTOW
144 ft (43.9 m)	155 ft 5 in (47.4 m)	361,554 lb (163,998 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Probe and drogue	2 Pods	50 +/- 5 psi	2,805 lb/min (1,270 kg/min)	5000 ft AGL to 35000 ft	200–300 KIAS

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
158,200 lb (71,900 kg)	5,400 kg/hr	F34

Features

The A-310 MRTT is a military derivative of the Airbus A-310 airliner. It is designed as a dual-role air refuelling tanker and cargo transport aircraft.
The aircraft is equipped with two under wing-mounted AAR pods located about 3.5 m (12 ft) from the wingtip.
• In cargo configuration, the A-310 can transport 214 Passengers or 79,366 lb cargo (36,000 kg) with no fuel.

L-1011 TriStar

Manufacturer
Lockheed

Variants
TriStar KMk 1, KCMk1, L1011 TriStar

Quantity in NATO Nations
UK: 6 (RAF), 2 KMk1, 4 KCMk1

A Royal Air Force TriStar Refuels two Tornado F3s during operations in the Middle East.

General Aircraft Information

Wingspan	Length	Weight MTOW
50.09 m (164 ft 4 in)	50.05 m (164 ft 3 in)	540,000 lb (245,000 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Probe and drogue	Single hose centreline	Not to exceed 3.5 bars (50 psi)	2,200 kg/m at 40 psi (2.75 bars)	MSL to 35000 ft	200–320 KIAS

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
260,500 lb (128,000 kg)	18,000 lb/hr (8,000 kg/hr)	F34, F35, F40, F43, F44

Features

The Royal Air Force operates nine L-1011-500s TriStar, six ex-British Airways and three ex-Pan Am aircraft. The TriStar provides long range capability to the RAF through its AT and AAR role.
• Six out of nine RAF TriStars are AAR-capable;
• RAF operates two versions of the TriStar for AAR: two TriStar KMk1 and four TriStar KCMk1;
• Both versions have single hose and two centreline Hose Drum Units (HDU) mounted side-by-side, recessed into the lower rear fuselage of the aircraft; only one hose is available for use at a time;
• KMk1 versions can operate with Passengers (187) and has no freight door. KCMk1 version can operate with 20 pallets or 20 passengers, or a combination of both.

KC-10

Manufacturer
McDonnell Douglas

Variants
–

Quantity in NATO Nations
USA: 59 (Air Force)

USAF KC-10 refuelling a Hornet over Afghanistan.

General Aircraft Information

Wingspan	Length	Weight MTOW
165 ft 4.5 in (50 m)	181 ft 7 in (54.4 m)	590,000 lb (267,600 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Boom; Probe and drogue	Centreline boom; Centreline hose & 2 Pods (WARP)	3.5 +/- 0.35 bar (50 +/- 5 psi)	Boom: 8,000 lb/min (3,630 kg/min) Centreline Hose: 4,000 lb/min (1,820 kg/min) Pods (WARP): 2,400 lb/min (1,100 kg/min)	Boom: MSL – 37000 ft Centreline & Pods (WARP): MSL – 35000 ft	Boom: 180–350 KIAS Centreline: 200–280 KIAS Pods (WARP): 230–300 KIAS

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
340,000 lb (154,240 kg) (limited on takeoff by MTOW)	18,000 lb/h (8,170 kg/h)	F34, F35, F40, F44

Features

The USAF has 59 KC-10 Extenders in service. All KC-10s are equipped with an AAR boom and centreline drogue; many are fitted for Wing Air Refuelling Pods (WARP). The aircraft has a receptacle for receiving fuel from boom-equipped tankers, and has a reverse fuel pumping capability.

- There is one centreline flyable boom for boom-type refuelling. Additionally, a Sargent Fletcher fuselage-mounted hose drum unit is fitted for probe and drogue operation. Approximately twenty (20) aircraft have the capability to be fitted with two WARPs;
- The KC-10 Extender is derived from the civilian DC-10-30 airliner;
- The KC-10 can be used for both the AAR and Air Transport roles.

