AUTOMATED ANALYSIS OF AIRCRAFT CONFIGURATIONS FOR SAFE SEPARATION ENABLED BY QUANTITATIVE GRADING OF RESULTS

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Aeronautical Systems Competency
Defence, Peace, Safety and Security (DPSS)

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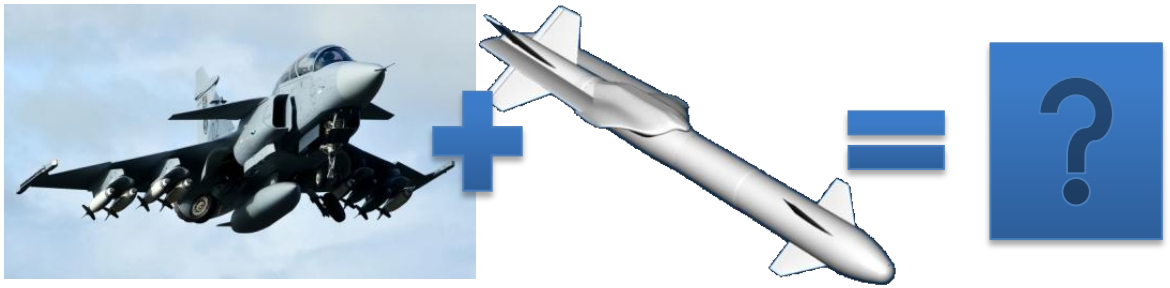
Objectives

- Background
- Why are store separation analyses required?
- Regulatory requirements for store separation analyses
- The problem
- Automation of separation analyses
- Development of quantitative separation criteria
- Implementation of quantitative separation criteria
- Conclusions

Background

Comprehensive aero/mechanical compatibility evaluation must be done when integrating stores onto aircraft	Why? Ensure that:	Aspects include:
• MIL-HDBK-244A Guide to aircraft/stores compatibility 1990 • MIL-HDBK-1763 Aircraft-stores compatibility 1998	• All aircraft/store combinations have acceptable aerodynamic, structural, dynamic characteristics • under all flight and ground conditions. • Ensure safety & minimise risk of functional failure	• Carriage loads • Aeroelastic (flutter) compatibility • **Store separation safety** • Performance & handling

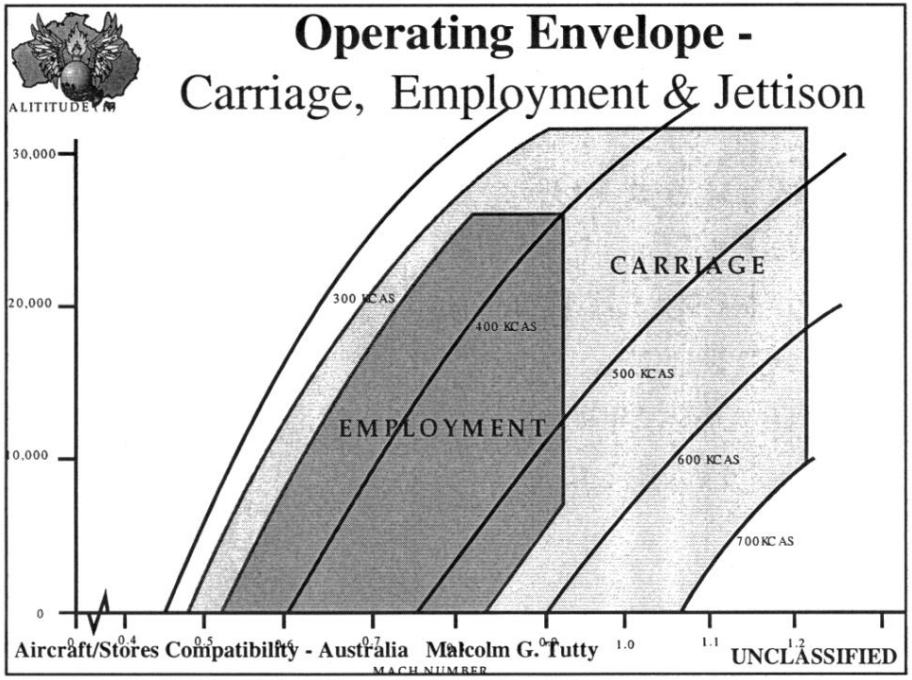


Why are store separation analyses required?

