Store Separation Overview

Alex Cenko
AIWS LLC
Huntingdon Valley, PA 19006
UNITED STATES

cenkoa@gmail.com

ABSTRACT

Any time a new aircraft is introduced into service, or an old aircraft undergoes substantial modifications or needs to be certified to carry and employ new stores, the store separation engineer is faced with a decision about how much effort will be required to provide an airworthiness certification for the aircraft and stores. Generally, there are three approaches that have been used: Wind Tunnel Testing, Computational Aerodynamics and Flight Testing. During the past sixty years there have been considerable advances in all three areas. In particular, a method for combining the three approaches was developed: Integrated Test and Evaluation Approach (IT&E) to Modeling & Simulation for Store Separation. This lecture describes how this process evolved.

1.0 BACKGROUND

In the early days, store separation was conducted in a hit or miss fashion - stores would be dropped from the aircraft at gradually increasing speeds until the store came closer to or sometimes actually hit the aircraft. In some cases, this led to loss of aircraft, and made test pilots reluctant to participate in store separation flight test programs.

During the 1960's, the Captive Trajectory System (CTS) method [1] for store separation wind tunnel testing was developed. The CTS provided a considerable improvement over the hit or miss method, and became widely used in aircraft/store integration programs prior to flight testing. However, CTS was not utilized in an integrated approach, since the group conducting the wind tunnel test was generally separated both in organization and location from those responsible for conducting the flight test program and determining the safe separation envelope. Furthermore, since fairly small scale models had to be used in the wind tunnel tests, in many cases the wind tunnel predictions did not match the flight test results. No mechanism was then in place to resolve the wind tunnel/flight test discrepancies.

Since the time Computational Fluid Dynamics (CFD) was first capable of representing the geometric complexity of an attack aircraft with external stores [2], there has been the desire to replace/reduce the need for wind tunnel testing. The three detriments for full utilization of CFD in this fashion were computational speed, computer resources and accuracy of the solution. For the Advanced Weapons Carriage and Separation (AWCAS) configuration [3], one solution using a linear code with 1000 panels required full utilization of the supercomputer of that time (CDC 6600) for twenty-four hours. Clearly, the wind tunnel was in no danger. As a metric of where we are now, the same solution will now run in seconds on a PC.

The most critical feature that determines a store's separation trajectory are the carriage moments, which are principally caused by the aircraft flowfield. For this reason, the first step in separation analysis is to estimate the region of the flight envelope that might have the worst carriage moments. This is done by deriving an estimate of the aircraft effects at the store location. Prior to the development of the Chimera technique [4] the only tools to evaluate the aircraft/store aerodynamics were the wind tunnel, linear theory or potential flow techniques.

Although potential flow codes had demonstrated the ability to predict complex aircraft flowfields in the linear speed regime, yaw head probe flowfield test data, when available, were always used to validate the analytical aircraft models. In the US, the yaw head probe test data were usually acquired at the DTRC 7x10, AEDC 4x4 and the CALSPAN 8x8 foot transonic wind tunnel.

Due to the enormous time required for one computation, a technique that could use the clean aircraft flowfield was developed at Grumman under an Air Force contract. The Influence Function Method (IFM) [5, 6, 7] was used to determine the effect of the aircraft flowfield on the store loads and moments.

Using the aircraft flowfield and store influence coefficients, an estimate of store aerodynamic coefficients was made everywhere in the flowfield, including carriage. The store aerodynamic coefficients were then input in a Six-Degree-of-Freedom (SDoF) program to simulate the store's trajectory prior to the wind tunnel test. The simulated trajectories were used to help design the wind tunnel test to ensure that the most critical regions of the store separation envelope were tested. This approach was the principal technique for inserting computational aerodynamics in the flight clearance process during the 1980's, and its derivative (FLIPTGP) is still used by the air force.

Starting in the late 1980's the US Air Force and Navy made an effort to validate and accelerate the insertion of CFD methods into the store certification process. There have been several organized international conferences for this purpose.

The first of these was for the Wing/Pylon/Finned-Store, which occurred in Hilton Head, SC in the summer of 1992. One of the important results from this initial conference was the discovery that full potential methods [8, 9] gave answers equivalent to those provided by a Euler code for the wing lower surface in the presence of the store.

The second conference was sponsored by the Office of the Secretary of Defence funded Applied Computational Fluid Dynamics (ACFD) program. This was for the F-16/Generic Finned Store, also called ACFD Challenge I; the conference took place in New Orleans in the summer of 1996[10].

Starting in early 2000, after ACFD Challenge II [11], CFD became a regular tool in the store separation process for external stores.

2.0 INTRODUCTION

Store separation forms a key part of establishing the compatibility of aircraft configurations so that they are operationally suitable and effective at performing testing, training and operations. Traditionally many NATO nations use MIL-STD-1763 and MIL-HDBK-1763, MIL-HDBK-244A, NATO STANAG 7068 and Science and Technology (STO) AGARDograph 300 Vol 29 [12-18] as the basis for conducting analyses, wind tunnel testing and modelling and simulation (M&S), prior to ground and flight testing. This is done to establish the certification basis for the aircraft/stores configurations needed.