KDC-10

Manufacturer
McDonnell Douglas

Variants
KC-10A

Quantity in NATO Nations
The Netherlands: 2 (Air Force)

RNLAF KDC-10 refuelling F-16s.

General Aircraft Information

Wingspan	Length	Weight MTOW
165 ft 4.5 in (50 m)	181 ft 7 in (54.4 m)	590,000 lb (267,600 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Boom	Centreline boom	3.5 bar +/- 0.35 (50 +/- 5 psi)	5,000 lb/min (2,270 kg/min)	MSL – 37000 ft	180–350 KIAS

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
244,000 lb (110,993 kg)	18,000 lb/h (8,170 kg/h)	F34, F35, F40, F44

Features

The KDC-10 is functionally equivalent to the USAF KC-10A series aircraft except that the aircraft has no receptacle for receiving fuel from boom equipped tankers.
• The two Dutch KDC-10s, T-264 'Prins Bernard' and T-235 'Jan Scheffer', are all used for AAR and Air Transport.

SUPER ETENDARD MODERNISE (SEM)

Manufacturer
Dassault-Breguet

Variants
–

Quantity in NATO Nations
France: Unknown number of kits (Navy)

French Super Etendard making buddy-buddy refuelling.

General Aircraft Information

Wingspan	Length	Weight MTOW
9.60 m (31 ft 6 in)	14.31 m (45 ft 11½ in)	26,455 lb (12,000 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Probe and drogue	Centreline pod	3.2–3.5 bar (46–51 psi) for the F34, F42/F40	660–800 lb/min (300–400 kg/min)	MSL to 25000 ft	250–280 KIAS

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
5,290 lb (1,800 kg) (at 100 NM from the Carrier)	No information	F34 or F42/F40

Features

SEM uses buddy-buddy for AAR.
- The SEM evolved from the Dassault Étendard IV;
- The French Navy operates an upgraded version of the Super Etendard;
- The Super Etendard Modernisé is fitted with an externally carried Intertechnique AAR Pod;
- The maximum offload is taken at 100NM from a Carrier or base.

RAFALE M

Manufacturer
Dassault

Variants
–

Quantity in NATO Nations
France: Unknown number of kits (Navy)

Two French Rafales making buddy-buddy refuelling.

General Aircraft Information		
Wingspan	**Length**	**Weight MTOW**
10.80 m (35.4 ft)	15.27 m (50.1 ft)	54,000 lb (22,200 kg)

AAR Information					
AAR System	**Equipment**	**AAR Fuel System Pressure**	**AAR Fuel System Transfer Rate**	**AAR Altitude Envelope**	**AAR Speed Envelope**
Probe and drogue	Centreline pod	3.2–3.5 bar (46–51 psi) for F34 and F42/F40 fuel types	660–800 lb/min (300–400 kg/min)	MSL to 30000 ft	250–300 KIAS

AAR Fuel System		
Maximum Fuel Load	**Average Fuel Burn**	**Fuel Type**
11,750 lb (4,000 kg) (at 100 NM from the Carrier)	–	F34 or F42/F40

Features

Rafale M uses buddy-buddy for AAR. The French Navy (FN) operates Rafale M fitted with an external AAR Pod. For training purposes, the minimum altitude is 5000 ft. The maximum offload is taken at 100 NM from the Carrier or base.

S-3B Viking

Manufacturer
Lockheed

Variants
–

Quantity in NATO Nations
US: USN/USMC (unknown number of kits)

A S-3B Viking refuels another S-3B.

General Aircraft Information

Wingspan	Length	Weight MTOW
Unfolded: 68 ft 8 in (20.93 m) Folded: 29 ft 6 in (9.00 m)	53 ft 4 in (16.26 m)	52,539 lb (23,831 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Probe and drogue	Centreline pod	30–60 psi (2.5–3.8 bar)	1,370 lb/min (620 kg/min)	500 ft to 25000 ft	175–275 KIAS

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
13,500 lb (6,120 kg)	–	JP5 (F44), JP8 (F34), JP4 (F40)

Features

- The S-3B Viking uses buddy-buddy for AAR;
- It carries an AAR pod to fulfil the tanker role.

