

# *A Pragmatic Approach to JHMCS Ejection Safety*



**Flight Lieutenant Andrew Eden**

**Royal Australian Air Force**

**Hornet Upgrade Project – Phase 2.2**

**Resident Team – Saint Louis, Missouri**

**+1 314 583 3666 ace\_eden@yahoo.com**

# *Background – Hornet Upgrade (HUG) Phase 2.2*

- ◆ **HUG Phase 2.2 is integrating the following systems to the Royal Australian Air Force F/A-18 A/B aircraft.**
  - **Colour displays**
  - **Joint Helmet Mounted Cueing System**
  - **AN/ALE-47 Countermeasures Dispenser**
  - **TAMMAC-Advance Memory Unit**
  - **Multi-functional Information Distribution System (MIDS)**
  - **Software Configuration Set – 19C**
- ◆ **The Commonwealth has chosen to implement this upgrade through a combination of Foreign Military Sales cases with the USN and a commercial contract with Boeing IDS – Saint Louis.**

# *Background - JHMCS*

- ◆ **Joint Helmet Mounted Cueing System (JHMCS) is a USN/USAF developed system to add 'HUD on the head' capability to F-15, F-16, F/A-18 and F-22 to take full advantage of new High Off Boresight (HOBS) missiles such as AIM-9X and ASRAAM.**
- ◆ **Due to added weight, shifted centre of gravity and structural integrity of the JHMCS visor and display unit, the JHMCS is cleared for safe ejection by the USAF and USN to 450KEAS.**



# *Background - Similarity*

- ◆ **USN and USAF ejection safety Centres of Expertise (COEs) raised concerns about ejection safety after the integration of JHMCS to the AF/A-18. The RAAF configuration differed from cleared USN and USAF configurations in the following areas:**
  - **Ejection seat (SJU-9A vs NACES)**
  - **Restraint System (simplified combined harness vs torso harness), and**
  - **Aircrew Life Support Equipment.**
- ◆ **Based on these differences, the Commonwealth was advised that qualification by similarity would not be supported by these COEs.**

# *Background - Ejection seat*

- ◆ **The RAAF operates the SJU-9/A and SJU-10/A ejection seats in the F/A-18 fleet which was designed and qualified in the late 1970's to the standards of the day.**
- ◆ **The major differences between the NACES and Mk10 series seats is seat stability once the seat is clear of the aircraft, due to:**
  - **3 point drogue attachment (NACES), and**
  - **drogue parachute timing.**

# *Background - Harness Comparison*

- ◆ **The USN uses a custom fit torso harness. This harness was designed and developed by the USN. It uses Koch fittings to attach to the parachute risers and the lap belt of the seat.**
- ◆ **The RAAF uses a Generation I Simplified Combined Harness (SCH) that is designed by Martin Baker. It is permanently fitted to the ejection seat and the pilot fits it each time he enters the aircraft.**

# *Background - Harness Comparison*

- ◆ **The USN raised concerns about the level of restraint offered by the SCH as being inferior to that of the Torso Harness.**
- ◆ **Poor restraint of the occupant can contribute to greater seat instability due to the shift in Centre of Gravity.**
- ◆ **USN concerns are based primarily on a test program that utilised a less than ideal fitment of the SCH and did not energise the inertia reels.**
- ◆ **Recent RAAF sponsored testing has shown that with a correct fitment and energised inertia reels that the USN results cannot be replicated.**

# *Background - Harness Comparison*

- ◆ **Martin Baker have further developed the SCH to a Generation III design that improves the restraint offered to the pilot.**
- ◆ **The Generation III design reduces the restraint effect of a pilot strapping in poorly.**
- ◆ **The Gen I harness when used properly will give restraint the same as the Gen III design, however field surveys of pilots and anecdotal evidence show that pilots rarely strap in correctly.**
- ◆ **The RAAF is upgrading its SJU-9/10A ejection seats to incorporate the Gen III SCH.**

# *Background - Injury Criteria*

- ◆ **The addition of Helmet Mounted Systems like JHMCS that shift the CG and introduce a greater supported mass has driven greater emphasis to be placed on head and neck loadings during ejection.**
- ◆ **At the time that the SJU-5/6/9/10 ejection seats were qualified, head and neck loads were not considered.**
- ◆ **The only metric for ejection safety available to the HUG team were the JSF design goals.**

# *Background - Ejection Probability*

- ◆ **The RAAF is yet to experience an ejection in over 16 years of operating the F/A-18 aircraft.**
- ◆ **The RAAF hull loss rate is 20 per 1,000,000 flight hours.**
- ◆ **The USN has experienced 20 ejections per 1,000,000 flight hours as compared to 33 hull losses per 1,000,000 flight hours**
  - RAAF loss rate is based on 75 jets, 16 years service at a rate of 170hrs per jet per year and 4 actual losses.

# *Background - Ejection Probability*

- ◆ **Martin Baker and USN sources have shown that the majority of ejections occur below 350KEAS.**

# *Background*

## *RAAF Approach*

- ◆ It became evident to the RAAF team that the current ejection seat was never going to meet the JSF Design goals and would also fall short of the current performance of the NACES system.
- ◆ An expensive sled test program would only go to prove this assertion and not bring the RAAF any closer to a way ahead short of replacing all SJU-9/10 ejection seats.
- ◆ Whilst the JSF design goals are a good standard to aim for – it is also evident from the number of ejections in Mk10 series seats that they do not perform as badly as USN predictions may suggest.

