Stores Release from ASTOVL Aircraft with Vectoring Jets

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ABSTRACT

The effective and safe integration and deployment of external (bombs and ferry tanks) or internal stores (smart weapons) their "accurate" and "safe" release and delivery is an important aspect in design and operation of combat aircraft. The ASTOVL aircraft with vectoring jets operate under very "perturbed" flow-fields during the transition phase and large off-design motions e.g. side-slip occur only too easily. The current trend towards smaller and lighter equipment and aircraft has magnified the problems associated with weapon integration. The store carriage location space on the aircraft is at a premium and it is often necessary to carry stores in locations where after release, or emergency jettison they may pass close to a vectoring jet. This implies study and analysis of many parameters to establish the safety parameters. The current CFD jet models (Navier-Stokes or Euler) have not yet reached sufficient maturity to become "ready" engineering tools (rapid turn-around). Emphasis has therefore been placed on adapting empirical models of jets in established wing theory to predict forces and moments over a 3-D flow grid. This information in turn formed the input to a trajectory code.

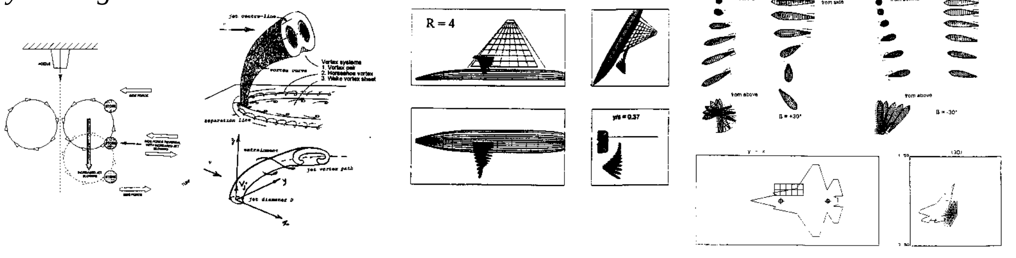
The objectives are to review the existing work, focus attention on findings and hence make a case for further applications to the current "wave" of ASTOVL aircraft including the JSF which have added complexities, bays/doors.

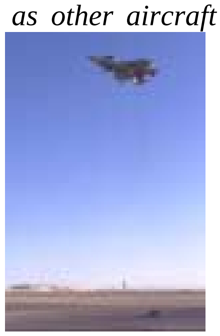
Results from pure theory approach are encouragingly very similar to those obtained from the data based on experiment.

For aircraft with multiple vectoring jets, the flow-field effects on the stores can be amplified and become adverse. This has been confirmed with parametric studies and release trajectories. The side-slip effects are particularly strong. It can be difficult to assess what the safe store locations are in presence of side-slip. "Internally" carried stores will be subject to significant jet effects when emerging from "semi-recesses" or "bays".

Results demonstrate the flexibility and potential of the techniques and several geometries may be explored to determine "safe" store locations. However, further verifications of the model need to be carried out e.g. higher α and ß cases with different jet configurations and strengths. The technique may be enhanced (cost & time savings) by the coupling of a six-degree of freedom equation programme with the flow solver. It is believed that aspects considered in this paper will lead to a constructive impact on the current and future ASTOVL aircraft with and without stores.

The techniques developed, can be adapted to more complex configurations as well as other aircraft layouts e.g. UAV's.





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1. INTRODUCTION & BACKGROUND

The effective and safe integration and deployment of external (bombs and ferry tanks) or internal stores (smart weapons) their "accurate" and "safe" release and delivery is an important aspect in design and operation of combat aircraft. The ASTOVL aircraft with vectoring jets operate under very "perturbed" flow-fields during the transition phase and large off-design motions e.g. side-slip occur only too easily. The current trend towards smaller and lighter equipment and aircraft has magnified the problems associated with weapon integration. The store carriage space on the aircraft is at a premium and it is often necessary to carry stores in locations where after release, or emergency jettison they may pass close to a vectoring jet.

For modern combat air vehicles new kinds of problems occur with the release of (smart) weapons, esp. single or multiple small weapons, from internal bays or from a low signature external installation. In both cases current modelling and experimental capabilities and engineering solutions may limit the effectiveness of the weapon and weapon delivery systems. In addition to the ever increasing cost of certification of weapons on existing and future air vehicles requires an increasing reliance on ground based testing and simulation.

With multiple vectoring jets on ASTOVL aircraft e.g. JSF, **Fig.1**, the flow-field effects on the stores placed or passing through in the vicinity of jets "amplify" and become adverse. The store configurations vary greatly, some have external lifting surfaces. The current trend is towards internal carriage of missiles. This poses a more complicated challenge as the effects of doors and cavities will need to be taken into account alongside jets.

Fig.2 (Ref.2) shows a typically heavily loaded VSTOL aircraft. Pylons of appreciable dimensions are also influenced by jets. Further, the effects of differential jet deflections need to be understood.

As store size reduces or proximity to the jet increases, the trajectory on release (intended or otherwise) becomes more affected by jets. "Internally" carried stores are under significant jet effects when emerging from the bays.

Towards safe and efficient store carriage and release, it is necessary to identify parameters and effects which may affect the trajectory of stores after release. The store carriage locations on the aircraft are at a premium and it is often necessary to carry stores in locations where after release, or emergency jettison they may pass close to a vectoring jet.

The above considerations and exploratory work showing force reversal on a store near a jet, **Fig.3** (Refs.3-4) have promoted a research programme. The overall objectives of this programme are to identify possible problems caused by store/jet interaction, and to develop prediction techniques. A two-fold approach embodying experiment and theory has been considered appropriate.

In a previous AGARD-FDP meeting (Ref.5) and ICAS'96 conference (Ref.6), we reported on jet effects and store releases in the symmetric (zero side-slip) case. Strong effects of jets were shown. At the ICAS'98 conference (Ref.7), we concentrated on the possibly more important aspect of side-slip effects.

The purpose of this paper is to review the existing work, focus attention on findings and hence make a case for further applications to the current “wave” of ASTOVL aircraft including complexities e.g. bays and doors.

2. EXPERIMENTS TO MEASURE FORCES & MOMENTS IN 3-D SPACE AROUND STORE MOTION

Studies have determined the magnitude of the forces and moments induced on a typical store by an inclined 60° jet, when also in the influence of the aircraft flow-field.

Fig.4 illustrates the tests arrangement (wing + body + store), forces & moments survey-volume (3-D grid) and plots of the incremental forces ΔC_N, ΔC_Y and ΔC_A arising due to jets (parameters defined by Jet velocity ratio $R = Vj/V$ and deflection angle θj). These studies indicate complex variations of jet-induced forces over the region surveyed. The jet-induced effects persist many calibres downstream of the jet reference. It is evident that the maximum effect can occur at a considerable distance from the jet reference, for instance maximum negative normal force and side force occurring at 6 to 7 calibres below the jet reference.

The measured jet-induced force and moment surveys were used in a numerical six degrees of freedom equation approach to develop store-release trajectories with jets on and off.

3. RELEASE TRAJECTORIES BASED ON EXPERIMENTAL SURVEYS

The knowledge that large forces and moments are induced by jets, is in itself of little operational importance. However, if these effects cause significant deviations in the store release trajectory, then this represents great operational concern.

3.1. Analysis Method for Trajectories

The data sets of forces and moments on a store, over a grid of known points in the vicinity of an aircraft, for both jet-off and jet-on cases form the input for a trajectory programme (Ref.4). The trajectory evolves from step-by-step integration approach, with the loads and moments at any time-step being generated from the store free-air loads and moments and the non-uniform interference loads and moments interpolated from the data grid, together with pre-set initial conditions**.**

3.2. Trajectory for a 1000 lb Bomb

The full-scale, store release trajectories of a l000 lb bomb have been calculated (jet-off (R=0) and jet-on cases) in the aircraft flow-field. The trajectories for the first 0.6 second, were started with the bomb positioned as for carriage on a typical wing inboard pylon. Representative ejection forces were assumed, together with the correct mass and inertias.

The jet blowing effects on the release trajectory are apparent from **Fig.5**. This shows the time history of the displacement of the store CG relative to the position of the jet reference point, and the angular displacements of the store about its CG. The resultant store trajectories are shown for no jet blowing, R = 0, and blown R = 3.09 & 4.54. The store trajectories for the cases with no jet blowing and with maximum blowing are illustrated as wire-frames in **Fig.6**.

Without jet blowing, the store separates cleanly and shows no undesirable effects, falling away steadily, exhibiting little sideways movement, no yaw displacement, and a very small nose-down pitching motion.

