Statistical Analysis of Jettison Ejection Scenarios

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A new tool is proposed for predicting the flight behavior of simultaneously jettisoned composite stores exhibiting a large number of possible configurations. This tool can be used for rapid identification of critical jettison scenarios, and its application to the case of two store groups released from an aircraft weapon pylon is demonstrated.

Nomenclature

cg	=	Center of gravity
DOF	=	Degrees of freedom
h	=	Altitude
I_{xx}	=	X-axis principal moment of inertia
I_{yy}	=	Y-axis principal moment of inertia
I_{zz}	=	Z-axis principal moment of inertia
M_∞	=	Freestream Mach number
mom	=	Moment center
x	=	Streamwise coordinate
y	=	Spanwise coordinate
z	=	Vertical coordinate
α	=	Angle of attack
β	=	Yaw angle

I. Introduction / Motivation

When many possible stores are considered for safe separation analysis (e.g., when different components can be assembled to form a store and many combinations are possible), the number of engineering analyses may be prohibitively large. This problem is compounded by the simultaneous jettison of multiple stores. For example, a composite store 's2', representing a four-missile launcher with up to four identical missiles loaded (**Figure 1**), results in 16 different configurations, a composite store 's3', representing a two-missile launcher with up to two missiles chosen among two different types (**Figure 2**), results in nine unique possibilities, and a composite store 's1', representing a rocket launcher with zero to seven rockets chosen among two different but mutually exclusive types (**Figure 3**), results in a total of 255 unique possibilities. In the case where the composite stores 's1', 's2', or 's3' are released from a parent aircraft location 'p1' (say, outboard pylon), while nearly simultaneously releasing 's1' or 's2' stores from an alternative location 'p2' (e.g., inboard pylon, **Figure 4**), the total number of distinct jettison scenarios is 75,880 per (M_∞, h, α, β) flow condition.

Performing such a large number of high-fidelity store launch analyses would be prohibitive, both computationally and because of labor cost considerations. Much of the cost of performing such specialized analyses is associated with preparation and checking of code input files, which include geometry and mass properties specifications, as well as detailed aerodynamic modeling (of the composite stores, of the parent aircraft, fixed stores, etc.). Additional labor costs are those associated with post-processing, graphics, and results analysis. With regard to input preparation, several advancements can be made, in particular automating the generation of mass properties for stores assembled from various known components. With regard to composite store aerodynamic modeling, experienced engineers can provide modeling simplifications for the store aerodynamic properties, both captive and ejected. Regarding the post-processing stage, the graphics generation, its analysis, and its dissemination are time-consuming and labor intensive. Thus, an economical alternative is needed.

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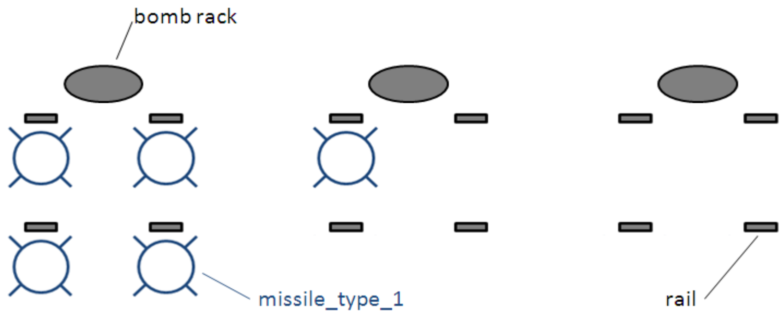


Figure 1. Three examples of composite store 's2' configurations (front view schematic).

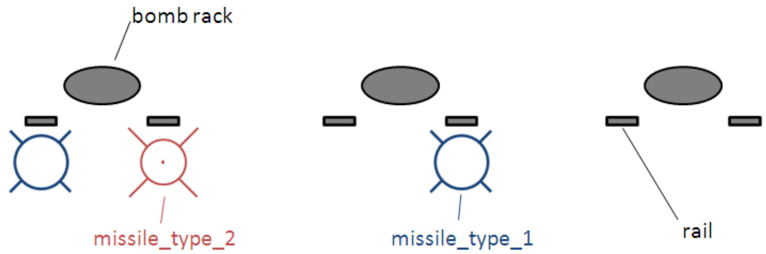


Figure 2. Three examples of composite store 's3' configurations (front view schematic).