The assessment of aircraft stores compatibility includes an engineering review for each aircraft store combination to determine if a 'significant change' (as defined in MIL-HDBK-1763) is made to an aircraft store configuration in the areas of physical, informational, operational suitability and effectiveness [19]:

1 Function;
2 Form and Fit;
3 Structural & Environmental;
4 Aeroelasticity;
5 Captive Carriage, Handling/Flying Qualities & Performance;
6 Employment & Jettison;
7 Information Suitability: External Interfaces, Mission Planning, Ballistics and OFP Validation & Verification, Safe Escape & Danger Areas (Safety Templates) [12];

8 Cognitive Suitability: Procedures, Tactics, Techniques and Procedures and Human Factors;
9 Emergent Properties for Critical Operational/Technical Issues / Measures of Suitability/ Effectiveness: Experimentation and T&E.

Store separation is primarily concerned with the employment and jettison of a store from the aircraft while the store remains in the aircraft flowfield. In most cases, this is approximately 20-30 feet from the store's carriage position.

2.1 Engineering Review

The engineering review is the first step in the store separation process. Use of the 'significant change' criteria in MIL-HDBK-1763 gives design engineers and operational users some tolerances that enable minor changes to be made without major commitment of time and resources.

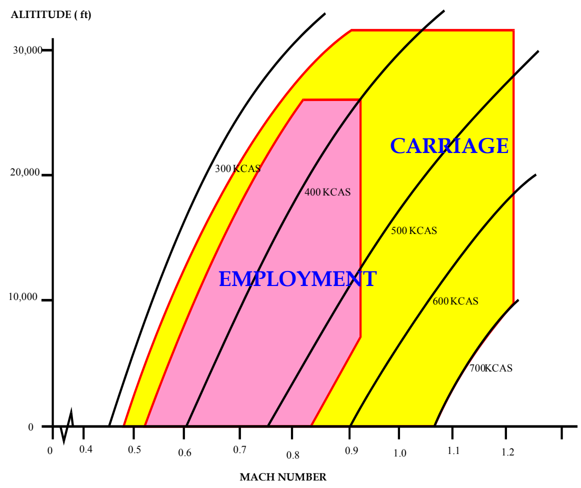

Figure 1: Aircraft Configuration Operating Limitations.

Depending on the *maturity* of the stores and/or aircraft, there are four separate compatibility situations involved when authorization of a store on an aircraft is required. The four situations, in order of increasing risk, are:

1 Adding 'old' stores to the authorized stores list of 'old' aircraft.
2 Adding 'new' stores to the authorized stores list of an 'old' aircraft, or adding new configurations and/or expanding the flight operating envelope of an 'old' aircraft.
3 Adding 'old' stores to the authorized stores list of a 'new' aircraft.
4 Adding 'new' or modified stores to the authorized stores list of 'new' or modified aircraft.

Depending on the engineering review, the store separation flight clearance may be done using similarity, Six Degree of Freedom (SDoF) trajectory predations, CFD computations and/or wind tunnel testing before proceeding to flight testing.

3.0 WIND TUNNEL TESTING

3.1 Drop Testing

Store separation wind tunnel testing began by releasing the stores from the aircraft at the desired Mach number and measuring their positions and attitudes using high speed cameras, Figure 2. The stores would be caught by a net positioned underneath the aircraft. This approach had several drawbacks. Because the aircraft and store models were a fraction of their true size, the aerodynamics and mass properties could not be properly scaled (aerodynamic coefficients increase by the square of the size, the mass by the cube).

Figure 2: X-15/B-52 Drop Test.

There were two techniques of drop testing used, light model and heavy model.

One disadvantage of heavy model testing was the tendency for the heavy models to break through the net and hit the tunnel walls. This would damage the tunnel and store models. There were stories [20] that early in the A-6 store separation program the store models were made from gold, so they could be rapidly melted down and recast. This required the placing of armed guards at the wind tunnel entrance doors. Drop testing is now rarely used, except for fuel tanks or other tumbling stores, which are not amenable to CTS wind tunnel testing.

3.2 Captive Trajectory System (CTS) Wind Tunnel Testing

The Captive Trajectory System uses a strain gauge balance within the separating store to continually measure the forces and moments acting on the store. An on-line computer simulation determines successive positions of the store through its trajectory.

CTS testing require a separate sting for the aircraft and store, as shown in Fig. 3.

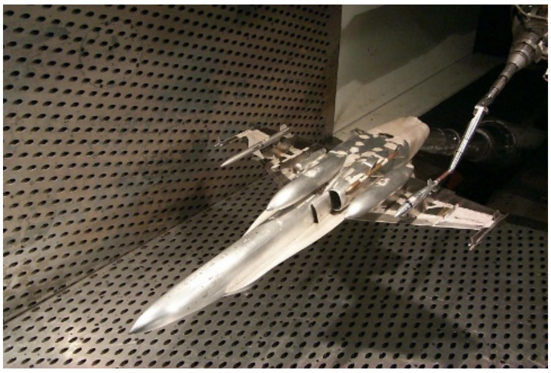

Figure 3: CTS Wind Tunnel Test.

3.3 Grid Data

Grid data are taken at various store positions and attitude from the carriage position; either CFD predictions or CTS trajectories are used to determine the store positions and attitudes required.