With jet blowing, the release trajectory is altered, even at the lower level of R = 3.09. A large angle of inwards yaw reached during the first 0.5 seconds. This yaw in turn causes the store to move inboard, although in this case due to the high mass of the store, the inwards movement is modest (of the order of 8 inches (203 mm)). For the highest R, blowing causes the store to roll. The store pitches to a significant nose-up attitude with both levels of jet blowing. Due to the large mass of the store**, t**he vertical separation of the store from the aircraft is, however, altered very little.

3.3. Trajectory for an Empty 1200 litre Fuel Tank

In view of the very significant jet effects on the release trajectory of the "dense" 1000 lb store, the assessment was extended to jet effects on a very much larger but lighter, empty fuel tank. Because of the reduced mass and inertias, store response to the jet effects is likely to be greater. The store geometry was based on a Jaguar 1200 litre fuel tank.

In absence of test data, it was assumed that the jet interference effects would be similar to those measured for the 1000 lb bomb. Interference grids for the 1000 lb bomb were used in conjunction with the free-air aerodynamics of the empty fuel tank and appropriate mass and inertias. The initial conditions for the trajectories were those appropriate to carriage on a typical inboard pylon (ejection velocity of 3 m/s and an initial nose-down pitch rate of 0.5 rad/sec). Considering strong jet-induced forces, the tank geometry, and the volume covered by the test data, this approximation is reasonable.

The effects of jet blowing on the trajectory are shown in **Fig.7**, CG and angular displacements, and **Fig.8** for three-view diagrams of the trajectories. For this lighter store, the jet effects on trajectory are more dramatic than for the 1000 lb bomb. The initial benign trajectory, with clean separation, modest nose-down pitch, and little or no lateral movement is significantly altered.

The effects of the jet blowing soon overcome the effect of the initially imparted nose-down pitch rate and the tank pitches upwards. This causes the store to generate lift, and arrests its separation from the aircraft, and the store CG "hovers" some 2.5 ft (0.75 m) below its carriage position. At the same time the store first yaws violently nose inboard followed by an even more violent outboards yawing motion. These yawing motions in turn cause the store to first move inboard by approximately 2.5 ft (0.75 m), followed by an outboard movement, leading to the situation where the store has entered a large lateral oscillatory movement whilst vertical separation remains constant. A significant rolling motion is induced by the jets.

A striking and an unusual effect is the forward movement of the tank caused by the jet-induced suction forces generated over the store nose region. This effect was not apparent for the 1000 lb bomb, but arises for the lighter fuel tank with its downward progress inhibited, it remains in the "suction region" longer.

4. THEORETICAL APPROACH, JET-INDUCED EFFECTS, SYMMETRIC FLOW

The release trajectories based on test data provide very significant challenges and clues for the theoretical approach. The origin of the jet induced forces and moments, and indeed the order of magnitude of the observed forces, can be related to the twin vortex structure developed downstream of a jet in cross-flow. We review the modelling of jets.

4.1. Semi-empirical Jet, Prediction Technique & Validation

Fig.9(a-c) summarises the semi-empirical empirical jet modelling and the validation aspects (Refs.8-11). It shows a jet of diameter d and velocity ratio R = Vj/V, in cross flow (deflection angle $\theta j = 90°$). In the semi-empirical model, the strength of the jet is modelled with doublet and source distributions. The vortex path has been described so that there is agreement with measurements of pressures induced as well as of jet stagnation lines. The model has been generalised for $\theta j <= 90°$. This jet model is incorporated within the framework of subsonic singularity methods. Thin or thick wing assumptions may be used. The jet model although essentially for "near-sonic" jets has been also used in the context of high pressure ratio jets with success. Currently the technique has been extended to multiple jets which enables store trajectories to be predicted in conjunction with developments of the NEAR code (Refs.12-13).

Effects of Varying R

Shown in **Fig.9(b)** are the effects of varying R (or blowing coefficient $C\mu$) and on a body + wing (Aspect ratio 3.4) configuration for two nozzle positions (forward and aft). Lift loss is predicted for both nozzle locations. Comparisons with experiment show very encouraging correlation. The spanwise loads shown for one data point depict good agreement. Other related cases for verification appear in Refs.9-10.

Store Location & Jet Effects

Fig.9(c) shows an aspect ratio 4 swept-wing (semi-span s) with a store (or a tank) located underneath. Pylons have been omitted for simplicity. The Cp distributions on the tank along 12 generators show the effects due to either forward or aft jet blowing. The effect of splaying the aft jet by 10° is also shown. The results show the high -Cp values arising due to the jets proximity. Splaying jets increases the -Cp.

This test case emphasises that the forces and moments arising are strongly dependent on store geometry and its placement relative to the jet.

5. TYPICAL PREDICTED STORE TRAJECTORIES, SYMMETRIC FLOW

We show release trajectories of an under-wing store (1000 lb type) for two aircraft configurations, one with a trapezoidal wing (2 or 4 jets), and the other with a "diamond" wing(3 jets).

5.1. Trapezoidal Wing-Body Configuration

The configuration of **Fig.4**, with two pairs of jets has been used to develop typical parametric variations in **Fig.10(a-e)**. Calculations were made for the first 0.6 second from a store ejected at 3 m/sec.

For configurations with both front + aft jets blowing at R = Vj/V = 6 and deflection $\theta j = 60°$, **Fig.10(a)** shows the effect of spanwise location of the store on its trajectory. This effect on the store persists to more than half a wing semi-span. At the inboard location, large changes occur in pitch and yaw angle of the store. The tail tends to move inwards initially and the calculations of trajectories could only be continued if the tail remains away from the jet path. The effects are strongest for the inboard location and are dominated by the front jets for this particular geometry.

The effect of varying jet velocity ratio R for fixed spanwise location is illustrated in **Fig.10(b)**. At R = 4 and 6, the tail of the store moves inwards towards the jet core and predicted trajectories can not be continued beyond 0.25 secs. At R = 8, the store has a more pronounced pitching and yawing motion and eventually points downwards and rearwards.

For three jet configurations: forward, aft, and forward + aft jets blowing at R = 6, **Fig.10(c)** shows the store trajectories. The store is near the LE and the the aft jets have a small effect only here.

For store locations further back on the wing, however, strong effects of aft jets can be detected as shown in **Fig.10(d)**. This shows a more "downstream" location of the store and as in previous figure, three jet configurations: front, aft, and front + aft jets blowing at R = 6 are considered. Note the near "chaotic" behaviour of the store trajectory under influence of all jets.

With all jets operating, the effect of jet deflection angle Ú$_j$ variation (30°, 45°, 60° and 75°) can be inferred from **Fig.10(e)**. In this sequence, R is held constant = 6. The jet effects are particularly strong for θj = 45° and 60°. The case for θj = 75° shows lesser effect mainly because the store trajectory has not "reached" the immediate vicinity of the jet in the first 0.6 secs. Similar trend was observed θj = 90°.

These analyses have emphasised the non-linear nature of jet interactions. It is interesting to note that the trends shown by these results are reminiscent of those displayed in Section 3.

5.2. A "Diamond-wing" ASTOVL Type Aircraft

This geometry was developed from the previous configuration by altering the wing planform. This type of "modern" ASTOVL configuration is likely to feature a front central jet in addition to one or two jets aft of centre of gravity. The nozzles are likely to operate at different pressure ratios and hence different R values result at a given flying speed. For present purposes however, we have assumed one front jet + two aft jets operating at same jet parameters θj and R.

Fig.11(a) shows the effect of R variation (4, 6 & 8) on a "forward" store trajectory. The jet deflection angle is held constant at 60°. Note the large changes in pitch and yaw angle of the store. For R = 8, the tail tends to move inwards and eventually the store points outwards and slightly upwards. For R = 6, the store "finally" points rearwards, outwards and downwards. For R = 4, the store "finally" points forwards, outwards and downwards.

The effect of θj variation (60°, 75° and 90°) can be inferred from **Fig.11(b)**. In this sequence, R is held constant at 6. Note the large changes in motion of the store for 60° and 75° jet deflection when compared with the trends for the 90° jets. For the 90° case, the store trajectory has not "reached" the immediate vicinity of the jets in the first 0.6 secs.

The foregoing analysis continues to emphasise the non-linear motion of stores in the vicinity of jets on ASTOVL types.

6. FULL CONFIGURATION MODELLING APPROACH FOR INCLUDING SIDE-SLIP

We now need to include full configuration (left and right halves) in the predictions.

Side-Slip 0° Case, Confirmation

Fig.12 illustrates the survey-volume (3-D grid) used to develop the theoretical incremental forces (ΔC_N, ΔC_Y and ΔC_A) and moments (ΔC_l, ΔC_m and ΔC_n) arising due to jets vectored 60°. These predictions were used in a numerical approach to develop store-release trajectories with jets on. This figure also marks the locations of store reference point used in subsequent runs.