F/A-18E/F TANKER

Manufacturer
McDonnell Douglas

Variants
–

Quantity in NATO Nations
US: Unknown number of kits (USN/USMC)

Buddy-buddy refuelling between F/A-18E Super Hornets.

General Aircraft Information

Wingspan	Length	Weight MTOW
43 ft (13.1 m)	60 ft (18.3 m)	51,550 lb (23,400 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Probe and drogue	Centreline pod	35–60 psi (2.5–3.8 bar)	1,370 lb/min (620 kg/min)	500 ft to 35000 ft	180–300 KIAS

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
24,500 lb (11,113 kg) (based on a 5-wet configuration)	No Information	JP5 (F44), JP8 (F34), JP4 (F40)

Features

- The F/A-18E/F Super Hornet can be converted to tanker mode by fitting an externally carried AAR pod. It can be equipped with an Aerial Refuelling System or 'buddy store' for the refuelling of other aircraft;
- The ARS includes an external 330 US gallon (1,200 L) tank with hose reel on the centerline along with four external 480 US gallon (1,800 L) tanks and internal tanks for a total of 29,000 pounds (13,000 kg) of fuel on the aircraft.

PA 200 Tornado

Luftwaffe PA 200 Tornados preparing for buddy-buddy air refuelling.

Manufacturer
Panavia (a tri-national consortium consisting of British Aerospace (previously British Aircraft Corporation) of the UK, MBB of West Germany, and Alenia Aeronautica of Italy)

Variants
- *PA 200, IDS* (Interdictor/Strike) fighter-bomber; the suppression of enemy air defenses;
- *ECR* (Electronic Combat/Reconnaissance);
- *ADV* (Air Defense Variant) interceptor.

Quantity in NATO Nations
Germany: Unknown number of kits
Italy: Unknown number of kits

General Aircraft Information

Wingspan	Length	Weight MTOW
13.91 m at 25° wing sweep	16.72 m (54 ft 10 in)	61,700 lb (28,000 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Probe and drogue	Centreline pod	35–55 psi	13,000 lb/min (600 kg/min)	German: 5000 ft to 20000 ft Italian: MSL to 20000 ft	German: 230–320 KIAS Italian: 200–320 KIAS

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
German: 12,000 lb (5,500 kg) under optimum conditions. Italy: Maximum 17,630 lb (8,000 kg)	No Information	F34 (Italian and German models) F35, F40 (German)

Features

- The Tornado can be fitted with a refuelling pod at the centreline fuselage station;
- It uses buddy-buddy for AAR.

KC-767

Manufacturer
Boeing Company

Variants
B767

Quantity in NATO Nations
Italy: 4 (Air Force)

Italian Air Force Boeing KC-767 Tankers.

General Aircraft Information

Wingspan	Length	Weight MTOW
156 ft 1 in (47.6 m)	159 ft 2 in (48.5 m)	395,000 lb (186,880 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Boom; Probe and drogue	Centreline boom (2 pods)	–	–	–	–

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
Over 202,000 lb (91,600 kg)	–	–

Features

- The Boeing KC-767 is a military AAR and strategic transport aircraft developed from the Boeing 767-200ER;
- The KC-767 currently being used by the Italian and Japanese Air Forces, who have ordered four tankers each. In cargo or passenger configurations, these aircraft can carry up to 190 passengers, 19 463L pallets or 19 patients.

KC-30B/C

Manufacturer
Airbus

Variants
KC-30A (Australian version),
KC-30B, KC-30C, A330

Quantity in NATO Nations
UK: 14 leased (RAF)

RAAF KC-30A refuelling Portuguese F-16s.