Trajectories are then calculated off-line using this information as inputs to an SDoF program. One advantage of the grid data approach is that the freestream data from the small scale CTS store model (5-10%), can be replaced by larger scale freestream data (usually, 40-100%).

The main advantage of the grid data approach is that various initial conditions can be simulated using the SDoF trajectory code after the wind tunnel test is finished.

3.4 Probe Flowfield Testing

A pressure probe is inserted in the flowfield through which the store must separate. The probe measures the Y and Z flowfield angles (sidewash and upwash) that the store would experience. Upwash is mostly due to wing effects and causes store pitching moments (CLM), while sidewash is usually due to engine inlet and produces store yawing moments, Figure 4.

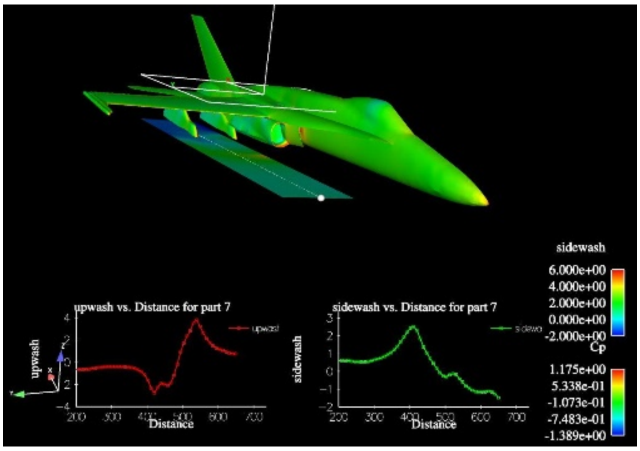

Figure 4: Aircraft Upwash and Sidewash effects.

This approach gives a good indication of aircraft configuration effects. Panel methods have shown good agreement with wind tunnel data even at transonic speeds.

3.5 Carriage Loads

In this test forces and moments are measured on the store, with the store attached to the aircraft in its correct carriage position. CTS mounted stores are usually 2-3 inches below carriage. These data are used as inputs to trajectory computation programs. This method does not require a separate sting for the store.

4.0 EXAMPLES OF IMPROVEMENTS OF STORE SEPARATION TOOLS

It appears at the present time that CFD for external stores has reached a mature phase. Lockheed has demonstrated that CFD can be used to design an aircraft to be "store friendly', and that the aircraft performance is actually improved by the process, Boeing also used CFD in the design phase for their MMA aircraft/store integration. Examples of how this process developed are described.

4.1 CFD Applications to Store Separation

4.1.1 External Store Separation

The Air Force, Army, and Navy had long-term, proven CFD modelling and simulation experience and software development expertise that supported advanced weapon development and integration. Each used their preferred CFD codes to augment traditional sources of engineering data such as flight and wind tunnel testing. During the first decade of 2000, the three services, under the auspices of the High Performance Computing (HPC) center combined their efforts to establish an Institute for HPC Applications to Air Armament (IHAAA).

There have been several improvements in utilizing CFD for store separation analysis since that time. In one IHAAA project, the Air Force provided the Navy with CFD predictions that enabled the flight clearance process to proceed in a timely fashion.

Due to urgent requirements for Operation Iraqi Freedom, a flight clearance for the GBU-12 on the F-18C Canted Vertical Ejector Rack (CVER) adjacent to the 330 gallon tank was required. Since the time frame didn't allow for a wind tunnel test entry, and the Navy did not have a computational model of the GBU-12 store, it was decided that the "hit-or-miss" method would be employed. The hit-or-miss method involves dropping the store at increasing airspeeds (by increasing M at the same altitude) until it is felt that it is no longer safe to proceed.

This represented adding new configurations and expanding the flight operating envelope of an 'old' aircraft. Although the results for the first flight (M = 0.88, 5000') were relatively benign, the close distance between the fins of the first store and second store, and the fins of the second store and fuel tank raised flight safety issues.

As may be seen in Figure 5 there is very little clearance between the open tail of the outboard store and the inboard store closed tail. Of more concern was the close distance between the inboard store tail and fuel tank, Figure 6.

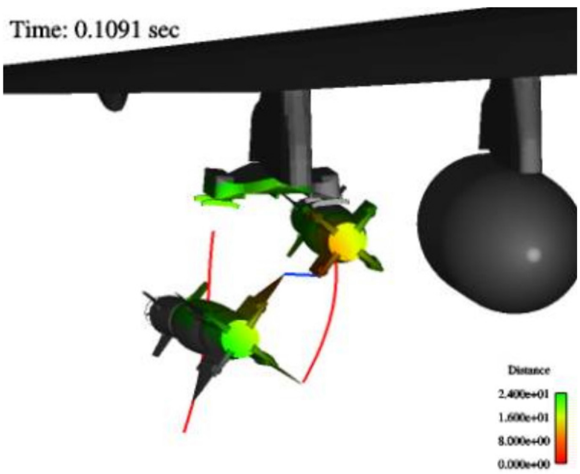

Figure 5: F-18C/GBU-12 Outboard.