Fig.13 shows the trajectory parameters for the basic symmetric case (the same 1000 lb store as in **Figs.5 & 6**). **Fig.14** shows the 3-D wire-frame representation of the trajectory with store location 0.3m and ejection velocity V_{ej} = 3m/s. Note the encouraging agreement between release trajectories based on experimental and predicted jet effects. Slight discrepancy in spanwise character is noted and if desired, this could possibly be improved by a "finer" specification of x & y starting locations.

For present analysis, this gave adequate confidence to proceed and apply the methodology to side-slip cases.

Side-Slip 30° Case

Fig.15 illustrates the survey-volume (3-D grid) used to develop the theoretical incremental forces and moments arising due to jets on a configuration with side-slip 30°. The reference position was x = 4.19, y = 2.51m & z = 3.18 with respect to the jets. The figure also marks the other initial locations of the store used in subsequent runs. This grid has enabled parametric variations of effect of store location on release trajectories.

Fig.16 shows the effect of initial chordwise location of the store on the store release trajectory. The main changes are in pitch and yaw angles that are more adverse for the forward location.

Fig.17 illustrates the effect of initial spanwise location of the store on the store release trajectories. The main changes are in pitch and yaw angles that are more adverse for the outboard location.

Fig.18 shows the 3-D wire-frame representation of the store trajectory with Vej = 3m/s. The store pitches down, yawing negatively as it falls.

Fig.19 shows the effect of store initial positions on starboard and port side of the configuration. This can also be interpreted, alternatively as the effect of positive and negative side-slip, ß. Note the lack of symmetry and much larger variations for the positive ß case. **Fig.20** shows the 3-D wire-frame representations to emphasise the trends. The positive ß case shows pitch-down and large negative yaw whilst the negative ß case shows a moderate pitch-up and a small positive yaw. The shift in y (inwards) is much greater with positive side-slip, compared with shift in y (outwards) with negative side-slip.

The foregoing analysis emphasises the non-linearities in the motion of stores in the vicinity of jets.

The present technique offers the capability for investigation of several geometric variables to determine "safe" store locations for different types of STOVL and ASTOVL aircraft. **Fig.21** illustrates an ASTOVL aircraft with tandem jets (forward and aft) and a typical grid 3-D survey volume for stores near the front jet at ß = 0°. This aspect along with internal carriage of stores points towards the next "natural" programme !

7. INFERENCES, POSSIBLE BENEFITS & IMPLICATIONS IN WIDER CONTEXT

Typical results presented have demonstrated the flexibility and potential of the techniques. The symmetric / asymmetric jet effects are strong and usually adverse.

The present technique offers the capability for study of several geometric variables to determine "safe" store locations for different types of ASTOVL aircraft.

The experience has been that, the forces and moments on the store will tend to increase as the store size reduces. This will affect the trajectory on release (intended or otherwise). High suctions may cause local separations on the stores or on adjacent surfaces. "Internally" carried stores will also be subject to significant jet effects when emerging from "semi-recesses" or "bays".

The technique relies heavily on jet effects evaluated over a 3-D flow grid and this process can be time consuming for arbitrary grids. The jet-induced effects are strong and they can be "peaky" for stores in close proximity and a closely spaced 3-D flow grid may be required. Widely spaced grids may compromise quality. Therefore, further verifications of the technique need to be carried out e.g. higher α cases with different ß and different flying speeds.

This implies that to shorten the process, we need to couple a six-degree of freedom equations solver with the flow solver. This should be the next step that needs to be undertaken and then we will have the potential for the obvious benefits of very appreciable cost and time savings on many other parameters to be explored. Manoeuvering aircraft effects on stores can also be considered.

In view of the considerable non-linearities in jet-induced flow-fields, the approach can assist in designing acceptable experiments, or for checking the validity of existing information.

8. FUTURE WORK POSSIBILITIES

On basis of the work carried out so far, several avenues for further work have arisen; some important ones are:

(1). Coupling of six-degrees of freedom equations with the flow-solver.

(2). Manoeuvering aircraft effects on stores trajectories.

(3). High pressure ratio jets and Supersonic Jet modelling to same sophistication level as present "near-sonic" jet.

(4). Consideration of modern ASTOVL configurations. This will call for extending the capabilities to stores emerging from cavities, bays and with "splitter" doors.

(5). Considering Over-wing stores.

Some of the work could be carried out by expanding the scope of the NEAR Inc. STRLNCH store separation code (Refs.14-15). This code handles a parent aircraft that can manoeuver and be in side slip. The STRLNCH code was developed from the older NEAR store separation codes (Refs.12-13) to satisfy requirements of the Naval Air Warfare Center, Weapons Division, China Lake, CA (Technical Monitor: Ed Jeter, Airframe projects Office, Aeromechanics Division, Code 476F00D). The U.S. Air Force is familiar with the STRLNCH code.

This list is by no means exhaustive. Further avenues are likely to emerge as experience grows.

In more general terms:

- The techniques developed, can be adapted to more complex configurations and aircraft layouts.
- The potential benefits to the military user are considered to be significant and include: reduced life cycle costs, improved operability, improved reliability and maintainability, enhanced performance, enhanced survivability, reduced complexity and weight, and reduced environmental impact

9. CONCLUDING REMARKS

The effective and safe integration and deployment of external (bombs and ferry tanks) or internal stores (smart weapons) their "accurate" and "safe" release and delivery is an important aspect in design and operation of combat aircraft. The ASTOVL aircraft with vectoring jets operate under very "perturbed" flow-fields during the transition phase and large off-design motions e.g. side-slip occur only too easily. The current trend towards smaller and lighter equipment and aircraft has magnified the problems associated with weapon integration. The purpose of this paper is to review the existing work, focus attention on findings and hence make a case for further applications to the current “wave” of ASTOVL aircraft including the JSF.

The formulations of the jet models using Navier-Stokes or Euler solvers, have not yet reached sufficient maturity to become "ready" tools for design and analysis. Emphasis has therefore been placed on adapting empirical models of jets in established wing theory to predict forces and moments over a 3-D flow grid. This information in turn formed the input to a trajectory calculation code.

Results from a purely theoretical approach were very encouragingly similar to those obtained from the data based on experimental measurements.

For ASTOVL aircraft with vectoring jets (including JSF !), the flow-field effects on the stores can be amplified and become adverse. This has been confirmed with a series of parametric studies and release trajectories. The effects of side-slip are particularly strong. It can be difficult to assess what the safe store locations are in presence of side-slip. "Internally" carried stores will also be subject to significant jet effects when emerging from "semi-recesses" or "bays".

The forces and moments on the store will tend to increase as the store size reduces. This will affect the trajectory on release (intended or otherwise). High suctions may cause local separations on the stores or on adjacent surfaces.

Results presented have demonstrated the flexibility and potential of the techniques and several geometric variables may be explored to determine "safe" store locations. However, further verifications of the model need to be carried out e.g. higher α and ß cases with different jet configurations and strengths. The technique may be enhanced (cost & time savings) by the coupling of a six-degree of freedom equation programme with the flow solver.

The approach can assist in designing acceptable experiments, or for checking the validity of existing information.

Areas for further work and improvements of the model have been mentioned. In particular, the coupling of a six-degree of freedom equation programme with the flow solver, must be a top priority.

It is believed that these aspects will have a constructive impact on the current and future practical VSTOL and ASTOVL aircraft with and without store carriage. The paper goes some way towards satisfying the objectives of the symposium (Appendix A).