General Aircraft Information

Wingspan	Length	Weight MTOW
60.3 m (198 ft)	58.80 m (193 ft)	514,000 lb (233,000 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Probe and drogue	2 pods and/or Centreline hose	–	–	–	–

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
250,000 lb (113,500 kg) plus 95,800 lb (43,500 kg) of additional cargo or fuel load	–	–

Features

- The Airbus A330 MRTT is a tanker aircraft based on the civilian A330-200. The A330 MRTT has been ordered by the Royal Australian Air Force (RAAF), UK's Royal Air Force (RAF), United Arab Emirates Air Force, and Royal Saudi Air Force. The KC-30B/C is an A330 MRTT UK; first of 14 aircraft commissioned into service with the RAF is planned for delivery in Oct 2011. These aircraft are based on a PFI (Private Finance Initiative) solution. Air Tanker Ltd will provide 14 A330-200 aircraft, which will be capable of AAR and AT;
- The KC-30B will be configured with 2 wing-mounted AAR refuelling pods. The KC-30C will also be capable of the installation of a fuselage refuelling unit centreline drogue;
- In cargo passenger configuration: 380 passengers, and 8 military pallets + 1LD6 container + 1 LD3 container (lower deck cargo compartments) will be used.

A400M

Manufacturer
Airbus

Variants
–

Quantity in NATO Nations
France: 10 Kits
Germany: 10 Kits
Spain: 9 Kits

A400M, one of the next generation tankers.

These NATO Nations had ordered the AAR version of the A400M (The number of AAR kits for each Nation is listed; some of these have Hose Drum Units, others pods, or in some cases both)

General Aircraft Information

Wingspan	Length	Weight MTOW
42.4 m (139 ft 1 in)	45.1 m (148 ft)	310,851 lb (141,000 kg)

AAR Information

AAR System	Equipment	AAR Fuel System Pressure	AAR Fuel System Transfer Rate	AAR Altitude Envelope	AAR Speed Envelope
Probe and drogue	2 pods and/or Centreline hose	–	–	–	–

AAR Fuel System

Maximum Fuel Load	Average Fuel Burn	Fuel Type
Around 81,571 lb (37,000 kg)	–	–

Features

- The Airbus A400M is a European four-engine turboprop military transport aircraft. It was designed by Airbus Military as a tactical airlifter with strategic capabilities;
- Currently, 174 aircraft are ordered by 8 Nations. According to the manufacturers, all A400M could be rapidly re-rolled to become AAR tankers able to refuel fighters, helicopters and other large aircraft at those receivers' preferred speeds and heights.

ANNEX C

Description of Air to Air Refuelling Transfer Systems

1. Introduction

This Annex gives a general description of current AAR equipment. There are 2 different AAR systems in use: Probe and Drogue and the Flyable Boom. The two systems are not compatible. However, some booms can be adapted (on the ground) using a Boom Drogue Adapter kit; this makes the boom compatible with probe equipped receivers. Some tankers (eg KC-10/KC-135) are equipped with both boom and hose/drogue systems and either may be used on the same flight.

2. Probe and Drogue

The tanker trails a hose; the free end of the hose terminates in a reception coupling and a conical shaped drogue. Receiver aircraft are fitted with an AAR probe which terminates in a fuel nozzle; the receiver aircraft is flown to engage the probe into the drogue:

2.1 System Description. The tanker hose is carried on a power driven hose drum (or reel). To trail the hose, the hose drum brake is released and air drag on the drogue pulls the hose, at a controlled rate, into the airstream. When the hose is at full trail, a winding-in torque (response system) is applied to the drum; this counters the air drag of the drogue. The controlled balance between winding-in torque (response system) and air drag absorbs the impact of the receiver making contact; it also damps any tendency for the hose to whip as contact is made, provided excessive receiver closure rates are avoided.

When contact is made the probe engages coupling latches, which grip the probe to make a fuel tight joint; fuel valves in the coupling and probe then open. The receiver continues to move forward, pushing the hose back onto the drum. When sufficient hose has rewound onto the drum, the main fuel valve in the AAR equipment opens and fuel can be pumped to the receiver.

After making contact the forward movement required of the receiver to open the fuel valve is typically about 2 m (6 ft); however, the distance varies according to AAR equipment type, details are provided in the National Annexes contained in ATP-3.3.4.2.