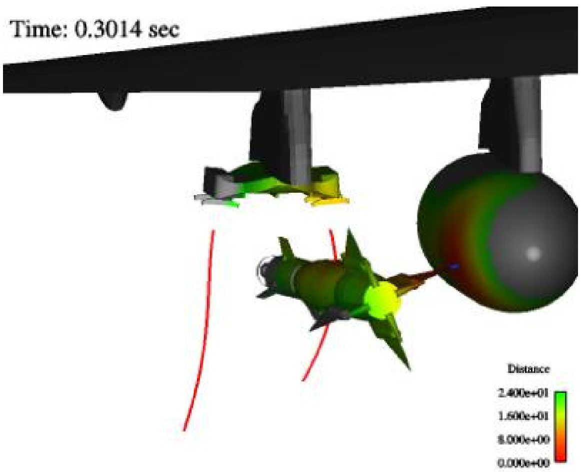

Figure 6: F-18C/GBU-12 Inboard.

Usually, when the miss distance gets within six inches there is a reluctance to proceed with the next flight test point; unless wind tunnel data indicates it's OK to go ahead.

Fortunately, the Air Force SEEK EAGLE office had the geometry of the F-18C/D available, since they participated in ACFD Challenge II. They were also experienced in performing trajectory calculations for the

GBU-12 store, and offered to perform CFD calculations simultaneously with the flight test program. Their predictions were in excellent agreement with the flight test data, and the flight test program was able to proceed to the desired end point.

This, and several other IHAAA projects, are explained in greater detail [21-23].

4.1.2 Store Separation from Weapon Bays

Although CFD applications to external store separation problems are well documented, such is not the case for stores separating from bomb bays. There have been two attempts to determine how CFD can be used to address this problem.

For the case of the Small Smart Bomb (SSB) separating from the F-111 aircraft, Australia, Canada, the UK and the US Air Force and Navy participated in a TTCP project to determine whether CFD could be used to determine discrepancies between wind tunnel test data and flight test results. The participants agreed that some of the differences between the wind tunnel and flight test data could be attributed [24] to the fact that no wind tunnel aerodynamic data were taken inside the cavity. However, the flight test data were not sufficiently accurate to determine which CFD tools gave the correct answer. One interesting result was that Reynolds Averaged Naiver Stokes (RANS) results appeared to be in better agreement with the wind tunnel test data than a DES solution.

Another attempt to apply CFD to store separation from bomb bays was under an IHAAA funded project examining the separation of the GBU-38 bomb from the B-1 aft bay. Two major findings [25, 26] from this project were that for well-designed spoilers the cavity flowfield had negligible effect on the trajectory, and that quasi-steady techniques work equally well to time accurate for these cases.

These were the first bomb bay flight test data telemetry that have been released, and demonstrated that, at least for this case, there were no unsteady flowfield effects inside the cavity. Further details for this project are available [27-31].

4.2 Advances in Wind Tunnel Testing

4.2.1 Carriage Loads

There have been four developments in wind tunnel testing that have improved the process. The first was the determination that store loads measured with the store on the carriage pylon could vary considerably from those measured from an aft mounted sting. Comparison with flight test data demonstrated that pylon measured loads gave better trajectory predictions [32], particularly at transonic Mach numbers.

4.2.2 Store Attitude Effects for Grid Testing

The second improvement in wind tunnel testing occurred as a direct result of the close integration between the wind tunnel and flight test community. Flight test data demonstrated that store attitude effects were critical to getting a good trajectory match with flight test results. Flight test data were then used to determine which of these effects were dominant.

Originally (1988), for every data point (i.e. Mach number, aircraft angle of attack) three values of X and Y (coupled), three of store roll and yaw (Phi and Psi), and five of pitch (The) were taken for every Z position (18 grids). At the end of the flight test program, it was discovered that if only one value of X, Y and Phi and two values of Psi and The had been taken (5 grids), the results would have been similar, while reducing the size of the wind tunnel test program by more than a factor of 3.

As seen in Figure 7, the prediction using a grid of 5 variables was just as good as that using the original 18. However, using only one grid variable, the prediction departs from the test data when the attitudes exceed 10 degrees in pitch and yaw.

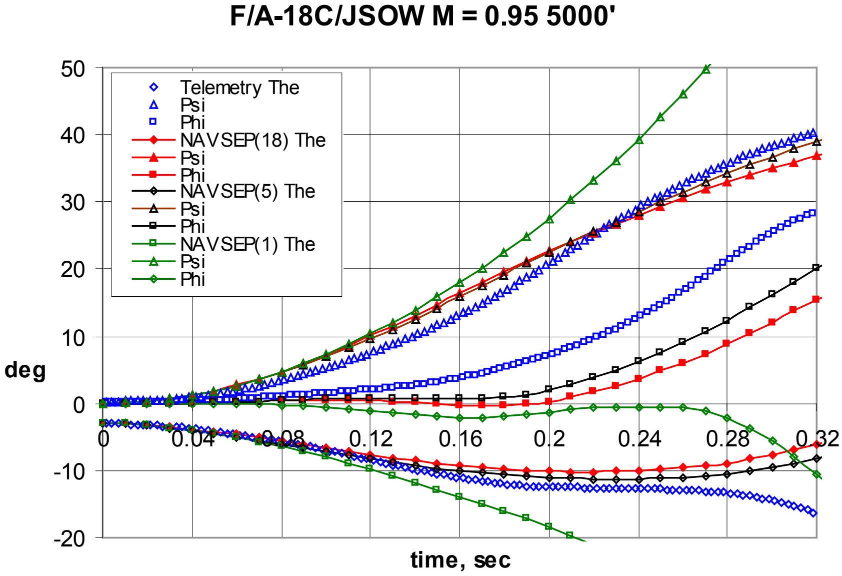

Figure 7: F-18C/JSOW Grid Effects on Trajectory Prediction.