- Based on painful experience
  - Stores that are individually stable can behave VERY differently in aircraft flowfield

Regulatory requirements for store separation analyses

- Verify that stores can be released safety over full employment & jettison envelopes
  - Includes all perturbations of:
    - store mass and physical properties
    - ejector rack performance
    - aircraft release flight conditions
    - stations on aircraft
    - neighbouring stores
      - MIL-HDBK 1763: 271.4
  - Results in a very large analysis matrix!



From: Tutty, M.G., "Aircraft/Stores Compatibility - The Australian Perspective", 1998

The problem

- Integration of even 1 store type onto aircraft generates large matrix of permutations
  - One integration contract resulted in 128 aircraft configurations in addition to permutations
- Traditionally separation evaluated by analyst subjectively assessing animations of each store separation
- With increasing computer speeds, more releases & configurations can be done rapidly
- Swamps manual means of separation assessment
- Needed to develop fully automated separation analysis software & technology

Automation of separation analyses

Requirements for automated separation analysis software

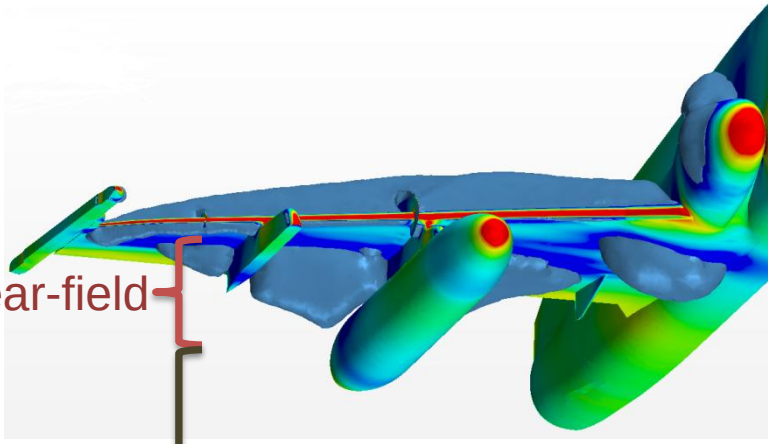
Import Excel script of all release scenarios for specific “aerodynamic” configuration	
Determine aircraft trim states for each release scenario	
Analyse each release scenario	Use ARUV panel code for subsonic releases
	Use wind-tunnel or CFD grid data for near-field in transonic releases
Automatically & quantitatively assess result of each release, assign score	
Write results for all scenarios into file imported into Excel	
Write all underlying files & data into ZIP file for each scenario	