Most systems afford a considerable range of fore and aft hose movement within which fuel will flow to an in-contact receiver. A range of movement from the valve open position to 7 m (20 ft) forward of this, is typical. On some equipment, the fuel valve closes if the hose is pushed in too far. Refer to National Annexes contained in ATP-3.3.4.2 for specific recommended or permitted ranges of hose movement.

When AAR is complete, the receiver pilot makes a small power reduction and drops back slowly to stabilise in the pre-contact position. As the hose nears the full trail position, the AAR equipment fuel valve closes. When the hose reaches full trail, the probe begins to pull out of the reception coupling; the coupling and probe fuel valves close, then the coupling latches release the probe. If the tanker pilot commands a Breakaway, the receiver drops back quickly. A sensor in the AAR equipment detects the high rate of hose movement and the hose drum brake is automatically applied; this achieves a swift, positive disconnect and occurs well before the hose reaches full trail. The Mk 17 hose remains in the braked position until it is manually reset but most hoses retrail automatically.

2.2 Tanker Installations. There are 2 general types of tanker AAR equipment: the podded store and the integral system.

AAR pods are self-contained units requiring only fuel and low voltage electricity from the parent aircraft; the power source for fuel pumping and hose drum drive is usually a pod ram air turbine. AAR pods are widely used to give fast jet aircraft an alternate tanker capability; one pod is mounted on an under-wing or under-fuselage pylon; refer to National Annexes for specific installations. Pods are also carried by some large tankers; usually a pylon mounted pod is carried under each wing.

Self-contained AAR drogue pod installed in a KC-135 wing.

Integral AAR systems may be carried on large tankers; normally these are installed within the main fuselage and the hose is trailed from a centreline fairing or tunnel. However, there are variations on this general principle; for example the FAF Transall AAR equipment is mounted within the left-hand fuselage undercarriage bay. Integral AAR systems use a variety of high powered aircraft supplies (pneumatic, hydraulic and electric) for fuel pumping and hose drum drive.

2.3 Hose Dimensions and Markings. Generally pod hoses are shorter, lighter and have a narrower bore than integral system hoses. The lengths of pod hoses vary between 15 m (50 ft) and 27 m (90 ft) depending on the system and use; 24 m (80 ft) is typical of an integral system hose. National Annexes provide specific information.

Most hoses are marked with coloured bands; there is a wide variety of colours and marking patterns, refer to National Annexes in ATP-3.3.4.2. However, most hoses have a series of bands or a block of colour to indicate the optimum receiver refuelling position; this is achieved when the hose is pushed in so that the markings enter the hose fairing or tunnel. On some hoses, the refuelling position marks are bounded by additional markings indicating the start and stop positions for fuel flow. Usually, there is a series of closely spaced bands at the tanker end of the hose; these provide cues for the receiver pilot to assess rates of fore and aft movement after making contact, or during disconnect.

2.4 Compatibility. Probe and drogue couplings are built to dimensions established by STANAG 3447; the aim of the STANAG is to ensure probe and drogue compatibility irrespective of the country of manufacture.

However, the initial STANAG proved to be insufficiently precise in certain areas with the result that some British Flight Refuelling Limited (FRL) probes were incompatible with some US MA-3 and MA-4 couplings; there was a risk of the FRL probe becoming locked into the US couplings. STANAG 3447 has since been revised to eliminate this problem and all affected MA-3 and MA-4 couplings used within NATO have been modified to restore compatibility. Note that some MA-3 and MA-4 couplings supplied to other air forces outside NATO may still be unmodified. The National Annexes contained in ATP-3.3.4.2 list the type of couplings fitted to tankers.

2.5 Signal Lights. Associated with each tanker AAR installation is a set of rearward facing signal lights, using the colours red, amber and green; although some equipment may have only amber and green lights. On some systems, the signal lights are duplicated for redundancy.

The lights provide indications of the operating status of the AAR equipment; on most installations, the lights can be controlled by the equipment operator to give radio silent commands. The NATO standard light signals are: red light means do not make contact or Breakaway, amber means clear contact and green signifies fuel is flowing. Variations on these principles are noted in National Annexes contained in ATP-3.3.4.2.