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LIST OF SYMBOLS & ABBREVIATIONS

AoA	α, Angle of Attack	AR	Aspect Ratio
b	= 2s, span	c	local chord
c_{av}	= c, Average chord	C_A	=A/(qS),Axial Force Coeff. (A Axial Force
ΔC_A	Incremental Axial Force Due to Jets	CG	Centre of Gravity
C_L	= L/(qS), Lift Force Coeff, L is Lift force	C_{LL}	Local Lift Force Coefficient
C_N	= N/(qS), Normal Force Coeff,	C_N	Incremental Normal Force Due to Jets
C_{NL}	Local Normal Force Coefficient	C_p	Pressure Coefficient
C_Y	= Y/(qS), Side Force Coeff, (Y Side Force)		
ΔC_Y	Incremental Side Force Due to Jets		
L	Lift Force		
LE	Leading Edge		
N	Normal Force		
q	= ½ ρ V^2, Dynamic Pressure		
R	= V_j/V, Jet Velocity Ratio		
s	wing semi-span		
S	Wing area		
TE	Trailing Edge		
u,v,w	perturbation or induced velocities in x,y,z directions		
V	Airstream Velocity		
Vej	Store Ejection Velocity		
Vj	Jet Velocity at Nozzle		
x,y,z	Orthogonal Co-ordinates		
α	Angle of attack		
ß	Angle of sideslip		
θj	Nozzle Jet Deflection angle		
η	= y/s, Non-dimensional spanwise Distance		
ρ	Air Density		

APPENDIX A : AVT-108 SYMPOSIUM OBJECTIVES

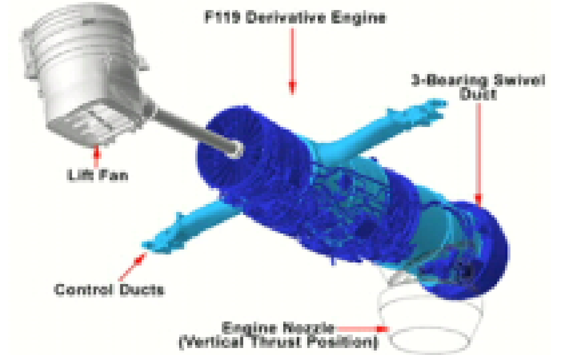
AVT-108 Meeting Background

Effective and safe integration and deployment of weapons with (inhabited or uninhabited) aircraft is a fundamental aspect of weapon system design. The current trend towards smaller and lighter equipment and aircraft has magnified the problems associated with weapon integration. This is likely to be more critical on ASTOVL aircraft where weight is particularly critical.!

For modern combat air vehicles new kinds of problems occur with the release of (smart) weapons, esp. single or multiple small weapons, from internal bays or from a low signature external installation. In both cases current modelling and experimental capabilities and engineering solutions may limit the effectiveness of the weapon and weapon delivery systems. In addition to the ever increasing cost of certification of weapons on existing and future air vehicles requires an increasing reliance on ground based testing and simulation.

Meeting Scope

It is realised that the prime objective is to contribute to improving weapon integration capability within the defence community by bringing together specialists in critical areas of the weapon/vehicle interface; specifically those concerned with the functional and mechanical integration and with safe separation. Current status of simulation, design, engineering development, and system equipment will be reviewed and priority needs to be identified for weapon integration with lightweight ground vehicles, with air vehicle weapons bays, and external installations. Emphasis will be given to methodologies and strategies for simulation, validation, and certification of the integration with the aim to identify technology gaps and promulgate the best practice.



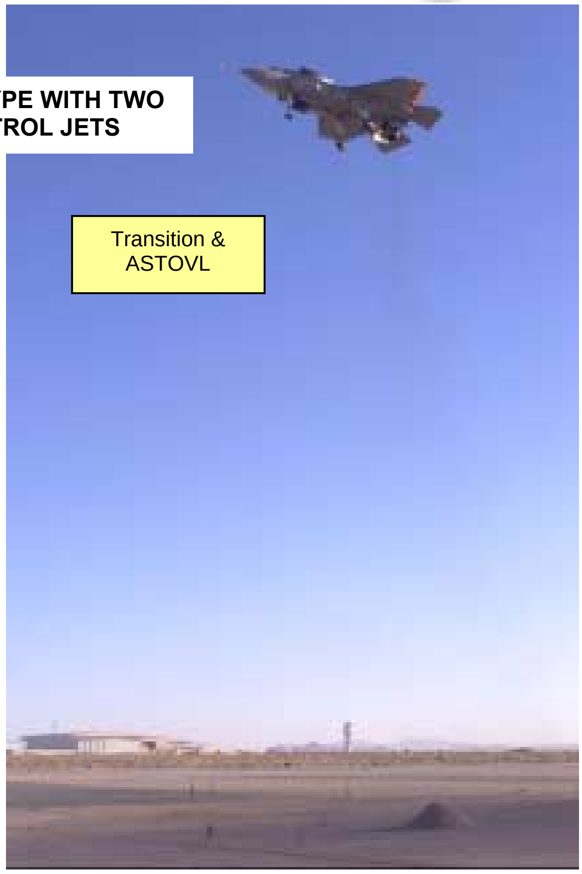


FIG. 1 JSF ASTOVL PROTOTYPE WITH TWO VECTORING JETS & CONTROL JETS

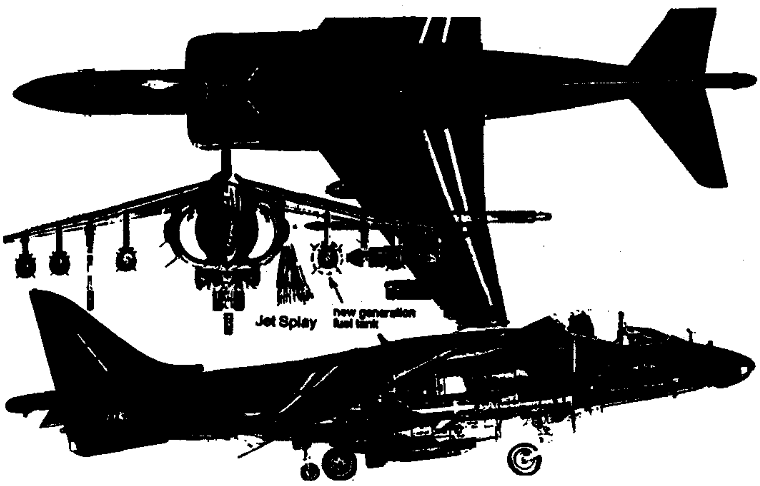


FIG. 2 VECTORING JETS FROM HARRIER GR Mk. 5 WITH STORES (Airplane Part 6, Orbis)

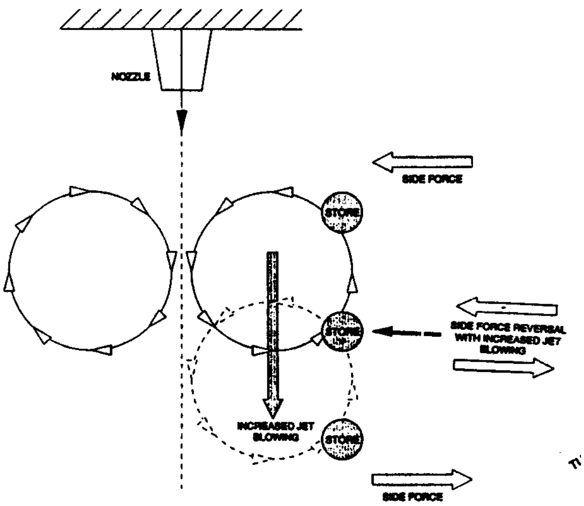
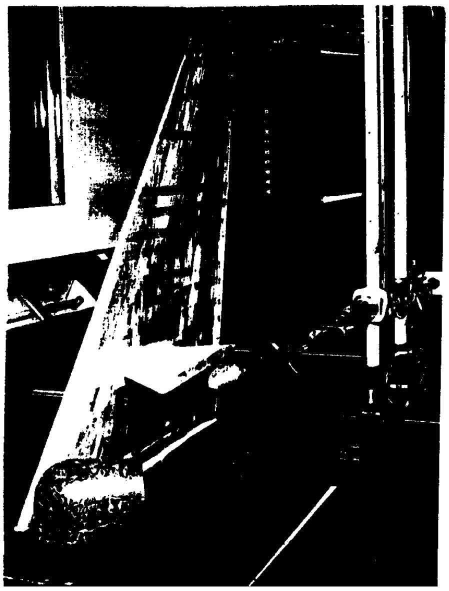
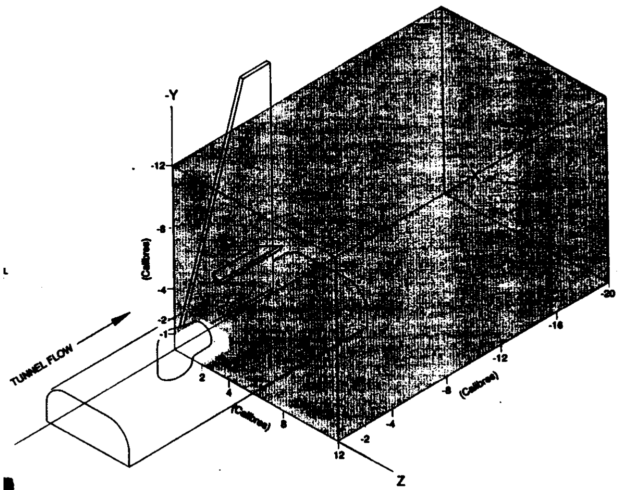