The GBU-31, GBU-32 and GBU-38 (GBU refers to Glide Bomb Unit) stores certification programs were successfully completed (1988-2003) using only one value of X, Y, and roll angle, and three values of yaw and pitch angles (7 grids). Excellent correlation was achieved between the predictions and test data [33].

4.2.3 Store Model Geometry Effects

Store separation wind tunnel test data is usually done with small scale models (5-10%). It is hard to accurately model all the geometric effects in such small scale. For that reason, freestream coefficients are subtracted from the grid data at the appropriate angle of attack and Mach number to produce incremental coefficients.

These incremental coefficients are added to the freestream at the appropriate angle of attack for the store at each time step to compute the quasi-steady trajectory.

Since the CTS is done with the store at the aircraft model scale, it’s important to use small scale models representative of the full scale geometry. As seen in Figure 8, small scale models closely match the large scale results for the GBU-32 store Normal force. However, Figure 9 shows the error that using a slab tail (AEDC 6%) in the small scale model to the pitching moment. The GBU-32 pitching moment appears to be neutrally stable, while the large scale and CALSPAN results indicate the store is unstable at low angles of attack. This was attributed [34] to the vortex shed by the GBU-32 strakes on the tail. The CALSPAN 6% geometry attempted to model the GBU-32 tail by using faceted tail geometry.

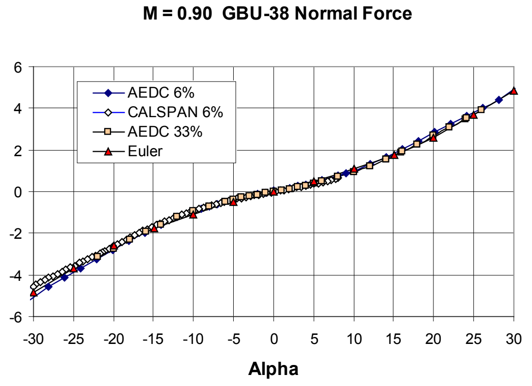

Figure 8: GBU-32 C_N.

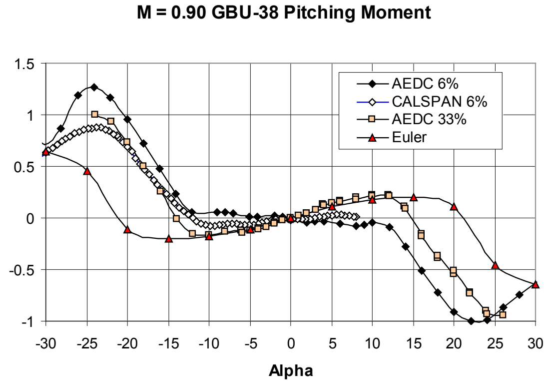

Figure 9: GBU-32 C_m.

4.2.4 Mach Sweep Effects

A third change in store separation testing was the development of the Mach sweep technique. Originally, wind tunnel testing would be conducted at pre-specified points in the flight envelope, i.e. M = 0.6, 0.80, 0.9, 0.95, 1.05, 1.1, 1.3. However, at transonic speeds, the aerodynamic coefficients can change substantially and non-linearly for small Mach number increments.

The Mach sweep test technique uses a small incremental build up in tunnel Mach number in the transonic range (i.e. M = 0.02). As seen in Figure 10, the yawing moment coefficient for the GBU-32 store changes by more than 100% between M = 0.90 and 0.92. Furthermore, aircraft configuration changes have a significant impact on the store aerodynamics. The large yawing moment effect of the Targeting Forward Looking Infrared (TFLIR) can also be seen.

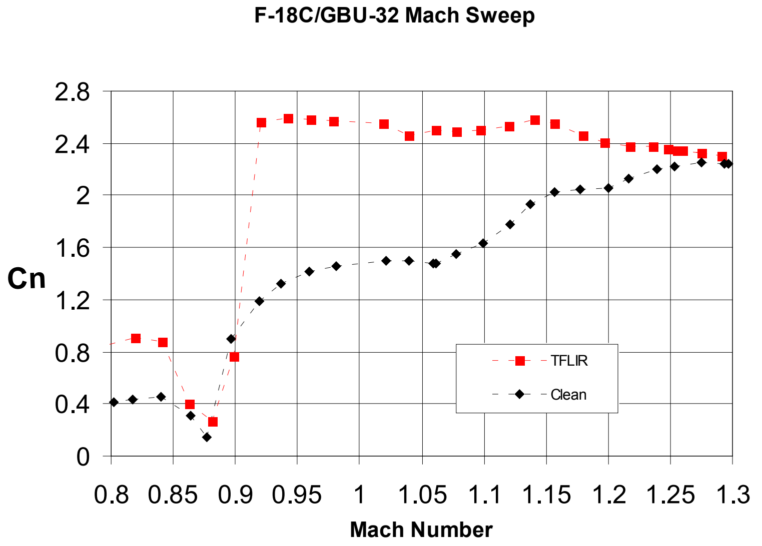

Figure 10: GBU-32 Yawing Moment as a Function of Mach number.

