

**HQ NO 1 GP ODH TOLERABLE & ALARP STATEMENT – MID-AIR COLLISION WITH COMMERCIAL AIR TRAFFIC (MAC-CAT)**

<b>Risk Reference</b> TOR 09	<b>Aircraft Type</b> Tornado GR4	<b>Risk Owner</b> ODH	<b>Risk Manager</b> Tornado SCM
<b>Description of Safety Risk</b> Mid Air Collision with Commercial Air Traffic (MAC-CAT).			
<b>Effect</b> Collision leading to significant loss of 1 <sup>st</sup> and 3 <sup>rd</sup> party life.			
	<b>OCCURRENCE LIKELIHOOD</b>	<b>OCCURRENCE SEVERITY</b>	<b>CLASSIFICATION</b>
<b>Unmitigated HRM</b>	Improbable	Catastrophic	<b>MEDIUM</b>
<b>Mitigated HRM</b>	Improbable	Catastrophic	<b>MEDIUM</b>
<b>BACKGROUND</b> The air operating environment of Tornado GR4 poses an ever present possibility of MAC with another aircraft. The Defence Air Accident Taxonomy (DAAT) lists 4 aircraft-aircraft Accident Subsets under the Primary MAC Accident Set: <ul style="list-style-type: none"><li>- MAC with cooperating military ac (MAC-CPMIL)</li><li>- MAC with non-cooperating military ac (MAC-NCPMIL)</li><li>- MAC with General Aviation ac (MAC-GA)</li><li>- MAC with Commercial Air Traffic (MAC-CAT)</li></ul> This ALARP Statement refers exclusively to the MAC-CAT Risk to Life (RtL). There are similarities across the 4 Accident Subsets which are part of the air operating environment in which the Tornado GR4 flies: <ul style="list-style-type: none"><li>- It is not possible to completely remove the risk of colliding with another aircraft regardless of the controls and mitigations put in place.</li><li>- It is possible that the result of a collision could entail no loss of life; however, RtL is always present.</li><li>- The spectrum of outcome varies widely and correspondingly it is necessary to consider the worst credible outcome along with a range of more likely outcomes.</li></ul>			
<b>MID-AIR COLLISION: TORNADO – COMMERCIAL AIR TRAFFIC</b>			
<b>Definition of CAT:</b> CAT is deemed to be a commercial airliner, most likely something of similar size and capacity to the Boeing 737 <sup>1</sup> family, the best selling commercial airliner. <sup>2</sup> For the purposes of analysis, these aircraft are deemed to carry typically between 20 to 200 non-military crew and passengers (3 <sup>rd</sup> party).			

<sup>1</sup> dstl Cost Benefit Analysis: GR4 Collision Warning System (CWS). It is acknowledged that CAT could be anything from a small passenger carrying aircraft through to "jumbo" class airliners, but for the purposes of these calculations, a mid-class aircraft has been assumed.

<sup>2</sup> <http://www.flightglobal.com/news/articles/boeing-737-aircraft-profile-218496/>, Flight Global, 2008.

There have been no accidents between Tornado and CAT on which to base real world analysis. DSTL have conducted analysis<sup>3</sup> to provide best advice with regard to the risk of a Tornado GR4 colliding with a CAT aircraft.

#### CAA Analysis:

The Civilian Aviation Authority (CAA) report that in “the last 10 years (1995-2004) there have been 7 fatal mid-air collision accidents worldwide involving large fixed-wing turbine-powered aeroplanes, resulting in 451 fatalities. Although there has not been such an accident in UK airspace since 1949, there have been several high profile 'near-misses'”. If a mid-air collision accident were to occur, historic data shows an average of 64.4<sup>4</sup> fatalities (3<sup>rd</sup> party) per accident.

**Associated Hazard:** There is an eCassandra Hazard linked to this risk:

**H27 - Minimum Safe Separation Distance Breached with Other Aircraft.** Minimum Safe Separation Distance Breached with Other Aircraft due to failure of Avionics or other aircraft systems. Includes formation and non-formation flying.