FIG. 3 EMPHASISING FORCE REVERSAL ABOUT A STORE DUE TO JET

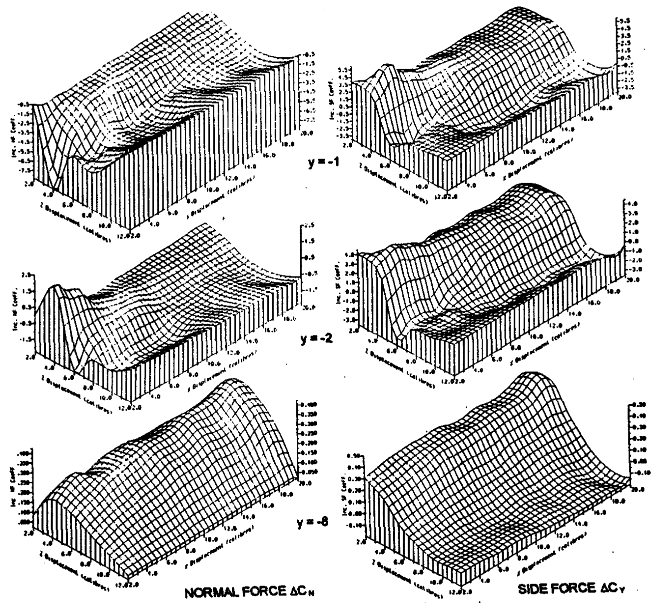


Forward View of VSTOL Model, 13x9ft WT
with traverse Mechanism & Wing Pylon

Flow Viz. of 60° Jet in Cross-flow

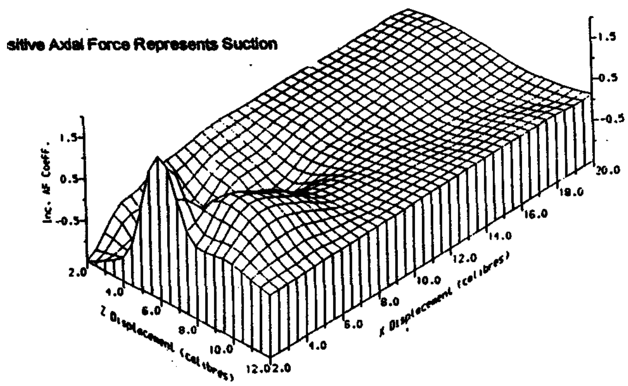


Axes System & Measurement Grid
(store Calibres in Survey Volume



ΔCN & ΔCY in zx-plane
At y=-1,-2 & -8 calibres.

FIG. 4 WIND TUNNEL MODEL ARRANGEMENT, JET VISUALISATION, MEASUREMENT GRID & TYPICAL JET INDUCED FOCES ON A STORE



Axial Force ΔCA in zx-plane

At y=-1 calibre (outboard of Jet Reference pt.

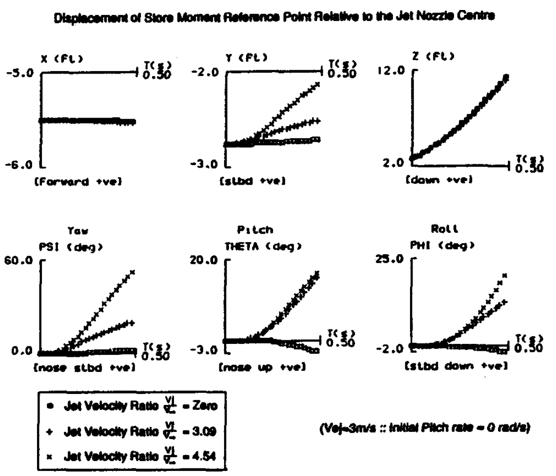


FIG. 5 COMPARISON OF 1000 lb BOMB RELEASE TRAJECTORIES, Jet off (R-0) & Jet on (R=3.09, 4.54, θj =60°), Low α

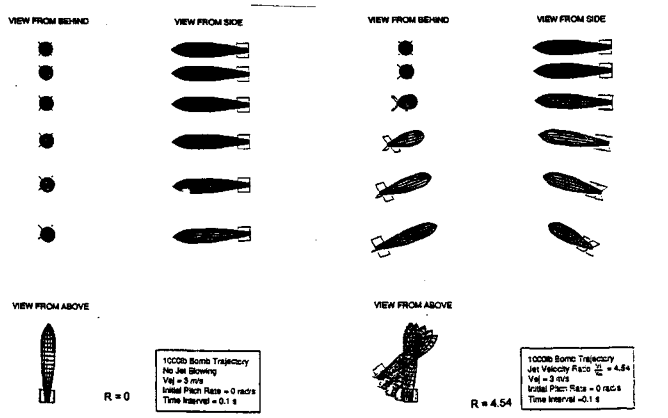


FIG. 6 WIRE-FRAME COMPARISON OF 1000 lb BOMB TRAJECTORIES, Jet off (R=0) & WITH JET (R=4.54, θi =60°), Low α

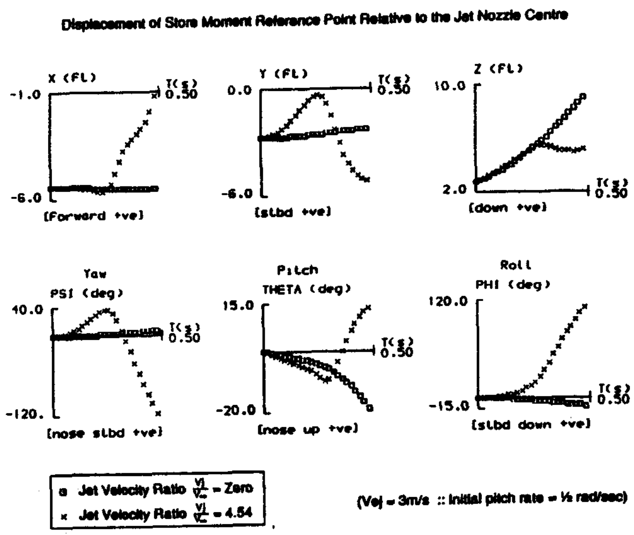


FIG. 7 COMPARISON OF 1200 lb TANK RELEASE TRAJECTORIES, Jet off (R-0) & Jet on (R=3.09, 4.54, θj =60°), Low α