One major advantage of the Mach sweep technique is that it is easy to identify the critical Mach numbers for the remainder of the test. For the GBU-32 and GBU-38, most of the grid data were taken only at M = 0.85, 0.95 and 1.20; an excellent match with the flight test data were achieved [33].

4.2.5 Advances in Flight Testing

The flight test process is the most expensive part of store separation testing, and thus can lead to the most overall savings.

Shown in Figure in 11 is an Integrated Test and Evaluation (T&E) approach to store separation [35, 36]. This approach uses CFD to design the wind tunnel test, results of which in turn are used to design the flight test matrix. The process is continuously improved, since the wind tunnel test results are used to validate the CFD predictions, and the flight test results are used to both check the wind tunnel test data, and the original CFD predictions.

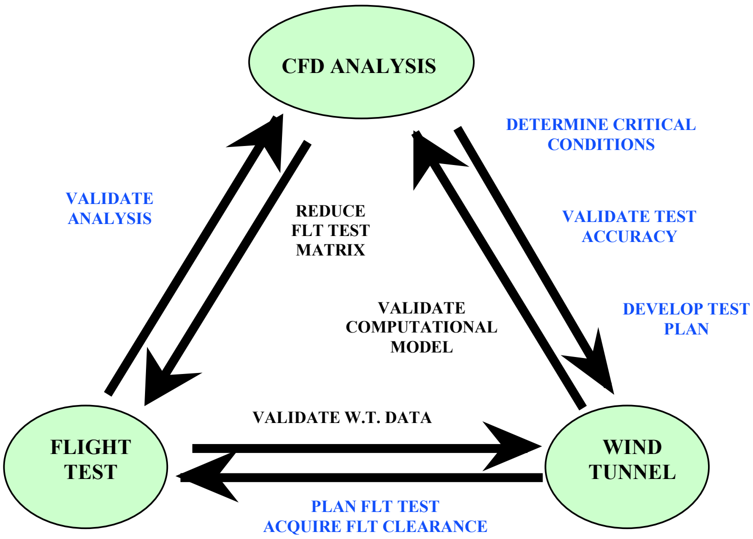

Figure 11: Integrated T&E Approach to Store Separation.

Two developments in flight testing have considerably improved the efficiency of the integrated T&E approach to store separation process. These were the development of high quality acceleration and angular rate telemetry data, and testing from both sides of the aircraft in a single flight. Telemetry data enabled a continuous improvement in the T&E process and added real-time decision making, while testing from both sides of the aircraft enabled twice the number of tests to be conducted for a given flight.

4.2.6 Number of Flight Tests Required

The Joint Stand of Weapon (JSOW) was certified for carriage and release on the F-18C aircraft in 1994. The original flight test matrix called for testing starting at M = 0.66 (400 KIAS) and proceeding to the transonic endpoint M = 0.95 (575 KIAS) in 25 knot increments. The testing was done for three aircraft configurations – JSOW released from outboard pylon with a JSOW on the inboard pylon, JSOW released from the inboard pylon, and finally JSOW released from outboard pylon with a 330-gallon tank on the inboard pylon. Since these flights were done from one side of the aircraft, this would have required twenty-four separate flights. Due to a good match with the pre-flight trajectory simulations, we were able to reduce the number of flights to fifteen. The program manager for Strike Weapons mentioned [37] these cost savings in his keynote address at the RTO meeting on Aircraft Weapon System Compatibility and integration, and said he expected we could reduce the number of flights to 8-10.

Were we to repeat the JSOW program at the present time, it might be possible to do that in 1-2 flights, with at most 4 weapons released, by dropping the stores from both side of the aircraft.

4.2.7 High Quality Telemetry Acceleration and Rate Data

There are two ways to determine flight test trajectory data. One is photogrammetrics and the other telemetry. Although both methods have their supporters and detractors, telemetry is unmatched in the ability to improve the modelling and simulation process of store trajectories.

Since every trajectory simulation consists of time integration, if the initial conditions are incorrect, then the trajectory can't possibly match the flight test data. Telemetry test data have been invaluable in determining the ejector force characteristics and their effects on the resultant trajectories.

Originally, ejector force characteristics were determined by using pit stand test data. The pit test data consist of parking an aircraft over a pit, and then ejecting the store into the pit and measuring its end of stroke velocity. These velocities were then used as the initial conditions for the trajectory predictions. As seen in Figure 12, the major cause of the discrepancies between pre-flight predictions and flight test data can be attributed to using pit stand data for ejector force calculations. The solid purple line represents the average of six pit test results, while the green line represents the flight test results for the same store.