#### Worst Credible

It is assessed that the worst credible scenario for Tornado GR4 with regard to the MAC-CAT risk is a Mid Air Collision between 1 Tornado and 1 commercial aircraft resulting in the loss of civilians and both GR4 aircrew: **CATASTROPHIC** severity.

Based on judgement of SMEs and that so far during the operating life of the Tornado GR4 there has been no record of previous incidents, it is assessed that the worst credible likelihood is **IMPROBABLE** (unlikely to occur in 10 years).

This results in a **MEDIUM** RtL.

#### MITIGATION

##### Training

There is a comprehensive aircrew **flying training system** (FTS) that is constantly under review as well as being subject to frequent internal and external quality audits. In addition to teaching the ‘see and avoid’ principle and assessing candidates visual lookout scan on every sortie, the FTS seeks to develop good SA and airmanship and reduce accidents through a combination of rigorous training, high standards and graduating only those trainees who are deemed to be safe.

Specific to this potential accident sequence is training within Class A airspace, practised during flying training, Instrument Rating sorties and Overseas Training Flights in order to ensure knowledge of procedures within controlled airspace and proximity to CAT.

Given that aircrew arrive on the GR4 OCU correctly trained in general lookout techniques, Section 1 of the TGRF Handbook describes GR4 specific lookout procedures, including individual crew responsibilities and formation cross-cover.

<sup>3</sup> dstl Cost Benefit Analysis: GR4 Collision Warning System (CWS).

<sup>4</sup> 451 fatalities over 7 MAC accidents.

Crews are also trained on the rules applicable to different classes of airspace and what ATC control services are available. Crews are tested on ATSOCAS during their annual IRT.

**Synthetic training** is used to remind crews of the importance of lookout whilst in high intensity environments. The simulator instructor staff can generate other aircraft and this is done on an ad hoc basis when it is judged to be of positive learning benefit although the Tornado GR4 FMS has limitations in replicating the visual cues that would be picked up by crew lookout. In addition the simulator provides invaluable training in the use of aircraft systems, some of which can be used as mitigation under the equipment section.

The TGRF has **SOPs for actions in the event of inadvertent IMC** (such as during a low level abort), emergency procedures in controlled airspace and the use of the aircraft's navigation and autopilot systems in order to achieve VMC at low level.

#### Equipment<sup>5</sup>

Current technical mitigations are based on systems used primarily for alternative purposes other than for bespoke aircraft-aircraft spatial positioning and avoidance.

The **IFF** is a very reliable system<sup>6</sup> with excellent Built-In Test Equipment (BITE). In addition to its routine operation with ATC SSR, use of mode C will enable a CWS equipped ac to generate TA/RA and take avoiding action when necessary. Crews comply with the MAA Manual of Military Air Traffic Management<sup>7</sup> and No 1 Gp ASOs/UKLFHB<sup>8</sup>. Ac are not routinely flown if the IFF is known to be U/S.

Use of the **communications** suite to aid SA and to deconflict.

Use of ac **RADAR**<sup>9</sup>. The RADAR is not designed as an A-A system. It may be used to gain SA on other airspace users when it is serviceable, when it is not being used for Air-Ground operations, and when it is not being used to interrogate a specific volume of airspace for other tactical training. Use in A-A mode at low-level is limited with crews placing priority on lookout as opposed to heads-in activity.

The **FLIR** is an aid to navigation, although the thermal cues have the

<sup>5</sup> It is worth noting that equipment mitigations are rarely mandatory items in order for a flight to proceed. As such, these can at best be considered to be aids to deconfliction. Including all of these items on a "minimum equipment check-list" would likely lead to an unacceptably high number of sorties lost due to equipment unserviceabilities.