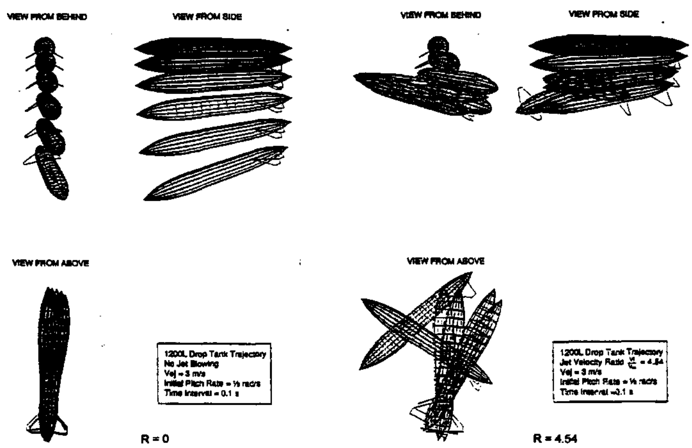
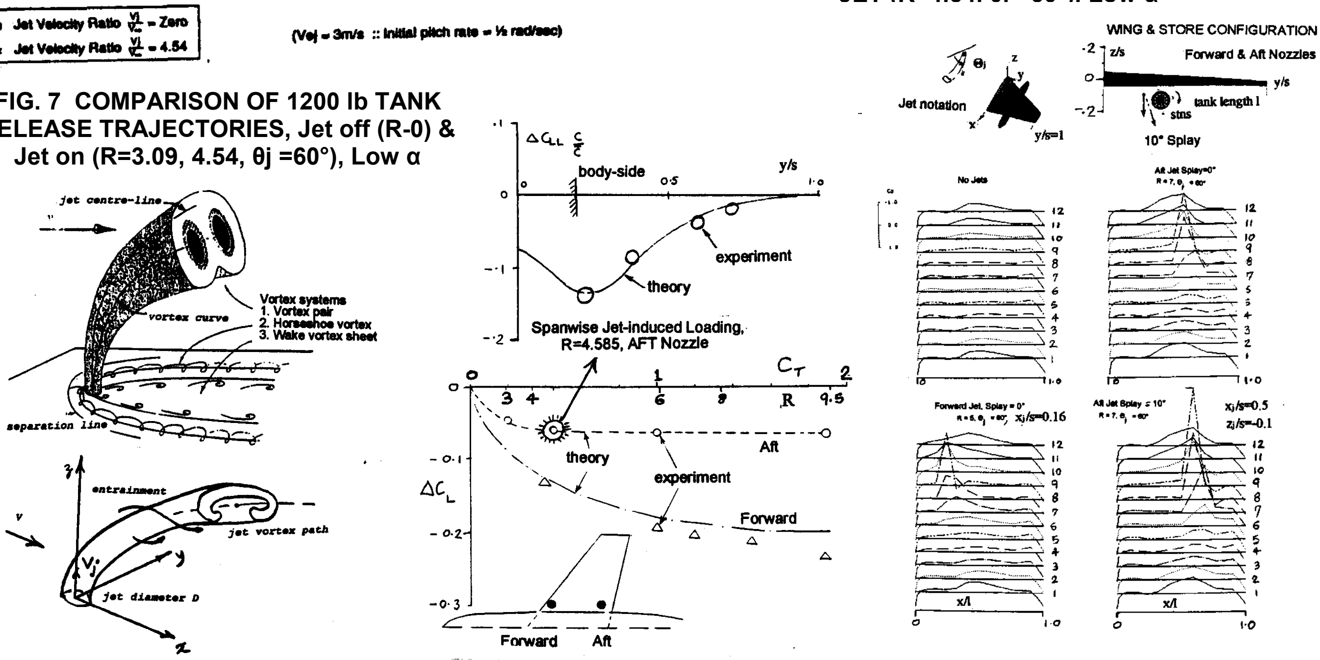
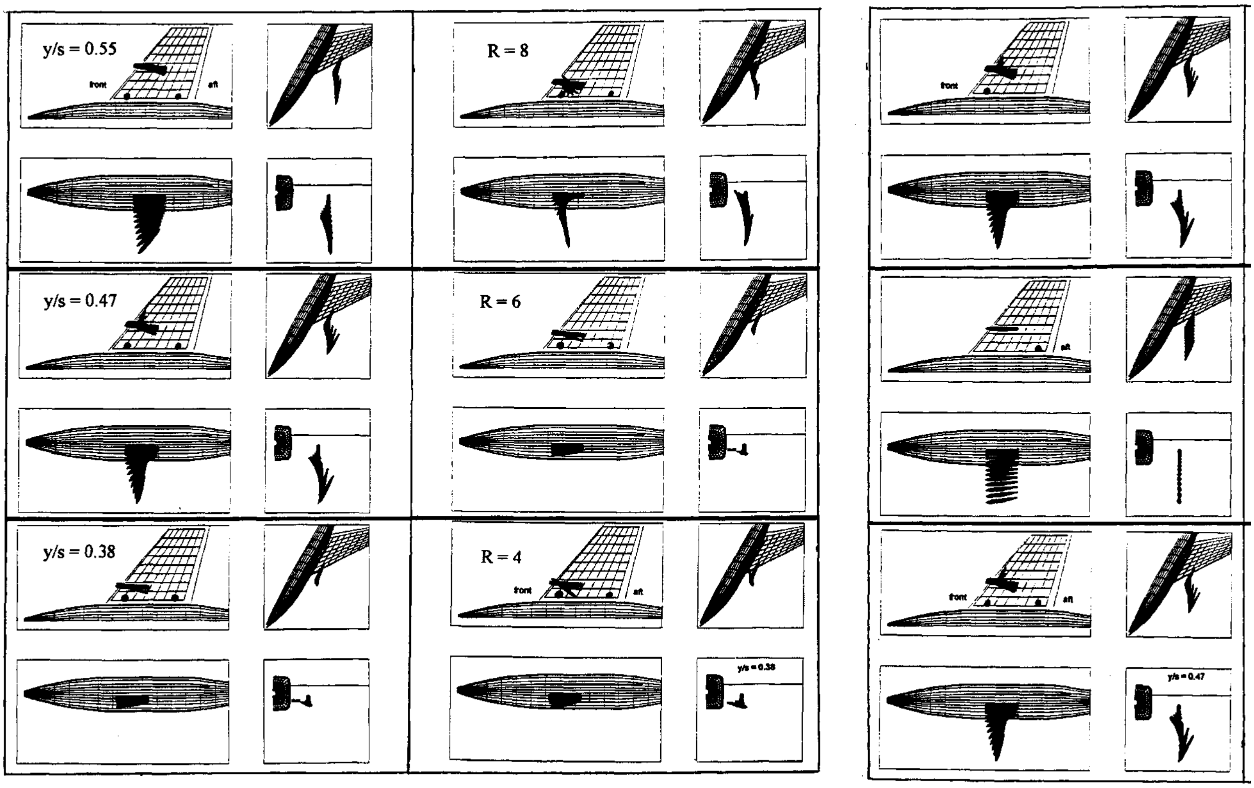


FIG. 8 WIRE-FRAME COMPARISON OF 1200 lb TANK TRAJECTORIES, Jet off (R=0) & WITH JET (R=4.54, θi =60°), Low α



(a) Jet Deforming in Cross-Flow (b) Lift Loss Due to Forward or Aft Jets, θj =60°, R & Cμ vary (c) Cp Distbns along Store generators, Effect of Forward & Aft Jets, Splay Angle 0°,10°

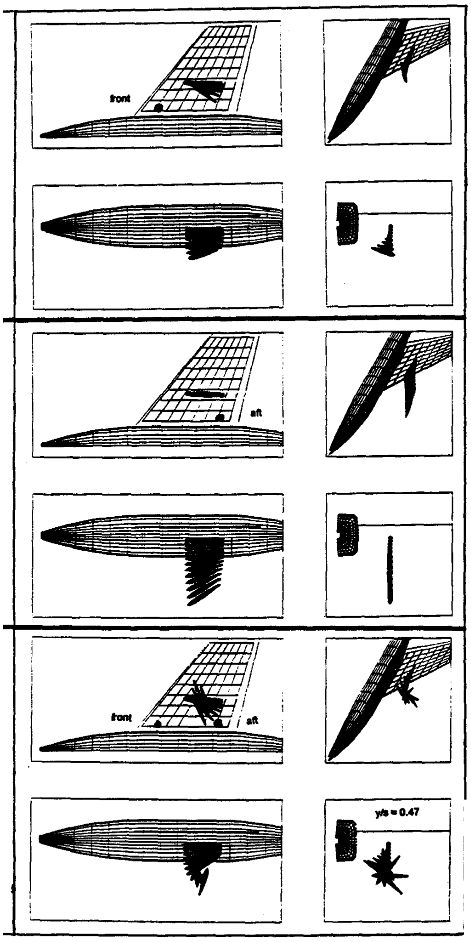
FIG. 9 VALIDATION OF JET IN CROSS-FLOW SEMI-EMPIRICAL MODEL



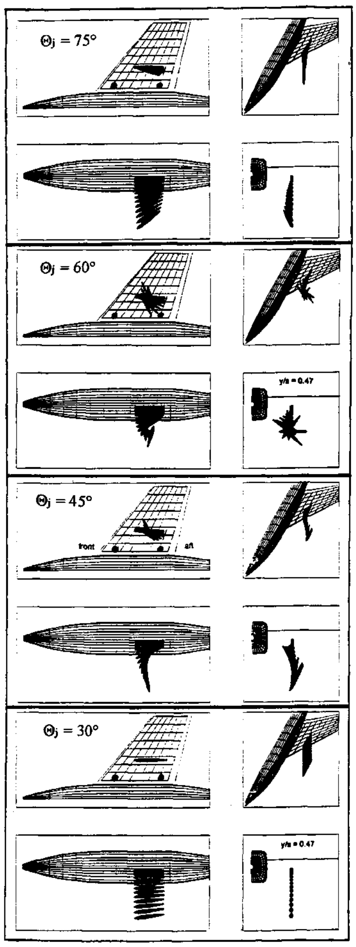
(a) Effect of Store Spanwise Location Variation, Front+aft jets, R=6, Θj=60°