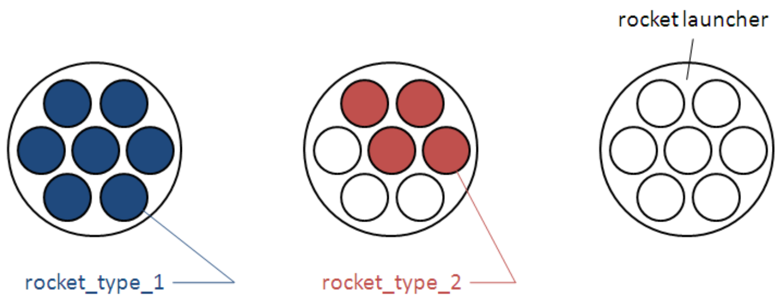


Figure 3. Three examples of composite store 's1' configurations (front view schematic).

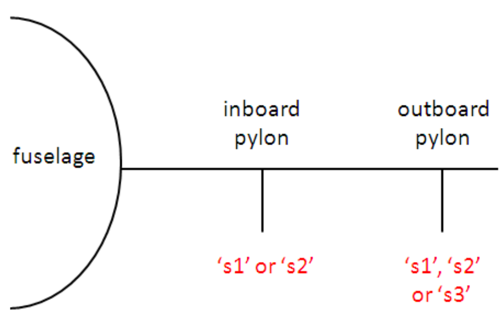


Figure 4. Front view schematic of store possible locations relative to parent aircraft.

To cut down on the number of required jettison analyses[a] or jettison tests[b], it would be ideal to rely on either (a) store similarity[c] when possible, or (b) expert knowledge.

One of the problems with the concept of "similarity" is that there is little guidance with respect to down-selecting the number of configurations to be investigated. MIL-HDBK-1763 Section 4.1.1 eludes to the possibility of using *analogy*, however, "sufficiently similar" is not defined. MIL-HDBK-1763 Tables B-I and B-III of Appendix B Test 271 provide release test measures of recommended allowable variations and expected maximum deviations. Although these could be used as a guide to define metrics of "closeness" for case equivalency,[d] they are defined for a single (i.e., component) store release and are likely not applicable to the type of composite jettisoned stores considered in this study. For many jettison configurations (see **Figures 1-4**) similarity cannot be justified. In addition, store separation, depending on the flow conditions but particularly for aerodynamically unstable stores (such as for jettisoned stores), is known to exhibit *sensitivity* to small perturbations in the input parameters.

This sensitivity not only makes relying on analogy a risky proposition, even if it were practical to do so, but also is the root cause of why intuition may be ineffective, even for experienced domain practitioners. For example, an "empty" jettisoned store may behave in a more benign fashion than a heavier, partially loaded one, depending on the configuration. Stated another way, the interactions caused by the dynamics of asymmetrical mass distributions, together with unstable aerodynamic characteristics, cannot easily be estimated using "back of the envelope" calculations.

II. Objectives

Given that neither similarity nor expert judgment can be relied upon to identify the most dangerous ejection scenarios a priori, a viable alternative must be sought. The objective of the present study is to explore the feasibility of developing a new data-informed approach for pre-store launch analysis, allowing early identification (filtering) of the potentially most problematic jettison events, which can then be flagged for further store separation analysis.

The proposed tool, referred to as SAJeS (Statistical Analysis of Jettison Scenarios) combines automated scripting for preparation of analysis input files, parallel execution of 6-DOF trajectory calculations, and mass post-processing, scoring and sorting of trajectory/rigid-body dynamics results.

III. Methods

To enable an automatic assessment of safe store separation on a massive scale, using non-graphical post-processing, we make use of the concept of Virtual Lanyards. "Virtual Lanyards" refers to hypothetical lines between fixed points on a store and other fixed points located, for example, on the parent aircraft or on other stores. The term is used to reflect our exploiting of an existing capability within an existing store launch analysis program. This capability was originally developed to model the release of the Penguin missile from an SH-60B helicopter (Ref. 1), where the wing deployment/store thrust sequence is initiated after umbilical disconnect, as the lanyard fully stretches between the weapon pylon and the missile. The implementation of this capability involves straightforward bookkeeping of lanyard-end positions, subject to coordinate transformations between the store reference frame and that of the parent aircraft. This same framework is readily amenable to the calculation of the length and geometry of multiple virtual lanyards. These are used, in turn, to assess critical distances between the ejected stores and portions of the aircraft, as well as between ejected stores as a function of time.