<sup>6</sup> IFF fault arising data received from BAES (20130218-IFF-U.PPT)

<sup>7</sup> MMATM Ch 35 para 25 states "All pilots of military aircraft are required to transpond in Mode 3/A Code 7000 and, where equipped, with Mode C at all times [except when flying in CAS, when using a different squawk allocated by ATC agency, when conducting special operations, when remaining within the aerodrome traffic pattern below 3000 ft agl, when recovering an ac with a u/s transponder and when code 7001 is required]."

<sup>8</sup> 1G395.200.1 states "aircraft entering or flying within the UKLFS are to have serviceable transponders" and UKLFHB 01.03.06 states "except for aircraft conducting authorised operational missions, aircraft should not enter the UKLFS without a serviceable IFF/SSR transponder."

<sup>9</sup> Regardless of mode utilised, the EV3 provides limited SA on airborne traffic within the forward hemisphere of the aircraft (60° either side of the aircraft datum). It is least effective for A-A in high-clutter environments such as low level.

ability to alert crews of the possibility of other traffic if sensed by the equipment. These thermal cues can be displayed in the HUD, providing possible cues to the pilot whilst still looking out. However, when operating overland, multiple thermal cues are often generated which are associated with ground hotspots.

**Anti-collision lights.**

Further technical mitigation of this risk requires a Collision Warning System (CWS) for the Tornado GR4. Full fleet embodiment of CWS would further reduce the risk Likelihood (i.e. more improbable). CWS on Tornado has passed Main Gate and is 'on contract'; IOC is currently Oct/ Nov 14.

In addition, there is constant assessment of potential new technology e.g. PFLARM and in future ADS-B (Automatic Detection Surveillance - Broadcast) by Tornado and Air Cap staffs.

Personnel

As a **two-crew cockpit**, the Tornado aircrew can employ the 'see and avoid' concept more effectively than single seat FJ ac.

**Medical Employment Standards (MES)** are rigorously monitored to ensure that crews meet the required eyesight and colour perception standards. Where necessary corrective spectacles or lenses are issued. Crews are also subject to anthropometric requirements as laid down in the RTS and AP1269. Gp ensures that the maintenance of medical standards through biannual attendance of the Air Medical Standards Steering Group.

The Royal Air Force employs a **rigorous selection process** which is under regular review.

Further personnel DLODs are covered through training (above) and through the governance of doctrine & concepts (below).

Infrastructure

**Airspace Structure** is constantly under review. When deemed necessary airspace is amended to reflect changes in operations, although the process for enacting these changes can be lengthy. Recent changes include the addition of advisory airways to cater for some changes to CAT routing and the reclassification of the Brize Norton MATZ to Class D airspace. There is a continuing lobby for the civil recognition of all MATZs. There is ongoing work, lead by DAATM, to review and where there is a case amend the airspace associated with AWRs.

**Air Traffic Control and RADAR services** – Whilst also covered in part through training, doctrine and concepts, the structure of UK airspace, RADAR services (such as Lower Airspace RADAR Service – LARS), Initial Contact Frequencies (ICF) etc are clearly laid out in publications such as the UKLFHB and the British Isles and North Atlantic (BINA) Supplement and are an integral part of all aircrew training and routine GR4 operation. This comprehensive structure provides the opportunity to receive Traffic or Deconfliction Service in most intermediate or transiting flight regimes. There has also been a review of PSR and SSR planned maintenance activity to ensure

deconfliction from periods of fg activity.

**Airfield facilities** are always subject to review and improvement. Such improvements have recently included upgrades to the Watchman RADAR system as well as modernisation or replacement of existing ATC Tower facilities at some airfields.

Doctrine & Concepts

The following are inherent within the **Tornado GR4 concept and design philosophy for collision avoidance**:

- 'See and avoid' principle.
- The 2 crew concept. Crew lookout responsibilities are procedurally outlined within TGRF SOPs.