Automation of separation analyses

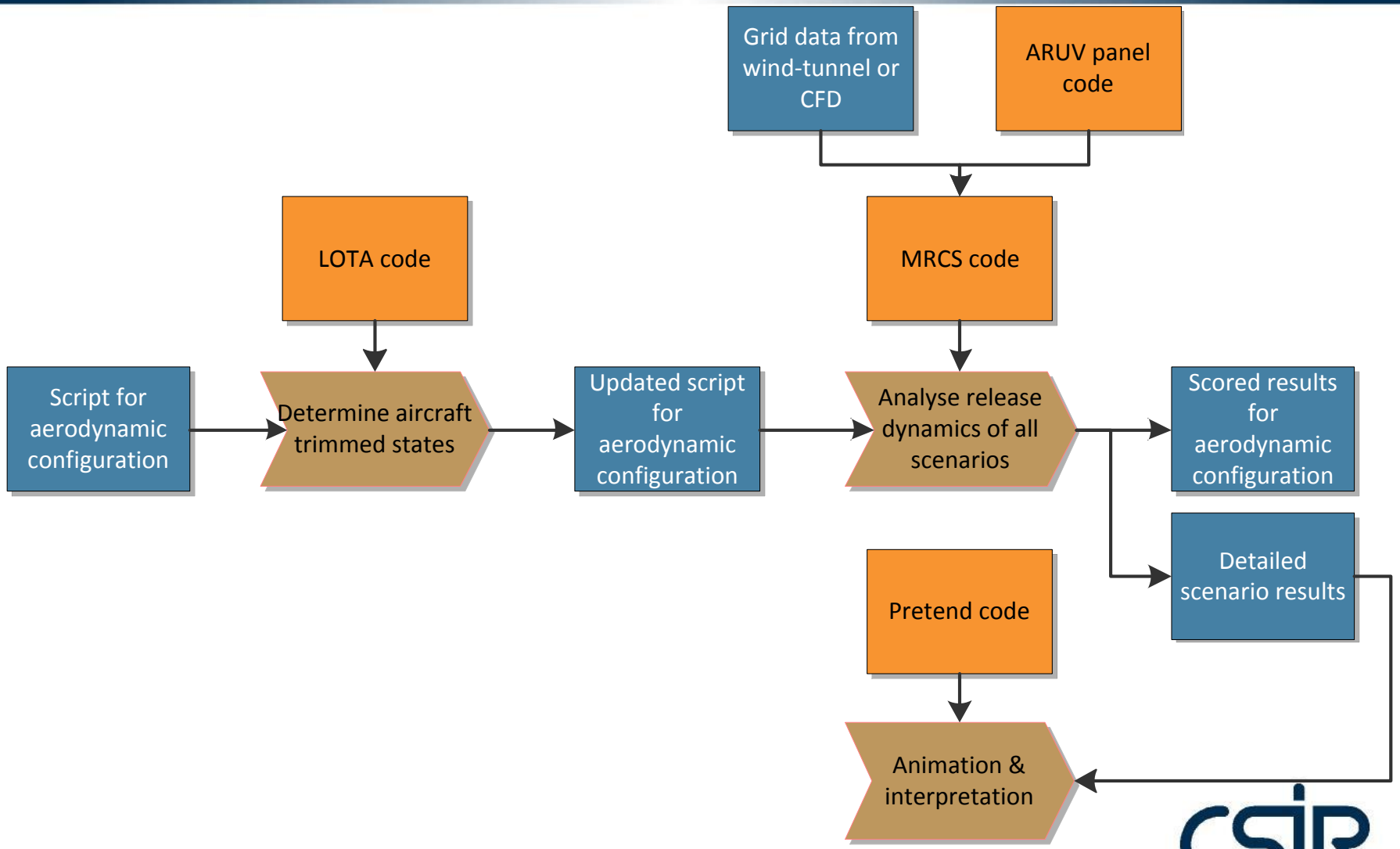
Approach to handling transonic releases

2 aerodynamic zones

Near field	Far field
Interaction with shockwaves	No shockwaves present
Use wind-tunnel or CFD data	Use ARUV panel code to generate flowfield
Limited extent	Use component look-up table to model store



Automation of separation analyses



Automation of separation analyses

- Separation analysis script
  - Excel file with rows specifying each release scenario