A prototype for the SAJeS tool was implemented in the form of a sequence of Matlab scripts. The analysis begins by taking into consideration the desired jettison parameter variations, i.e., the rules defining allowable store combinations (see Section I), and, as a result, creates a database of all possible jettison configurations/scenarios. As a byproduct of this analysis, it also generates a schedule of all the 6-DOF simulation runs needed and their corresponding inputs. The simulation input files are automatically generated based on the rules defining the assembly of each composite store from various known components, e.g., missile/rocket launchers, individual missiles and rockets, and their allowable positions, mutual exclusion rules, etc.

To facilitate bookkeeping, SAJeS uses component encoding to represent each store assembly. For example, the possible configurations of composite store 's1', which represents either a fully loaded, partially loaded, or empty seven-rocket launcher (see **Figure 3**), may be designated as shown in the following table.

[a] see MIL-HDBK-244A, Sections 5.1.1.2.3.1(h), 5.1.7.1.2, 5.3.6.1.3, 5.3.7.3.2(d)
[b] See MIL-HDBK-1763, Section 4.1.4.5.5
[c] see MIL-HDBK-244A, Sections 6.1.5.3.3.1, and 6.1.5.3.3.2
[d] e.g., center of gravity within 0.5 inches, moments of inertial within 10%, etc.

c10002022	bit encoding, in base *n*, where *n* is the maximum number of states for each subcomponent (for example: if the choices for a given component (bit) are 0 (`absent`), 1 (`rocket_type_1`), or 2 (`rocket_type_2`), then the natural representation for the component assembly is *base 3*). By convention, the configuration identified on the left-hand side represents the presence of 1 rocket launcher (first bit), followed by the identification of the subcomponents present in tubes 1 through 7 (in this case, `rocket_type_2` inside tubes 4, 6 and 7 only).
e2249	decimal encoding of 10002022 in *base 3*

An example of automatically generated mass properties for composite store 's1' (**Figure 3**), showing all 255 distinct configurations/scenarios, is shown in **Figures 5-8**.

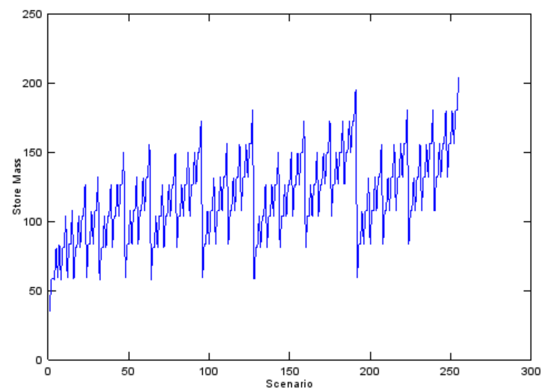


Figure 5. Possible masses for store 's1'.

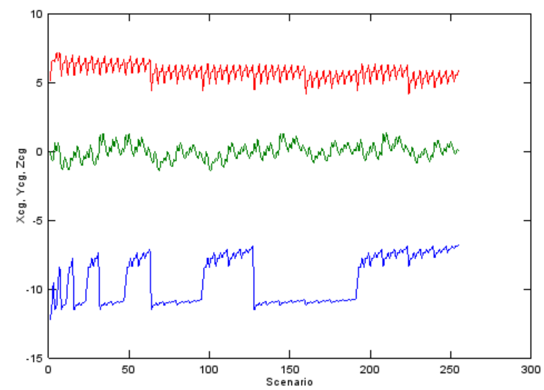


Figure 6. Possible center of gravity locations for store 's1' (blue : X, green : Y, red : Z).

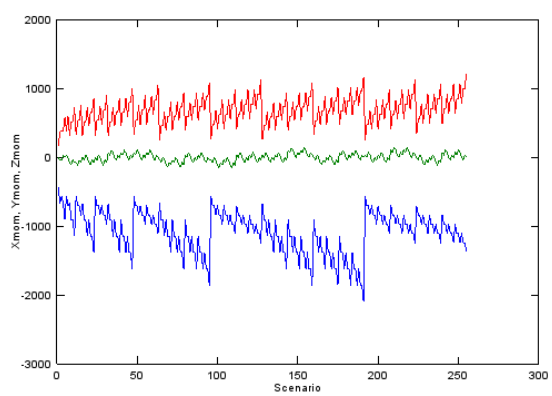


Figure 7. Possible moment components for store 's1' (blue : X, green : Y, red : Z).