**Regulations, Orders and SOPs** including, but not necessarily limited to:

- Air Navigation Order (ANO).
- Military Aviation Authority (MAA) Regulatory Publications (MRPs).
- 1 Gp Air Staff Orders (GASOs).
- UK Military Low Flying Handbook (UK MLFHB).
- Air Training Instructions (ATIs).
- Aircraft Document Set (ADS).
- Tornado GR Force Handbook and SOPs (TGRF Handbook and SOPs).
- Unit level Flying Order Books (FOBs).

These regulate and provide guidance for, for example:

- Methods of air navigational procedures, de-confliction and avoidance,
- Types and availability of radar services
- Use of tactics, procedures and equipment
- Mandatory briefing items, authorisation, supervision and qualifications
- Human Factors and performance limitations
- Debriefing, reporting and recording requirements.

Local avoids are often implemented by stns in order to reduce the likelihood of MAC or Airprox events, e.g. an avoid around Stornoway of 5nm up to 3000ft.

The RAF Flt Safety led [Mid Air Collision Campaign Plan](#) details numerous mitigations that have been identified as a result of the RAF FS Mid-Air Collision Risk Analysis and Feedback paper dated 1 Oct 12 and the HQ No 1 Gp Airprox Deep Dive paper dated 9 Oct 12. The full campaign plan is hyperlinked above and mitigations/ongoing work/future considerations are grouped under the headings Prevent, Detect, Avoid. Some examples are listed below.

Prevent

- CADS planning situational awareness tool.
- A system to notify of police helo activity (ongoing).
- A review of the suitability of AWR current sizes (ongoing).
- Mandate that ATSOCAS responsibilities, rules and regulations are checked as part of IRTs, annual handling checks and Standards Visits.

Detect

- Embodiment of CWS on Tornado (ongoing).
- Refresher trg carried out on basic principles of eye physiology and lookout techniques.
- Commence a Lookout Study (ongoing by No 22 Gp).
- Project MARSHALL.

Avoid

- Proposal for better TI phraseology (ongoing – with MAA for consideration).
- Air Awareness trg for air traffic controllers.

Organisation

The MAA and Air Cmd, No 1 Gp and Stn **Air Safety organisations** provide policy, guidance, ensurance and assurance.

**No 1 Gp employs a tiered system of fg authorisation** and supervision from the AOC (through GASOs) via the Stn Cdr and DCF to each sortie supervisor. Supervision of flying is carried out, for example through the use of:

- Reference and monitoring of crews' experience, currency and qualification (used from the scheduling stage through to the sortie execution stage).
- Individual mission plan scrutiny, by formation supervisors and independent sqn authorisers, during both the planning and airborne phases of a sortie.

**Liaison with local airfields** to improve deconfliction measures e.g. there is ongoing work at Lossiemouth with the Highland and Islands Airports in order to mitigate the risk of MAC in the vicinity of Inverness.

**Regional Airspace User Working Groups**, involving local military, commercial and civilian users and ATC units (e.g. police/ air ambulance helicopters, gliders, microlights, hot air balloonists etc.), aid the communication, cooperation and coordination of procedures and operations amongst local airfields.

The Royal Air Force has standing representation in the form of permanent membership, in both voting and advisory roles, of the UK Airprox Board. Additionally the RAF has membership, through IFS, of the UK Flight Safety Committee, GASCo and relationshipp with the LAA and BGA. There is regular liaison between the RAF and CAA through the Directorate of Airspace Policy, DAATM and other routine engagement.

Information

There is a well established and robust system for the **promulgation of NOTAMs, CANPs, PINs, Royal Flights and Late Warnings** to military aircraft, both prior to take-off and during flight via guard or formation radio frequencies. Additionally, the Defence Aerodrome Manual (introduced with RA 1026) provides a source of information on stn based ATC and radar services that are available.

CADS is in use by both Tornado MOBS and the majority of Defence users of the UK LFS. Efforts continue to use CADS to provide information of military activity to civil emergency air assets and other GA airspace users. The LFBC will aim to input relevant airspace

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usage by other users when notified.