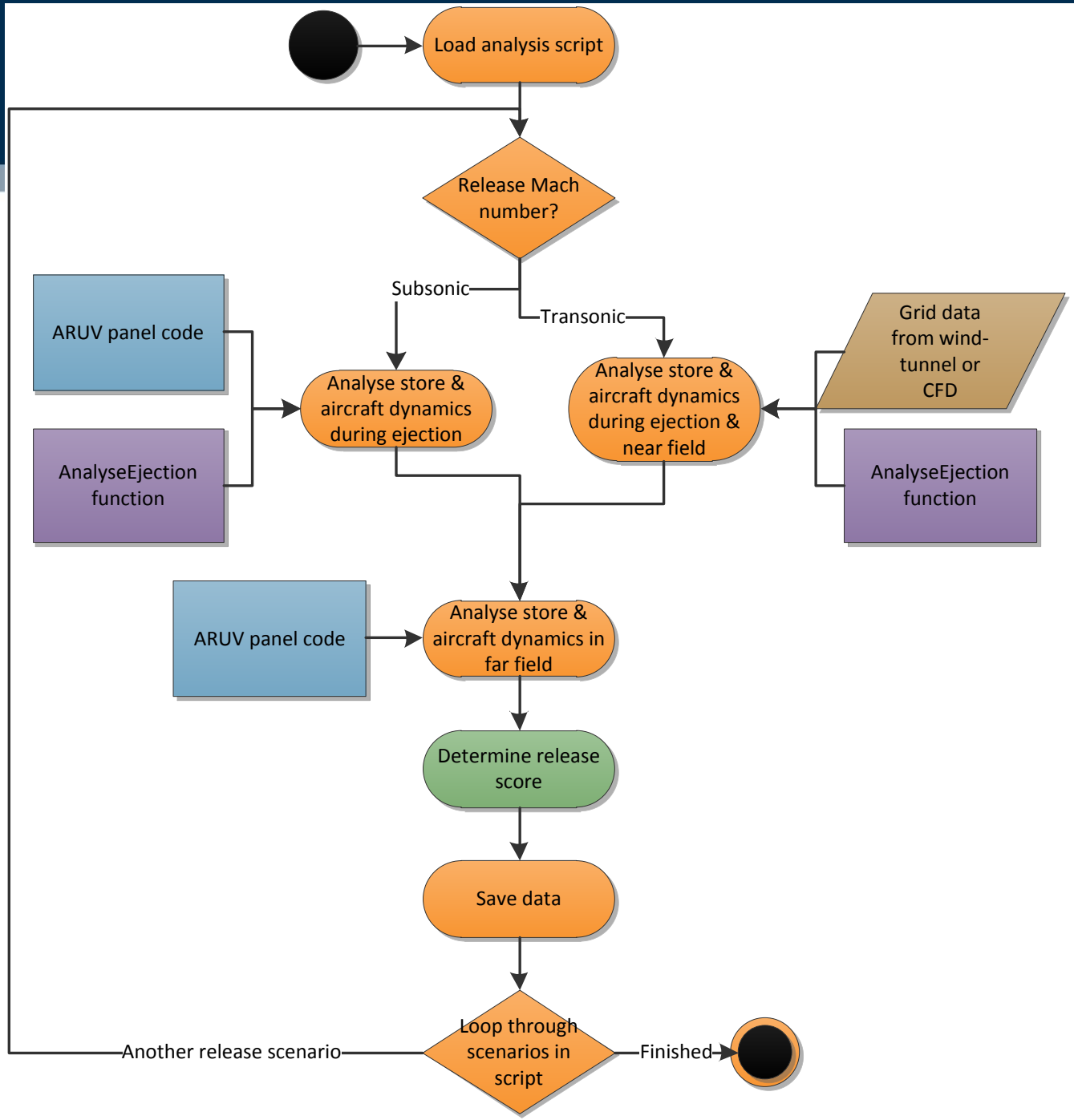
Aerodynamic configuration	Umbani version	Mach No.	Alt	Flight Path Angle	Roll Angle	Nz	Ny	Roll rate	Aircraft Mass ex-U	A/c cg-y ex-U	A/c cg-z ex-U	A/c Ixx ex-U	Store cg-x	Store mass delta	Roll offset	Ejector force setting	Alpha	Beta	Right aileron
			(ft)	(deg)	(deg)	(x 1g)	(x 1g)	(deg/s)	(kg)	(m)	(m)	(kg.m2)				(%)	(deg)	(deg)	(deg)