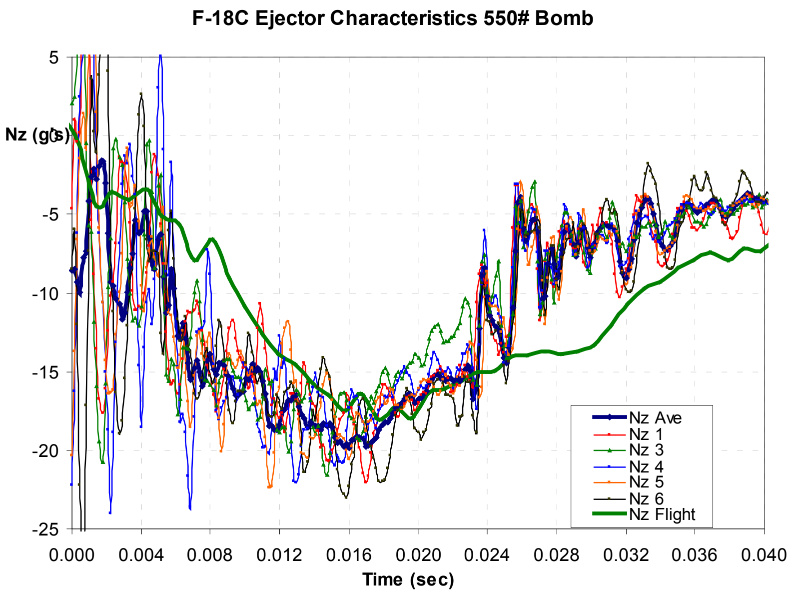

Figure 12: Pit Stand and Flight Test Ejector Force Data.

Clearly, the aerodynamically loaded wing in flight does not behave similarly to what is seen from the pit test data. Once telemetry data were used to determine store initial conditions, pre-flight predictions showed much better correlation with flight test results [38, 39]. Flight test telemetry data were also useful in interpreting the structural dynamic response [40].

Another advantage of flight test telemetry data is that it provides information before store release (time = 0). Since the telemetry gives a time history of the forces and moments the store sees, it's possible to determine whether any unsteady effects are present. As may be seen in Figure 13, the GBU-38 store exhibits no unsteady pitch and yaw behaviour (Q and R) in the B-1 bomb bay prior to store release. The variation in roll rate, P, is due to rack dynamics caused by the previous store.

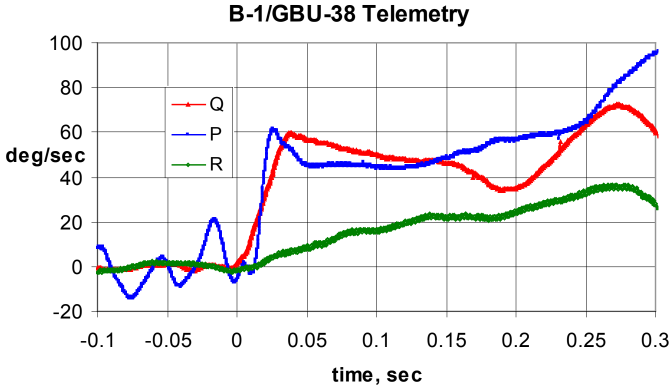

Figure 13: GBU-38/B-1 Flight Test Telemetry Data.

5.0 CONCLUSIONS

Store separation has undergone a considerable transition in the past 100 years. From throwing grenades out of open cockpits, we now drop smart bombs out of Unmanned Air Vehicle bomb bays.

Prediction capabilities have also shown significant improvement. Instead of the hit-or-miss method, there now exists an integrated process that includes CFD, wing tunnel, trajectory simulations and flight testing.

However, Aircraft/Weapon Integration is still not an integrated process**.** The Performance, Flying Qualities, Structures, Flutter and Store Separation flight testing usually occur as separate events.

Would it be possible for an aircraft that returns from a performance flight test with a full load of stores release them just prior to landing to satisfy the store separation requirements?

6.0 REFERENCES

[1] Bamber, M. J., "Two Methods of Obtaining Aircraft Trajectories from Wind Tunnel Investigations," AERO Report 970 (AD 233198), David Taylor Model Basin, Washington, DC, Jan. 1960.

[2] Rogers, R., M., "A Comparison Between the Nielson and Woodward Programs in Predicting Flow Fields and Store Loads," Naval Weapons Center TM 2854, July 1976.

[3] Cenko, A., and Tinoco, E. N., "PAN AIR - Weapons, Carriage and Separation," AFFDL-TR-79-3142, Dec. 1979.

[4] Steger, J. L., Dougherty, F. C., and Benek, J. A., "A Chimera Grid Scheme," Advances in Grid Generation, ASME, June 1983.

[5] Meyer, R., Cenko, A., and Yaros, S., "An Influence Function Method for Predicting Aerodynamic Characteristics During Weapon Separation," 12th NAVY Symposium on Aerobalistics, May 1981.

[6] Keen, K. S., "Inexpensive Calibrations for the Influence Function Method Using the Interference Distributed Loads Code," J. Aircraft, Vol. 22, January 1985, pp 85-87.

[7] Cenko, A., et al., "Further Development of the Influence Function Method for Store Aerodynamic Analysis," J. Aircraft, Vol. 23, August 1986, pp 656-661.

[8] Madson, M. et al "TranAir Computations of the flow about a Generic Wing/Pylon/Finned-Store Configuration," AIAA paper 94-0155, Jan. 1994.

[9] Newman, J.C. and Baysal, O. "Transonic Solutions of a Wing/Pylon/Finned Store Using Hybrid Domain Decomposition, AIAA paper 92-4571, Aug. 1992.