Crews are taught and instructed, where applicable, to make **disciplined radio transmissions** on relevant frequencies e.g. Inverness, Stornoway, Anglia Radar or the West Coast FIS when entering areas.

Local civilian **engagement programmes** enhance the mutual understanding of aviation activities.

The MAA has implemented an occurrence reporting and analysing system - **ASIMS**. The use of ASIMS coupled with the **promotion of a just culture** is helping to increase **reporting and awareness** of air safety issues, such as Airprox events.

The MAA, Air Cmd, No 1 Gp and each stn have organisations **promoting Air Safety**. In addition, the **UK Airprox Board** provides monthly updates.

The TGRF often conducts **Occurrence Safety Investigations (OSI)** following notable airprox incidents to determine the cause of the airprox and identify lessons that may be applied in the future. The results of OSI are widely broadcast across the TGRF.

Logistics

**Airworthiness of equipment** for Tornado GR4 is actively managed and the CAMO and platform PT are actively involved in the safety case and AS related equipment matters.

#### **TOLERABLE AND ALARP JUSTIFICATION:**

Overall Platform Risk is considered to be unacceptable if any 1<sup>st</sup> Party has a greater than a 1 in 1000 risk of death (RoD) per annum<sup>10</sup>. For 3<sup>rd</sup> Party RoD, this is increased to 1 in 10000<sup>11</sup> (see Figure 1).

The Defence Science and Technology Laboratory (DSTL) conducted a Cost Benefit Analysis (CBA) at the request of Capability Deep Target Attack (Cap DTA) on behalf of the ODH to assess the risk associated with Tornado GR4 and mid-air collisions<sup>12</sup>. The figures below are taken from this CBA.

The CBA assessed that the per annum risk of a Tornado GR4 (without CWS) having a mid-air collision with *all types* is 1 in 1166. Broken down further, **the per annum risk of a Tornado GR4 (without CWS) having a mid-air collision with CAT is 1 in 109189<sup>13</sup>**.

The CBA assessed that the per annum risk of CAT aircrew (relates to 3<sup>rd</sup> party risk) having a mid-air collision with GR4 (without CWS) is 1 in 404640.

<sup>10</sup> MAA RA 1210 Annex A

<sup>11</sup> *ibid*.

<sup>12</sup> The CBA was completed prior to the 3 Jul 12 accident. In addition, the model used was based on OSDs of 2018 and 2021, and for 2 different flying hour profiles for each OSD.

<sup>13</sup> The CBA states a Probability of Collision Event per Flight Hour (without CWS) between GR4 and CAT of 4.32E-08. Assuming 212 hrs of flying per crew per annum, this calculates as a per annum risk of collision with CAT of 1 in 109189.

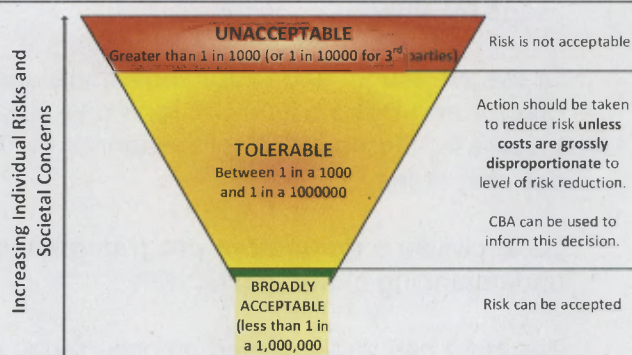


Figure 1: Tolerability of Risk to Life per Annum.

### 1<sup>st</sup> Party Tolerability

Not all Tornado collisions have resulted in 100% crew fatalities (some aircraft have landed safely and a number of crews have successfully ejected)<sup>14</sup>.