# *Background*

## *RAAF Approach*

- ◆ **The goal of the RAAF approach was to quantify the impact of adding the JHMCS to the current configuration.**
- ◆ **This approach requires an acknowledgement of the current level of risk as acceptable.**
- ◆ **The RAAF Airworthiness regulations do not require that legacy systems are qualified to updated standards.**

# *Scope - MB Simulation Task*

- ◆ **The simulation task sought to compare the performance of the SJU-9/10A ejection seat with and without JHMCS to gauge the impact of the modification at ejection speeds between 0 and 600KEAS.**
- ◆ **The comparison was to done for 136lb, 160lb and 213lb nude crew weights.**
  - (61.6kg, 72.5kg and 96.6kg)
- ◆ **The performance of the configurations would then be compared against the injury criteria that are currently accepted by MB and USN as world's best practice and are the design goal of the JSF escape system.**

# *Martin Baker Simulation*

## *Task Results*

- ◆ **The simulation covered 12 criteria:**
  - **Lower neck Tension (5ms duration)**
  - **Lower neck Tension (35ms duration)**
  - **Lower neck Tension (80ms duration)**
  - **Lower neck Compression (5ms duration)**
  - **Lower neck Compression (35ms duration)**
  - **Lower neck Compression (80ms duration)**
  - **Lower neck Shear (5ms duration)**
  - **Lower neck Shear (35ms duration)**
  - **Lower neck Shear (80ms duration)**
  - **Nij (this is combination of neck load and moment limits)**
  - **Neck Roll moment**
  - **Neck Yaw moment**

# *Martin Baker Simulation*

## *Task Results*

- ◆ The simulation showed that the ejection is a stochastic event that is not particularly dependent on one variable.
- ◆ The criteria do not allow for variable risk calculations.
- ◆ The Multi-axial Dynamic Response Criteria (MDRC) does allow this but it does not directly assess head and neck loads.
- ◆ The simulated MDRC results show an MDRC in excess of 1 at speeds greater than approximately 350-400 KEAS.

# *Martin Baker Simulation*

## *Task Results*

- ◆ **Martin Baker simulation results for each injury criterion and aircrew mass against ejection speeds - key outcomes were:**
  - **JHMCS increases the head and neck loads in all criteria, for all aircrew by only a small amount. JHMCS case reaches the same loading as the standard HGU-55/P approximately 50KEAS earlier on average.**
  - **Neither the JHMCS nor standard configurations perform well against the JSF injury criteria. The 136lb (61.6kg) case fails at all ejection speeds. The 160lb (72.5kg) case is limited to 200KEAS. The 213lb (96.6kg) case is limited to 300KEAS.**

# *Martin Baker Simulation*

## *Task Results*

- ◆ **The limiting injury criterion in all cases is Neck Roll Moment. (ear to shoulder)**
  - **The major cause of these forces is the aerodynamic loading on the helmet and head when the seat tumbles to right angles to the windblast. (seat stability)**
- ◆ **A correctly fitted SCH will offer restraint at least as good as a torso harness.**

# *Ejection Safety Implications*

## ◆ HUG Phase 2.2

- The HUG Phase 2.2 has satisfied the requirements of the Technical Airworthiness Maintenance Manual AAP 7001.053. The ejection system does not need to be re-certified to the latest standards. The effect of JHMCS is not an issue when the 450KEAS limitation of the JHMCS is taken into account.
- The HUG Phase 2.2 configuration at 450KEAS is at least as safe as the the current configuration at 600KEAS.
- However, the Martin Baker information reveals a shortcoming of the ejection seat performance when measured against today's best available metrics for injury criteria.

# *Ejection Safety Implications*

## ◆ In service

- The improved metrics show a potential for injury previously not considered.
- The duty of care is to investigate the issue and assess the risk associated with ejection.

# *Ejection Safety Risk Exposure*

- ◆ **Historical data suggests that the likelihood of ejection at speeds above 300KEAS is quite low. (<20%)**
- ◆ **USN has accepted the risk of 600KEAS fatal ejection due to the low exposure to the 600KEAS case.**

# *Draft Recommendations*

- ◆ **The limits that this data would impose are similar to what is already stated in the flight manual. However it could be argued that it currently understates the risks above 250KEAS.**
- ◆ **Recommend the following ejection limits.**
  - **Crew nude mass: 160-213lbs (72.5-96.6kg)**
  - **Boarding mass remains as currently defined in flight manual**
  - **0-450KEAS limit when JHMCS is being used - this is the JHMCS structural limit. Beyond this speed the JHMCS will fail and have negative impact on head and neck loading.**

# Draft Recommendations

## ■ Add the following WARNINGS to the flight manual

- *The ideal ejection speed for a 160lb (72.5kg) occupant to avoid serious injury is 200KEAS. This speed rises to 300KEAS for a 213lb(96.6kg) occupant. The potential for injury increases with aerodynamic loading on the seat and occupant during ejections beyond 300KEAS. The SJU-9/10A ejection seat is not stable before drogue deployment and this subjects the occupant to high lateral loading when at right angles to the windblast that will contribute to high head and neck loads. Pilots should attempt to eject below these speeds.*
- *Occupants under 160lbs(72.5kg) have a serious risk of injury at ALL ejection speeds.*

# *Draft Recommendations*

- ◆ **Retrofit of Gen III harness to SJU-9/10A ejection seats (may be considered for Hawk aircraft)**
- ◆ **Recommend investigation of potential improvements to SJU-9/10A ejection seat:**
  - **Simulation of potential improvements.**
  - **Liaise with other Mk10 seat users for possible collaboration.**