ANALYSING THE EFFECTS OF RIGID AND FLEXIBLE AIRCRAFT DYNAMICS ON THE EJECTION OF A LARGE STORE

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Mr Kevin Jamison
Aeronautical Systems Competency
Defence, Peace, Safety and Security (DPSS)
Objectives

- Present the process followed at CSIR to evaluate the integration of the Katleho PGM with the BAE Hawk Mk120
  - Emphasis on ejection dynamics
- Share some of the experience and lessons learned with the project
Outline

• Background to Hawk / Katleho project
• Requirements for integration evaluation
• Previous work in ejection dynamics
• The AnalyseEjection program
• Application to the Hawk/Katleho release
• Evaluation of effect of flexible & rigid aircraft dynamics on store release
• Closing the loop – comparison with flight tests
• Conclusions
Background to Hawk / Katleho project

• Katleho is a PGM under development by Denel Dynamics
• Hawk selected as platform for carriage & release testing
• Katleho on outboard pylon, Mk82 to balance
Requirements for evaluation of store integration

• Based on painful experience
  – Stores behave VERY differently in aircraft flowfield

• Regulations for military stores carriage and release:

• Requires evaluation of safe separation
  – Does not prescribe techniques or tools
  – Encourages use of similarity where justifiable

• Similarity cannot be justified for Katleho
A major factor in store release - ejection

- Pylons fitted with ejectors to propel stores rapidly away from aircraft
- Exert high forces (>30 kN) for short duration
- ERU forces + store weight release causes aircraft “g-jump”
- Period of ERU force is short enough to excite wing vibration modes
- ERU force/time & front/back force balance important for determining store separation rates from aircraft
The big questions

Would ejectors located well ahead of wing, on outboard pylon, accelerating a heavy store, induce significant flexible response affecting store release dynamics?

Would aircraft roll induced by the ejectors affect the store release dynamics?

Is it necessary to model both rigid roll and flexible responses?
Previous work in flexible release dynamics

- **Analytical**
  - Modal analysis
    - ADAMS software package

- **Empirical**
The AnalyseEjection program

- Panel code *ARUV* usually used for store release analyses
  - But found significant transonic shock waves in carriage position
  - Needed to incorporate CFD results for near-field loads while using *ARUV* for far-field loads
  - *ARUV* limited in modelling ejection dynamics
- *AnalyseEjection* developed as pre-processor to *ARUV*
The AnalyseEjection tool

- **Ejector force-time**
- **Store carriage aeroloads**
- **Rigid aircraft dynamics**
- **Flexible aircraft dynamics**
- **Rigid store dynamics**
- **Aircraft states at release**
- **Store states at release**
- **Aircraft flow field**
- **Store aerodynamics**
- **Aircraft translation**
- **Rigid store dynamics**

**Store ejection**

**ARUV**

**Store free-flight**
Factors influencing store release dynamics

- Ejection forces
- ERU force/time characteristics
- Aircraft g-loading
- Aircraft mass properties
- Aircraft elastic properties
- Aircraft forces
- Aircraft g-loading
- Aircraft flowfield
- Aircraft flexible accelerations
- Aircraft rigid accelerations
- Store aerodynamic properties
- Store forces
- Store aerodynamic forces
- Store accelerations
- Store in contact with ejectors?
- Store mass properties

Store separation from aircraft
ERU forces obtained from gantry tests with Hawk pylon performed by Denel Dynamics.

Two tests done – one in 2010 prior to release analysis and one in 2011 afterwards.
- 32% difference in measured forces and impulse.

Noted apparent release of ERU hooks 0.01 s before application of ejector forces.

Variability of Hawk ERU forces a major concern, especially for low altitude releases.
- An investigation has been recommended.
Modal properties obtained from broomstick finite element model of Hawk Mk-120 supplied by BAE Systems

Aeroelastic effects not modelled – flutter analysis shows limited change

Modal data generated for aircraft with pylons & Mk-82 but not Katleho

24 flexible modes included in model
Application to Hawk/Katleho - aircraft rigid accelerations

- 2 aircraft rigid body DOF analysed:
  - Normal (Z), roll
  - Constrained motion in other DOF
- Used mass, inertias, CG of aircraft without Katleho
- Used trimmed forces of aircraft with Katleho
  - Assumes delay in pilot response to g-jump
Application to Hawk/Katleho - store rigid accelerations

- Note links with aircraft
  - Ejector forces
  - Aircraft perturbation of flowfield
- 6-DOF model for store rigid dynamics

- ARUV panel code for all subsonic aircraft perturbation aerodynamics
Effect of flexible & rigid aircraft dynamics on store release

- Identical cases analysed considering flexible & rigid aircraft structure
- Impact of flexible aircraft structure on store trajectory is insignificant for this configuration
Effect of flexible & rigid aircraft dynamics on store release

- Compared different combinations against “ideal”
- Store pitch rate is critical for store release analyses
- Impact of flexibility is minimal, but ignoring rigid roll introduces 15% error

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<th>Vz (end of ejection) (m/s)</th>
<th>Error (%)</th>
<th>Pitch rate (end of ejection) (°/s)</th>
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Katleho flight tests

- Two releases of instrumented stores from instrumented aircraft took place in June 2011
  - Ideal opportunity to “close the loop”

(Pictures from release video supplied by SAAF)
Katleho flight tests

• Numerically, excellent correlation was found
  • Software and process validated
• Inconsistent ejector force/time behaviour is biggest concern
  • Compared with baseline measured at Denel Dynamics, the releases had 37% and 50% LESS impulse
  • For 50% less impulse case, Katleho could hit aircraft if released at low altitude, maximum Mach number case
Conclusions

• Store releases are complex to analyse – many interacting factors
• Analyses are only as good as their inputs
  • Investigation into inconsistent Hawk ERU forces recommended
• Adding roll to aircraft “g-jump” dynamics important for accurate release analyses
• Aircraft flexible response not significant for release of Katleho on Hawk
• Wind-tunnel testing recommended to supply near-field aeroloads for all configuration combinations
Acknowledgements

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