Automation of separation analyses

- LOTA code
  - Low-Order Trim Analysis code
  - Determines AOA, beta as well as aileron, elevator & rudder deflections to trim aircraft for specified Nz, Ny, at given mass, CG, Mach, altitude, flight path angles
  - Uses Digital Datcom model of aircraft
    - Hence “low-order”
    - Augmented with data from aircraft manual, ARUV models of stores
  - Uses optimisation approach

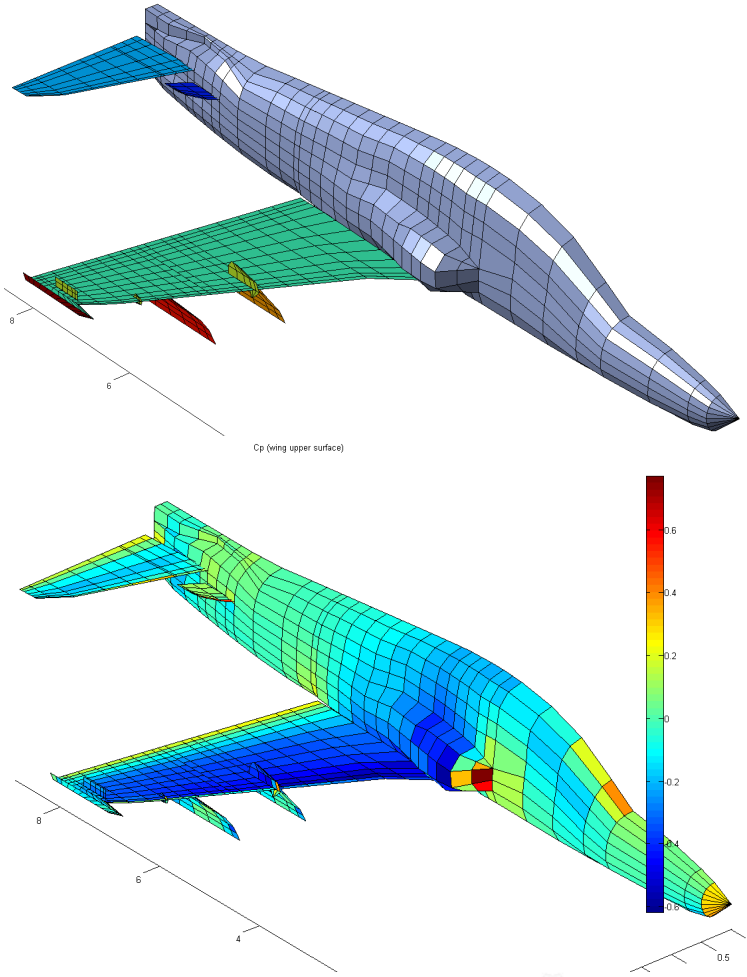
Automation of separation analyses

- MRCS code
  - Automatically executes a script of release analysis scenarios
  - Implemented in Matlab