2.6 Drogue Lighting. Most drogues are illuminated to assist night AAR. Some drogues are lit internally by lights at the coupling; alternatively, the drogue periphery may be highlighted by a series of luminescent tritium light sources. On some tankers, reflective paint is applied to the inside of the drogue.

2.7 Probe Lights. Many receivers have a light which illuminates the probe. These lights should be used with caution, because they can dazzle the refuelling operator in the tanker; furthermore, their use may accentuate a tendency for receiver pilots to chase the drogue and therefore possibly over control.

2.8 Drogue Tunnel/Serving Carriage Lights. The drogue tunnel or the serving carriage of most tanker AAR installations is lit from within. This is particularly useful for gauging the amount of hose pushed back onto the hose drum.

Fuel nozzle visible inside a KC-135 flyable boom.

3. Boom

The tanker is fitted with a flyable, telescopic boom; the free end of the boom terminates in a probe-like fuel nozzle. Receiver aircraft are fitted with a reception coupling, or receptacle.

The receiver flies a steady formation position whilst the boom operator manoeuvres and extends the boom to make contact with the receptacle. Some booms are equipped with a Boom Interphone system which permits direct communication with suitably equipped receivers. Full description of the types of boom in service, and their operation, is provided in the appropriate National Annex in ATP-3.3.4.2.

3.1 Pilot Director Lights (PDL). To aid receiver positioning, the tanker aircraft is fitted with PDL; these consist of 2 parallel light arrays, set longitudinally underneath the fuselage between the nosewheel bay and the main landing gear. The PDLs give an in-contact receiver directions to move to attain and maintain the ideal refuelling position.

One light array gives up and down commands and the other gives fore and aft commands. Coloured positioning bands on the telescoping portion of the boom correspond to the coloured segments of the fore and aft PDL. There are no lights for azimuth positioning. The PDL system should not be used when the BDA is fitted. A full description of PDLs and boom markings is given in the appropriate National Annex in ATP-3.3.4.2.

3.2 AAR Equipment Lighting. Boom tankers are fitted with a rear-mounted floodlight, which illuminates the receiver, to assist the boom operator. The boom is fitted with a boom nozzle light to assist the operator in positioning the nozzle into the receptacle. Some receivers' receptacles are also internally lit; the Universal Aerial Refuelling Receptacle Slipway Installation (UARRSI) is usually lit, or highlighted by marker lights.

4. Boom Drogue Adapter

The KC-135 and the C135FR boom can be modified to refuel some types of probe equipped aircraft by fitting a Boom Drogue Adapter; this consists of 3 m (9 ft) of hose attached to the end of the telescoping part of the boom. The hose terminates in a hard non-collapsible drogue. The BDA can only be fitted/removed on the ground. The PDLs should not be used with this system.

A French Jaguar refuelling from a US KC-135 tanker fitted with Boom Drogue Adapter (BDA).

The BDA does not have a hose response system; therefore receiver pilots should exercise caution during approach to contact. Excessive closure rates could result in a broken probe or hose. Attempts to disconnect which are not made down the correct withdrawal path could result in the probe binding in the reception coupling. For this reason, the USAF recommends the use of 'Flexitip' probes with the BDA. Flexitip probes have some internal bracings removed; this allows the probe mushroom valve tip some lateral movement within the probe structure and makes an off-centre disconnect easier. A full description of the BDA is given in the appropriate National Annex in ATP-56(A)/AJP 3.3.4.2.

5. Fuel Flow Rates and Pressures

Fuel flow rates vary widely according to AAR installation. In general terms, the boom system offers the highest rate of fuel flow up to 3,650 kg/min (8,000 lb/min), podded hose systems offer flow rates between 870 kg/min to 1,000 kg/min (2,800 lb/min to 3,200 lb/min) and integral hose systems offer flow rates around 2,300 kg/min (5,000 lb/min). Fuel pressure is regulated in most systems not to exceed about 3.5 bars (50 psi) at the reception coupling. Fuel transfer rates will be affected by the specific gravity of the fuel and the limitations of the receiver fuel system. See National Annexes in ATP-56(A)/AJP 3.3.4.2 for details.

