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• Designing for safe separation.
• Questions.
Aim of presentation

• Understand why safe separation analysis is required.
• Provide a flavour of the problems faced when integrating stores onto an aircraft.
• Provide some hints/ tips for aircraft/ store design
Stores Release Interfaces

- Software developers
- Aerodynamics
- Wind Tunnels
- Drawing Office
- Airworthiness
- Weapons Management
- Fuel Systems
- Weapons Manufacturers
- Launcher Manufacturers
- Avionics (ACS)
- Flight Test
- Ministry of Defence
- Partner Companies
What does safe separation entail

Primary:
• Ensure safe separation of stores from the launch aircraft, both single and multiple releases/ jettisons.

Also:
• Assess possibility of missile plume impingement on the aircraft and plume ingestion by the engines.
• Provide design advice to reduce store separation risks on new aircraft and feasibility of new stores/ new store configurations on an aircraft.
What do we class as a store

“A store is any object deliberately separated from an aircraft in flight”

- Classical.
  - Bombs: guided/unguided, free fall/retarded
  - Missiles: air-to-air, anti-armour, anti-radar, anti-bunker, anti-shipping
  - Torpedoes.
- Strange.
  - Tanks/pods/cannon/sonar buoys/chaff/flare
- Weird.
  - Canopy/full crew escape/towed decoys
The reason for safe separation analysis

• To ensure the safety of the launch aircraft.

Methods for safe separation analysis

• Engineering judgement or direct ‘read-across’.
• Flight trials alone.
• Wind tunnel investigation and flight trials.
• CFD.
• Mathematical modelling investigation and flight trials.
• T
Key aerodynamic drivers

- $\alpha$ (angle of attack).
- $M$ (Mach number).
- $q$ (dynamic pressure).
- $\beta$ (angle of sideslip).
- Mutual store interference (weapon fit).
Flight test

Drop stores at incremental steps.

Advantages
• Direct data (visible results).

Disadvantages
• Expensive.
• Many flights needed.
• Dangerous.
• Repeated if store is modified.
Drop model

- Wind tunnel model of store with:
  - scaled representative mass-inertia.
  - scaled representative ejection forces.
- Video/film trajectory.

Advantages
- Trajectory visualisation without actually flying.
- Cheaper than flying

Disadvantages
- Still little understanding about what affects trajectory.
- Repeatability is suspect.
- Exotic model materials required.
Computational Fluid Dynamics

- Computer based wind tunnel simulation.

Advantages
- Simulate stores with autopilot and boost motor if required.

Disadvantages
- Time consuming.
- Setup costs (time) may be high.
Mathematical model

Use of software (6 d.o.f.) with all necessary inputs to perform a computer based assessment.

Advantages

• Easy to use, over and over again, and repeatable.
• Trajectory available directly, numerical.
• Quick.
• Investigation outside envelope without repercussions.

Disadvantages

• Model accuracy dependant on input data accuracy.
• High computing power required for rapid analysis
STARS Mathematical model

Wind tunnel, CFD, empirical data sources

Aircraft manoeuvre

Target motion

Store autopilot

Store propulsion characteristics

Store physical characteristics (Mass, cg, inertia etc)

Aircraft flowfield

Store aerodynamics

Store carriage / grid loads

Aircraft - store aerodynamic interference characteristics

Release device - physical constraints

ERU characteristics (gas model)

Predicted store trajectory
Route to clearance

1. Weapon safe separation model
   - Pre-flight assessment
     - Safe separation flight trials
       - Fly-match-fly
         - Post-flight(s) analysis
           - Production clearance

2. Flight Trials Requirement
   - Update flight trial test points, as required
Analysis techniques

- simulations for a pre-flight investigation.
- CRASH (Collision Reporting And Separation History).
  - Minimum distance for a trajectory between store and specified geometries.
- Scatter analysis

Minimum acceptable separation distance

One of the most frequently asked questions is:

*What is the minimum distance we accept before it’s considered too low?*

Completely depends on how much the minimum separation distance is compared to the installed distance.
Throttle setting

- Regulates airflow depending on diameter.
- Preference is to have these at maximum throttle setting.
- Setting can also be governed by structural considerations.
- Throttle setting also governed by multi-store (type) considerations.
Effect of longitudinal centre of gravity position

PITCH UP DUE TO FWD CG

PITCH DOWN DUE TO AFT CG

Differential ERU Ram Forces

PITCH UP DUE TO HIGHER FORCE AT REAR

PITCH DOWN DUE TO HIGHER FWD FORCE
Bombs

- Lanyard routing.
- Deploying surfaces.
- Arming times.
- Guidance and control.
- Bomb capture process (retarded bombs).
Missile integration – plume effects

- Plume ingestion and/or impingement.
- Fin failures.
- Rail launch versus eject launch
Cannons

- Usually big chunky items.
- Recoil.
Moving surfaces

- Only MIL-spec regarding safe separation states a minimum of 1” clearance between fixed and moving parts.

- Flaps.

- Slats.

- Tail-planes.

- Gear.

- Moving wing
Fuel tanks

- Big stores.
- Fly back, especially if lifting surfaces.
- Large c.g. range in longitudinal direction.
- Very heavy, yet also very light.
Emergency jettison

- Dispose of all allowable stores in the fastest possible time in case of emergency.
- What would happen in case of internal bomb bay?

Minimum Release Interval

- Just looking at single store is not enough.
- What is the minimum time at which all bombs can be released.