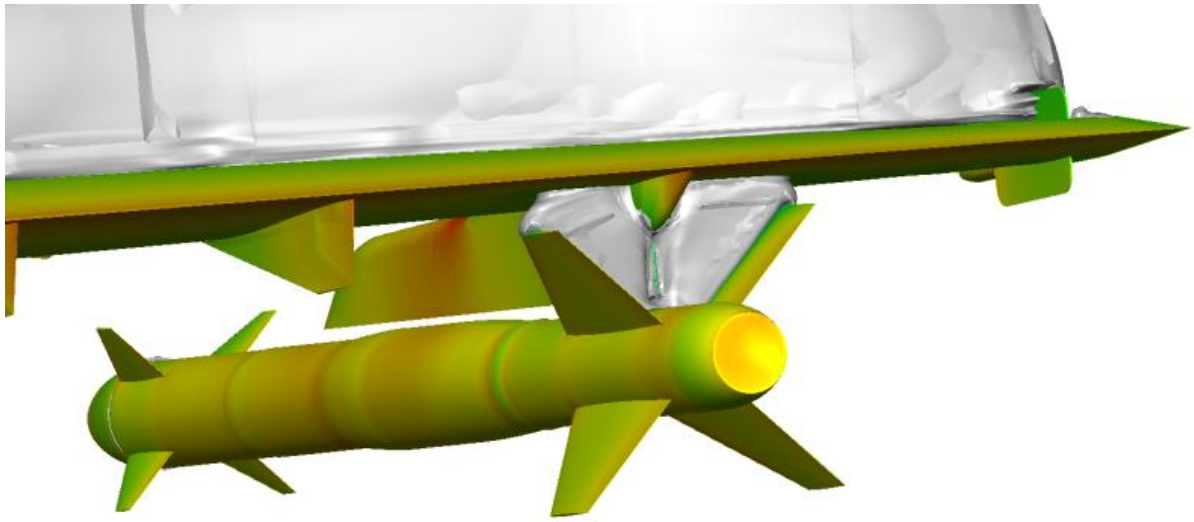
Automation of separation analyses

- ARUV panel code
  - Low-order panel code with extensive range of features for store release analysis
  - Based on Woodward's formulation using linear potential theory, takes compressibility into account.
  - Inviscid with no boundary layer model
  - Fast, performs well for low AOA subsonic flows
  - Extensively validated