(b) Effect of R Variation (4, 6 & 8) Front+aft Jets, Θj=60°

(c) Forward Store, Jets Config. Varies, Front, Aft & Front+aft Jets, Θj=60°, R=6

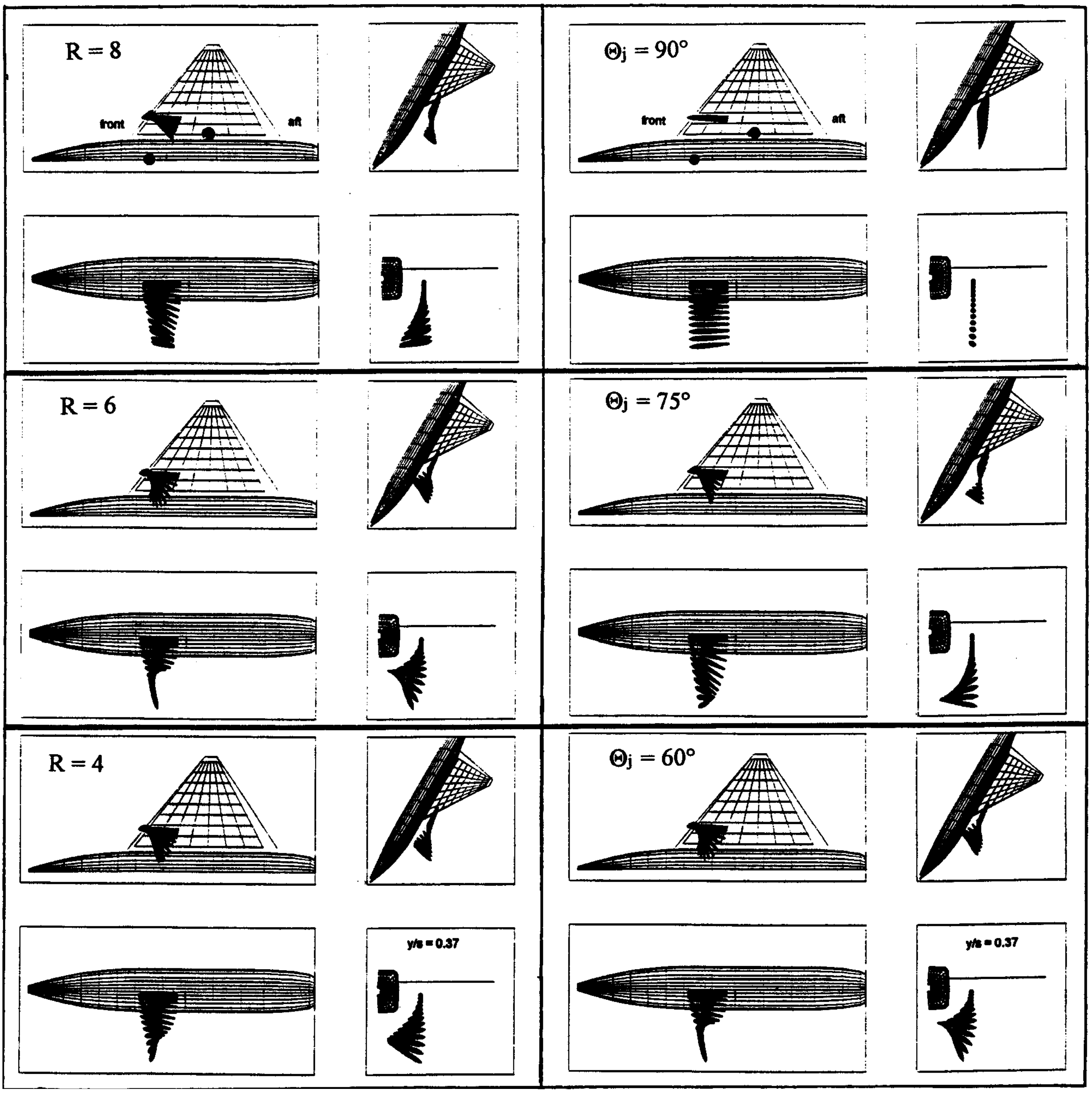


(d) Downstream Store, Jets Config. Varies, Front, Aft & Front+aft Jets, Θj=60°, R=6



(e) . Θj Varies, Front+aft Jets, R=6

FIG. 10 TRAP'M WING-BODY & 1000 lb STORE TRAJECTORIES WITH VARIOUS COMBINATIONS OF JET CONFIGURATIONS, Low α



(a) Effect of R. One Jet Front + A pair Aft=4.54, θj =60° (b) Effect of θj . One Jet Front + A pair Aft=4.54, R=6

FIG. 11 SIMPLIFIED "DIAMOND-WING" -BODY & 1000 lb STORE TRAJECTORIES WITH VARIOUS COMBINATIONS OF JET. Low α

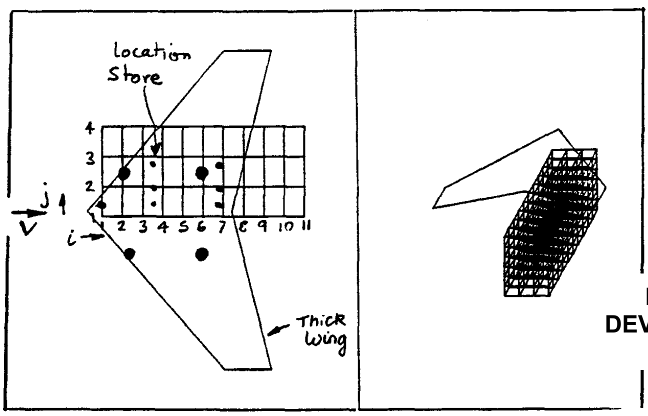


FIG. 12 3-D SURVEY VOLUME, THEORY, β=0°, TO DEVELOP INCREMENTAL FORCES & MOMENTS DUE TO JETS ON THE STORE

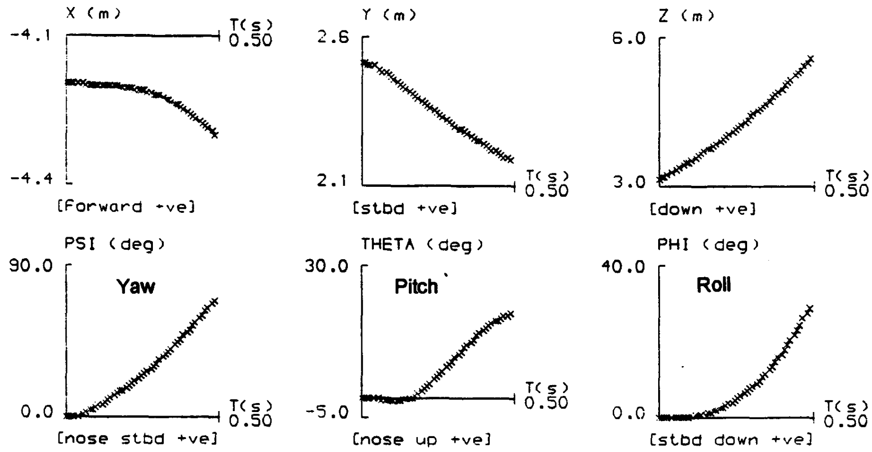


FIG. 13 BASIC 1000 lb BOMB RELEASE TRAJECTORY PREDICTED WITH JETS (R=4.54, θj=60°, β=0°)

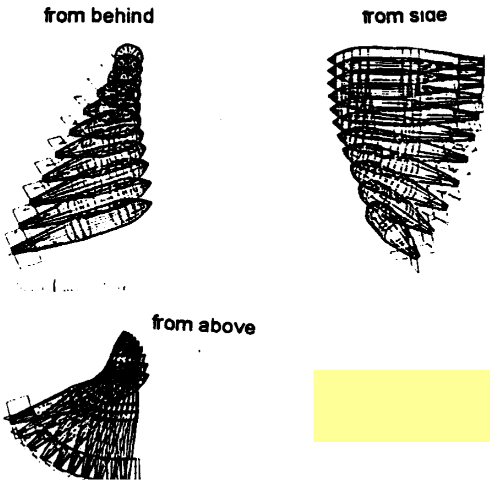


FIG. 14 1000 lb BOMB RELEASE TRAJECTORY, 3-D WIRE-FRAME, THEORY WITH JETS (R=4.54, θj=60°, β=0°)