Of 23 Tornados (including GR4, GR1 and F3) involved in mid air collision accidents (including NCPMIL, CPMIL and GA – nil involving CAT) since 1984 there were 14 Tornado crew deaths. This gives the historic rate of  $14/23 = 0.61$  crew deaths per Tornado mid air collision. Incorporating this rate into the CBA per annum risk of collision stated above, the annual **risk of death per annum to Tornado crews from mid air collision with CAT could be stated as 1 in 178998, with a worst case annual risk equalling the per annum risk of collision, 1 in 109189. Both of these calculations fall within the Tolerable region.**

The RtL to 1<sup>st</sup> party for continuing Tornado GR4 operations is therefore assessed as **TOLERABLE**.

### 3<sup>rd</sup> Party Tolerability

As stated above, the CBA assessed that the per annum risk of CAT aircrew having a mid-air collision with GR4 (without CWS) is 1 in 404640. This was based on an SME assessment of 750 flying hours per year as an estimated average for CAT pilots.

The CBA did not calculate the probability of involvement in a collision for 3<sup>rd</sup> party civilian passengers, but it could be assessed that the risk of death to 3<sup>rd</sup> party per annum would be equal to or less than 1 in 404640 (i.e. Tolerable).

The CBA assessed that once CWS is fully embodied in GR4, 3<sup>rd</sup> party risks (specifically for CAT aircrew) will be firmly within the Broadly Acceptable category.

The CBA, whilst acknowledging that results are sensitive to risk modelling and assumptions made, concluded that the case to fit CWS on Tornado GR4 was marginal and that even with the application of worst case casualty values, it could be deemed reasonable to accept that *“the cost-benefit case to fit Tornado CWS on an individual risk to life basis is not compelling”*<sup>15</sup>. However, due to societal concern, highlighted through the Tornado GR4 CWS business case<sup>16</sup>, it has been decided that **CWS is to be fitted to Tornado GR4.**

<sup>14</sup> Stated by HoC DTA in the Tornado Collision Warning System Review Note dated 9 Jan 12.

<sup>15</sup> Stated by HoC DTA in the Tornado Collision Warning System Review Note dated 9 Jan 12.

<sup>16</sup> *ibid.*

<sup>17</sup> *ibid.*

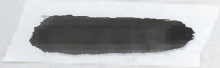


In addition to the quantitative assessment that the CBA provides and the evidence of good practice highlighted under 'Mitigations', the ODH's qualitative judgement referred to within the Tornado Collision Warning System Review Note stated "*the RtL of continuing Tornado GR4 operations without a CWS is, therefore, considered to be Tolerable and ALARP*"<sup>17</sup>.

The MAC-CAT risk for Tornado GR4 is assessed as **ALARP**.

#### ODH Chief Air Engineer Comments

The MG approval for CWS and subsequent success in agreeing a contract provide a programme baseline for a design approved technical enhancement that should mitigate societal concern in a finite timescale. In addition, there is ongoing work to identify potential ways of accelerating CWS implementation under EA. In sum, all that can be done technically to reduce exposure to residual risk is being done. I therefore agree that the risk can be considered as tolerable and ALARP.

Name   
Rank Gp Capt  
Post No 1 Gp CAE

Date: 10 Jan 13

#### ODH Senior Operator Comments

The quantitative assessment provided by the CBA, backed by evidence of good practise to mitigate the risk supports the claim the risk is ALARP. Regional Airspace Working Groups are improving the mutual understanding of the operations of all airspace users and improving the communication flow between them. Initiatives are also being tested and implemented to improve trg of military air traffic controllers, increasing their awareness of the cockpit environment. In terms of structures, the Future Airspace Strategy will address the requirement for dedicated user areas such as AWRs and this will be informed by TGRF. As for equipment solutions, pending implementation of CWS, the evidence is clear that the cost of further reduction is grossly disproportionate to the benefits of the risk reduction. I recommend agreement that this RtL is Tolerable and ALARP.

Name D J Waddington  
Rank Air Cdre  
Post Tornado Senior Operator

Date: 10 Jan 13

#### ALARP Statement:

**I agree with the reasoning detailed above and confirm that this hazard is both Tolerable and ALARP.**

S D Atha  
AVM  
ODH

Date Oct 13