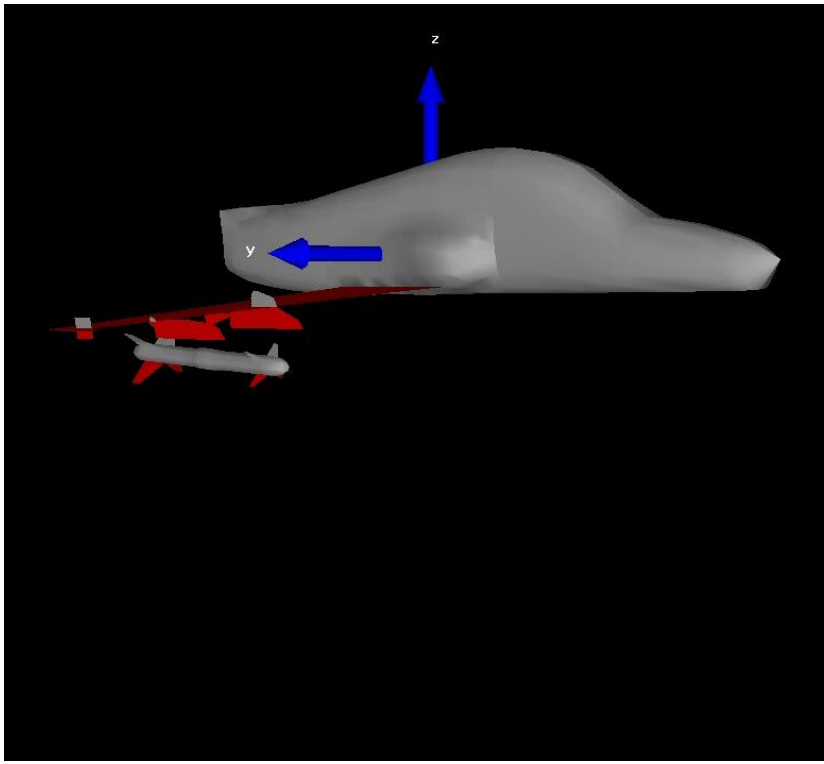
Automation of separation analyses

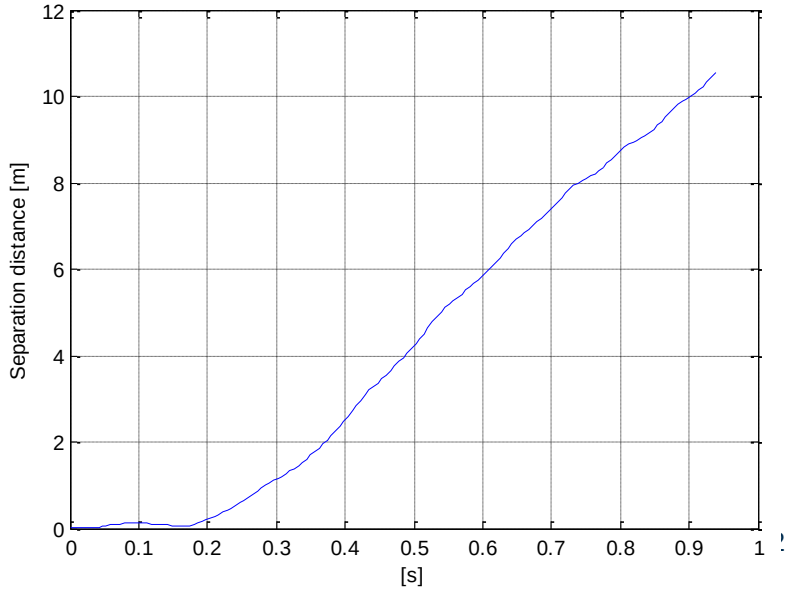
- AnalyseEjection function
  - Pre-processor to ARUV
  - Developed to analyse rigid & flexible store & aircraft ejection dynamics
  - Upgraded to either:
    - incorporate transonic store aeroloads derived from grid wind-tunnel tests or CFD analyses for near-field analyses OR
    - incorporate subsonic aeroloads derived from ARUV for pure ejection analysis
  - Store dynamic derivatives included in dynamic model



Automation of separation analyses

- Determination of release score
  - To support automation of store separation analyses, each separation must be assessed automatically
    - Assessment must be quantitative
    - Must use clear criteria to score the releases – ensure that marginal releases are correctly red-flagged for attention
  - Implemented using ARUV panel geometry
  - For specified time intervals, closest miss distance of store panel corners to aircraft panel corners is calculated





Development of quantitative separation criteria

Regulations discriminate between 2 classes of store separation with differing criteria:

Employment (no damage/contact to aircraft & store)			Jettison (emergency release of store)		
Positive movement away from aircraft	Positive velocities	No part of store penetrates interference boundary of aircraft 6 inch (152 mm) encapsulation	More risk	Minor damage to aircraft tolerated	Store may break up, but should not threaten aircraft

Development of quantitative separation criteria

- Additional consideration from “Definition of Safe-separation Criteria for External Stores and Pilot Escape Capsules”, E.E. Covert, NWC-TP-4995, 1971:
  - any store that fails to move one radius away in 0.25 s is assumed to be unsafe

Implementation of quantitative separation criteria

Decided to “score” separation scenarios in terms of quantitatively defined codes linked to regulations

Held workshop with stakeholders to forge common understanding on codes and interpretation

Stakeholders included:

- Military aircraft airworthiness specialist
- Senior test pilot
- Engineering representatives of the company designing the store
- Weapons integration technology manager
- Store separation analysis specialists
- Project managers