Note. In probed aircraft, it is generally the restrictions placed on the receiver fuel system that limit the flow rate. Many European aircraft have relatively poor onload rates and consequently require lengthy AAR time; this may make their use incompatible with single-point tankers.

6. Tanker Reference Markings

Most tankers have some form of reference markings, providing enhanced cues for formation and/or AAR station keeping. These markings may be painted lines, fluorescent stripes, or electro-luminescent panels. Boom tankers have a fluorescent yellow stripe on the bottom centreline of the fuselage to provide an azimuth reference. Some probe and drogue tankers have reference markings providing alignment cues for the approach to contact.

7. Tanker Lighting

Most tankers have floodlighting which make them readily visible to receivers. The lighting is designed to highlight parts of the tanker which may be used as formation visual references, to illuminate the AAR equipment and to light any reference markings provided for AAR. This lighting is usually dimmable. Some small combat aircraft with an alternate tanker role do not have floodlighting for AAR.

ANNEX D

Acronyms

AAR	Air to Air Refuelling
AARCC	AAR Coordination Cell
ACCS	Air Command and Control System
ACT	Allied Command Transformation
AE	Aeromedical Evacuation
AFSOC	Air Force Special Operations Command
AJP	Allied Joint Publication
AMC	Air Mobility Command
AO&TC	Air Operations Training Course
AoA	Analysis of Alternatives
AOC	Air Operations Centre
AOSpWG	Air Operations Support Working Group
APOD	Aerial Ports Of Disembarkation
ARSAG	Aerial Refuelling System Advisory Group
ARTK	Air Refuelling Tool Kit
AT	Air Transport
ATARES TA	Air Transport and Air to Air Refuelling and other Exchange of Services Technical Agreement
ATO	Air Tasking Order
ATP	Allied Tactical Publication
BDA	Boom Drogue Adapter
C2	Command and Control
C3	Command, Control and Communications
C4ISR	Command, Control, Communications and Computers, Intelligence Surveillance and Reconaissance
CAARIS	Commercial Air-to-Air Refuelling Interim Solution
CAOC	Combined Air Operations Centre
CJSOR	Combined Joint Statement Of Requirements
CNAD	Conference of National Armament Directors
CONOP	Concept of Operation
DRR	Defence Requirements Review
ECAP	European Capabilities Action Plan
EDA	European Defence Agency
EO	Expeditionay Operations
EU	European Union
FOB	Forward Operation Base
FSTA	Future Strategic Tanker Aircraft
FW	Fixed Wing
GPS	Global Positioning System
HDU	Hose Drum Unit
HQ	HeadQuarters
HVAA	High Value Airborne Asset
ICAO	International Civil Aviation Organisation

ICC	Integrated Command and Control
IDF	InDirect Fire
IR	InfraRed
ISR	Intelligence, Surveillance and Reconnaisance
JAPCC	Joint Air Power Competence Centre
JSF	Joint Strike Fighter
MANPAD	Man Portable Air Defence
MCASB	Military Committee Air Standardisation Board
MCCE	Movement Coordination Centre Europe
MCJSB	Military Committee Joint Standardisation Board
MCR	Minimum Capability Requirements
MOU	Memorandum Of Understanding
MRTT	Multi Role Tanker Transport
MTOW	Maximum Take Off Weight
NATO	North Atlantic Treaty Organisation
NCS	NATO Capability Survey
NDPP	NATO Defence Planning Process
NRF	NATO Reaction Forces
NSA	NATO Standardisation Agency
NSO	NATO Standardisation Organisation
PCC	Prague Capability Requirements
PDL	Pilot Director Lights
PFI	Private Finance Initiative
RFAS	Reaction Force Air Staff
RW	Rotary Wing
SME	Subject Matter Expert
STANAG	Standardisation Agreement
TOA	Transfer Of Authority
UARRSI	Universal Aerial Refuelling Receptacle Slipway Installation
UAS	Unmanned Air System
UCAS	Unmanned Combat Air System
WARP	Wing Air Refuelling Pod

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