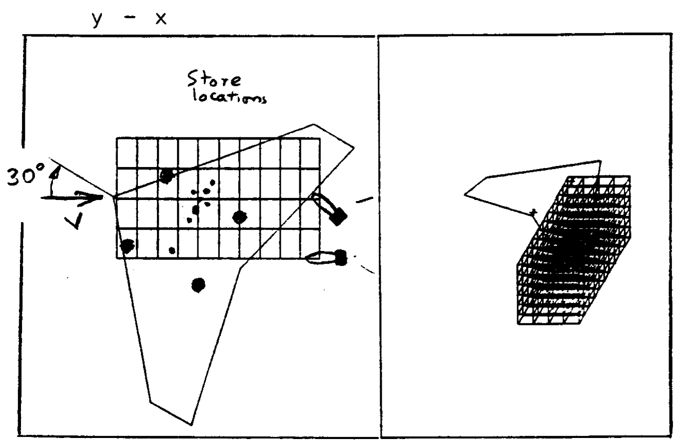


FIG. 15 3-D SURVEY VOLUME, THEORY, β=30°, TO DEVELOP INCREMENTAL FORCES & MOMENTS DUE TO JETS ON THE STORE

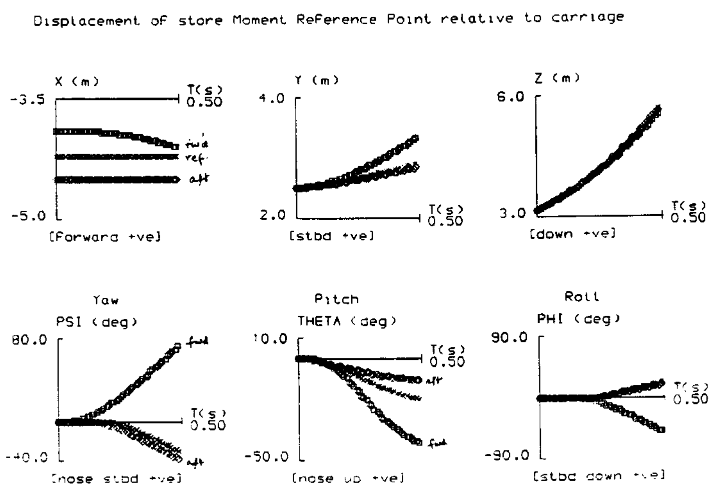
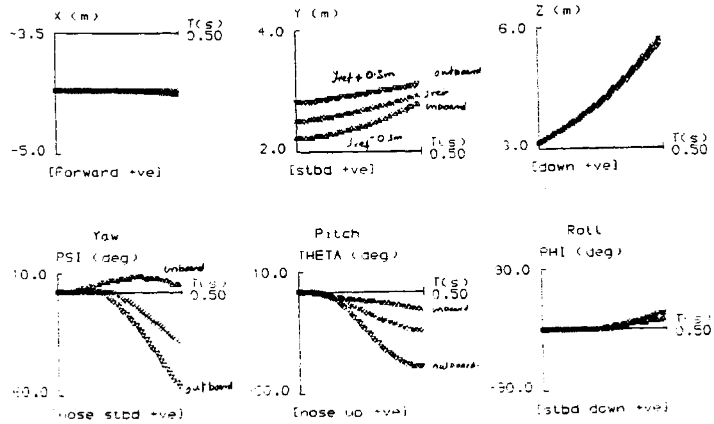


FIG. 2 :0°

FIG. 16 EFFECT OF STORE CHORDWISE LOCATION ON PREDICTED RELEASE TRAJECTORY, β=30°, R=4.54, Vej=3 m/s

FIG. 17 EFFECT OF STORE SPANWISE LOCATION ON PREDICTED RELEASE TRAJECTORY, β=30°, R=4.54, Vej=3 m/s



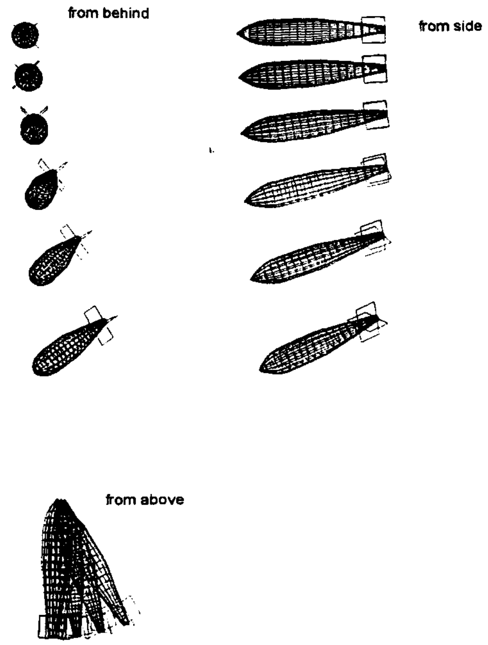


FIG. 18 WIRE-FRAME RELEASE TRAJECTORY FOR REFERENCE POSITION, β=30°, R=4.54, Vej=3 m/s

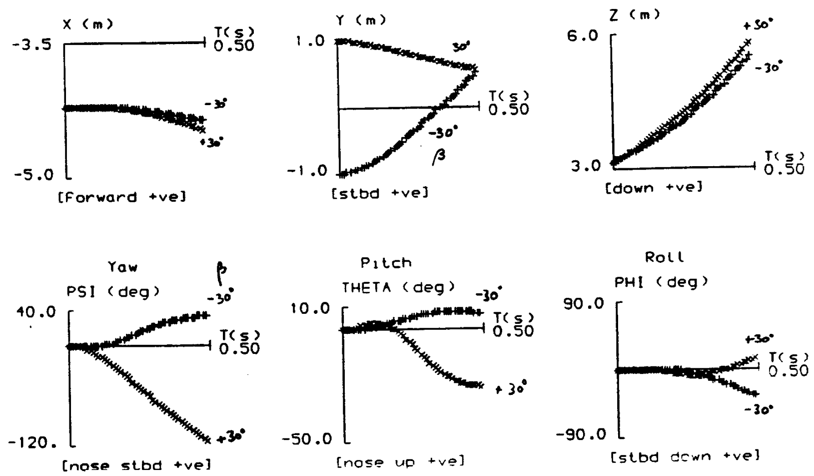


FIG. 19 EFFECT OF INITIAL STORE SPANWISE LOCATION (y=±1m, PORT OR STBD) ON PREDICTED RELEASE TRAJECTORY, β=30°, R=4.54, Vej=3 m/s

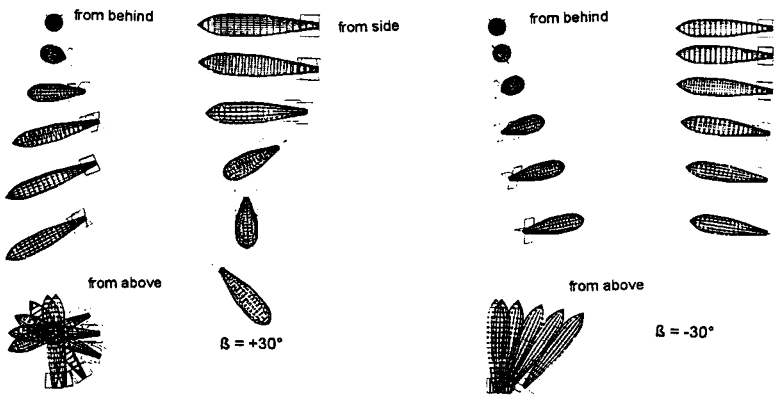


FIG. 20 WIRE-FRAMES, EFFECT OF SIDE-SLIP SENSE ON RELEASE TRAJECTORY, β=±30°, R=4.54, Vej=3 m/s

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(NEAR Inc.)

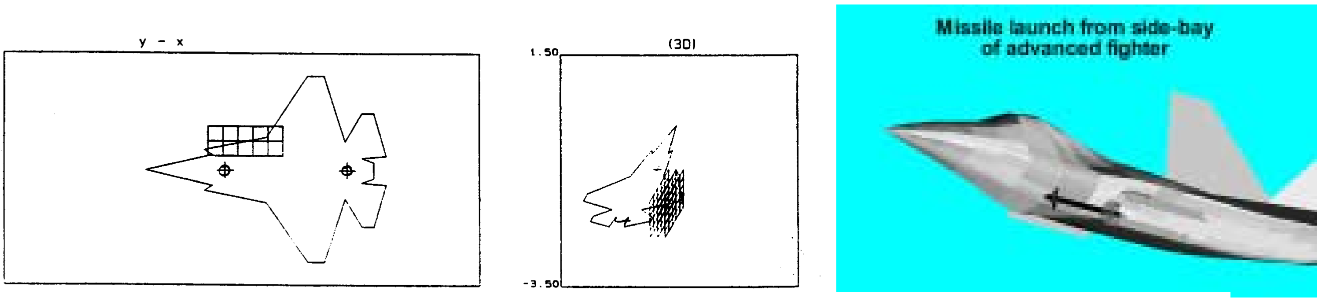

FIG. 21 ASTOVL AIRCRAFT, 3-D SURVEY VOLUME NEAR FRONT JET, THEORY FOR β=0° INCLUDE INTERNAL CARRIAGE & RELEASE

DISCUSSION EDITING

Paper No. 12: Stores released from ASTOVL Aircraft with vectoring jets

Authors: Dr.Raj Nangia

Speaker: s.a.

Discussor: Alex Cenko

Question: Would one be likely to jettison stores close to the ground?

Speaker's Reply: This could happen in an emergency situation – away from ship deck. This was certainly considered seriously in 1990´s at RAE/ DERA and several wind tunnel series were devoted to the subject.

Heavy aircraft may have to jettison stores prior to landing.