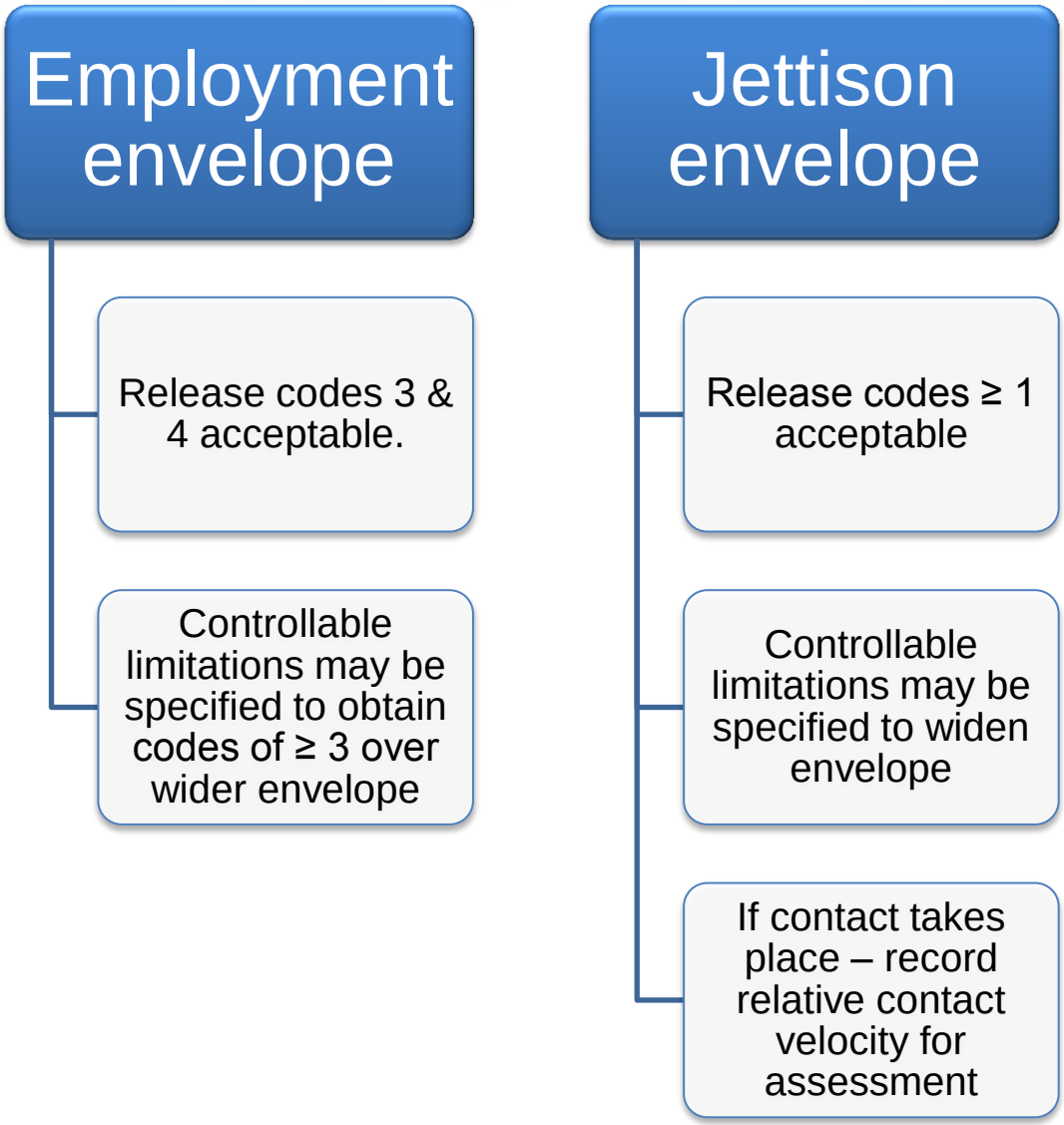
Implementation of quantitative separation criteria

- Results of workshop implemented in MRCS code:

Code	Definition
0	Store strikes some part of the aircraft
1	Store misses the aircraft marginally
2	Store moves towards the aircraft
3	Store “hovers” near the aircraft
4	Store separates cleanly from the aircraft

Code	Absolute Separation Distance	Separation Velocity	Separation Velocity Relative to Ejection Velocity
0	< 0		
1	< 0.020 after 0.06 s **< 0.152 after 0.25 s**	< 0 before 0.06 s	
2		< 0	
3			< 0.3 Veject after 0.06 s
4			

Implementation of quantitative separation criteria



Conclusions

- Development of advanced, automated store separation analysis code system described
  - Automation reduces time to analyse “aerodynamic” configuration from 1 month to 2 – 3 hours
  - Facilitates robust investigation of all perturbations required by regulations – increases safety
  - Reduces subjectivity due to manual interpretation of results
  - Clear criteria, agreed upon by all stakeholders facilitates common understanding of results

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