[10] Madson, M. and M. Talbot, "F-16/Generic Store Carriage Load Predictions at Transonic Mach Numbers using TranAir," AIAA-96-2454, June, 1996.

[11] Cenko, A., and Lutton, M., "ACFD Applications to Store Separation – Status Report," The Aeronautical Journal, Volume 104, Number 1040, Oct 2002.

[12] MIL-STD-1763, (1984), *Aircraft Stores Certification Procedures*, US Department of Defence, MIL-STD-1763A dated 31 December 1990, USA.

[13] MIL-HDBK-1763, (1998), *Aircraft Stores Compatibility: Systems Engineering Data*.

[14] *Requirements and Test Procedures*, US DoD Handbook, dated 15 June 1998, USA.

[15] MIL-HDBK-244A, (1990), *Guide to Aircraft/Stores Compatibility,* US Department of Defense, USA, dated 6 April 1990.

[16] STANAG 7068, (2001), *NATO Standardization Agreement Aircraft/Stores Certification*.

[17] *Procedures*, 12 July 2011, Edition 2, NATO Military Agency for Standardization, 1110 Brussels, Belgium.

[18] NATO STO AGARDograph 300 Vol 29, (2014) *Aircraft/Stores Compatibility, Integration and Separation Testing*, Brussels, Belgium.

[19] Tutty, M.G., (2015), The profession of arms in the Information Age: operational joint fires capability preparedness in a small-world, Thesis submitted for the Degree of Doctor of Philosophy, University of South Australia, 1 July 2015 [Online, posted July 2015]. See www.maltutty.com.

[20] Tessitore, F., Grumman Aerospace Corporation, "Private Communication," 1979.

[21] Cenko, A., "One CFD Calculation to End Point Flight Testing (*Has CFD Finally Replaced the Wind Tunnel?)*," Aeronautical Journal, July, 2006.

[22] "IHAAA Applications to Store Separation," 25th ICAS Congress, Paper 2006 P-2.8, Sept. 2006.

[23] Cenko, A., "IHAAA Applications to Reducing Store Separation Flight Testing," AIAA paper 2007-1653, Feb. 2007.

[24] Cenko, A., et al "Analysis of the Release of the SSB from the F-111 Aircraft," TTCP WPN-2 Key Task 2-22, final report, November 2007.

[25] Cenko, A., et al, "Unsteady Weapons Bay Aerodynamics – Urban Legend or Flight Clearance Nightmare?" AIAA paper 2008-0189, Jan. 2008.

[26] Cenko, A., et al "IHAAA Store Separation from Cavity Project -SSC," 26th ICAS Congress, Paper 2006 2.6.2, Sept. 2008.

[27] Cenko, A., Benek, J., Deslandes, R., Dillenius, M., Stanek, M., (2008), *Unsteady Weapon Bay Aerodynamics - Urban Legend or Flight Clearance Nightmare, AIAA 2008-0189*.

[28] Atkins, D., "Flight Test Results of a GBU- 38 Separating from the B- 1B Aircraft," AIAA-2008-0184.

[29] J. Lee and A. Cenko, "Quasi-Steady Computations of GBU-38 Trajectory from B-1B Aft Bay," AIAA-2008-0185, Jan. 2008.

[30] W. Stickles "High Fidelity Time Accurate Store Separation Simulations from a B1- B Bay," AIAA-2008-0186, Jan. 2008.

[31] R. Spinetti, and B. Jolly "Time- Accurate Numerical Simulation of GBU- 38's Separating from the B-1B Aircraft With Various Ejector Forces, Store Properties, and Load- Out Configurations," AIAA-2008-0187, Jan. 2008.

[32] Cenko, A., "Utilizing Wind Tunnel Test Data and Analysis to determine Flight Test Envelopes for Safe Store Release," AIAA paper 95-0328, Jan. 1995.

[33] Cenko, A.T. et al "Utilizing Flight Test Telemetry Data to Improve Store Trajectory Simulations," AIAA Paper 2003-4025, June 2003.

[34] Cenko, A. et al "Freestream Data Effects on Trajectory Predictions," AIAA Paper 2002-4417, Aug. 2002.

[35] Cenko, A. et al "Integrated T&E Approach to Store Separation - Dim Past, Exciting Future," 20th ICAS Congress, Paper 96-3.3.2, Sept. 1996.

[36] Taverna, F., and Cenko, A., "The United States Navy's Integrated Approach to Store Separation Analysis," RTO-Meeting Proceedings 16, paper 13, Sept. 1998.

[37] Chenevey, J. V., "The Challenge of Combat Superiority Through Modernization," RTO-Meeting Proceedings 16, paper K-1, Sept. 1998.

[38] Cenko, A. et al "Utilizing Flight Test telemetry Data to Improve Store trajectory Simulations," ITEA 13th Aircraft-Stores Compatibility Symposium, Feb. 2003.

[39] Cenko, A. et al "Utilizing Flight Test telemetry Data to Improve Store trajectory Simulations," AIAA paper 2003-4225, June 2003.

[40] Cenko, A. T., et al "Use of Statistical Tolls to Improve Modelling and Simulation of Store Separation," RTO AVT-108, Paper #13, June 2004.