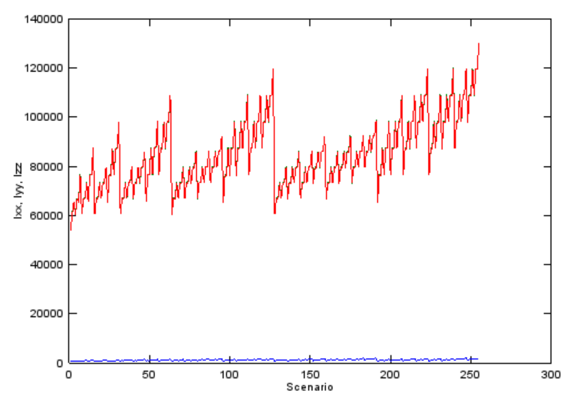
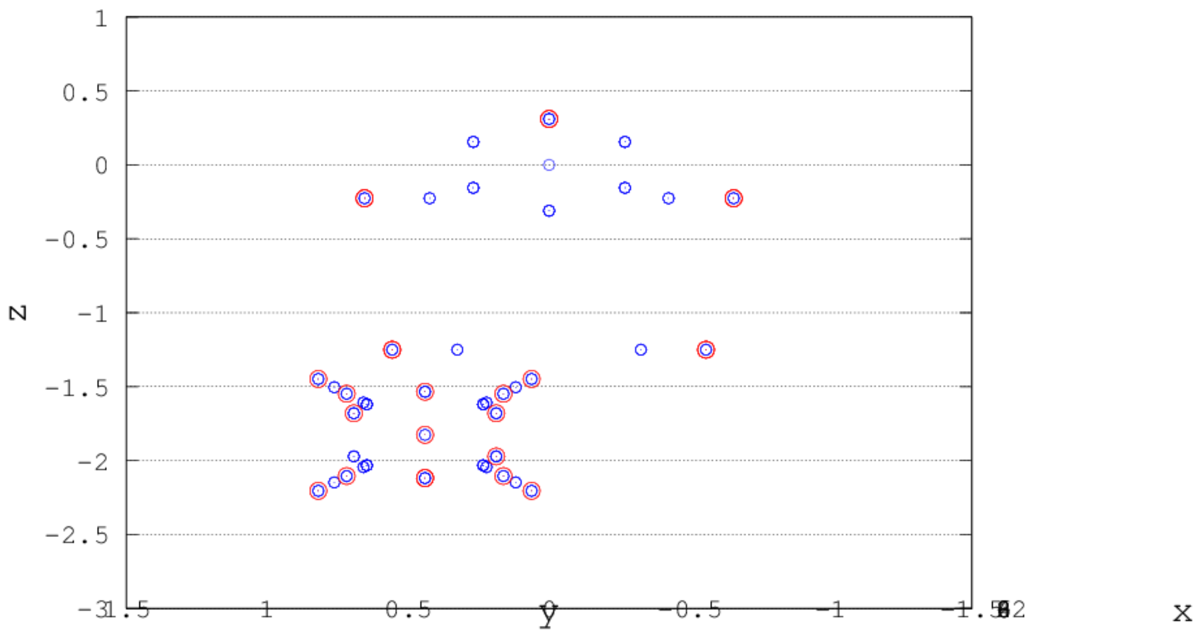


Figure 8. Possible principal moments of inertia for store 's1' (blue : I_{XX}, green : I_{YY}, red : I_{ZZ}).

As described in the introduction, considering all combinations involving composite stores 's1', 's2' or 's3' in their respective allowable initial positions results in a total 75,880 different jettison scenarios per flow condition.

In order to compute the virtual lanyards, each composite store is represented by an automatically generated point cloud, an example of which is given in **Figure 9** for store 's2', configuration c10010. Higher fidelity representations can be generated by using a larger number of points, while lower fidelity representations may consider a subset of the point cloud for computational efficiency, for example the protruding vertices shown in red (see **Figure 9**).



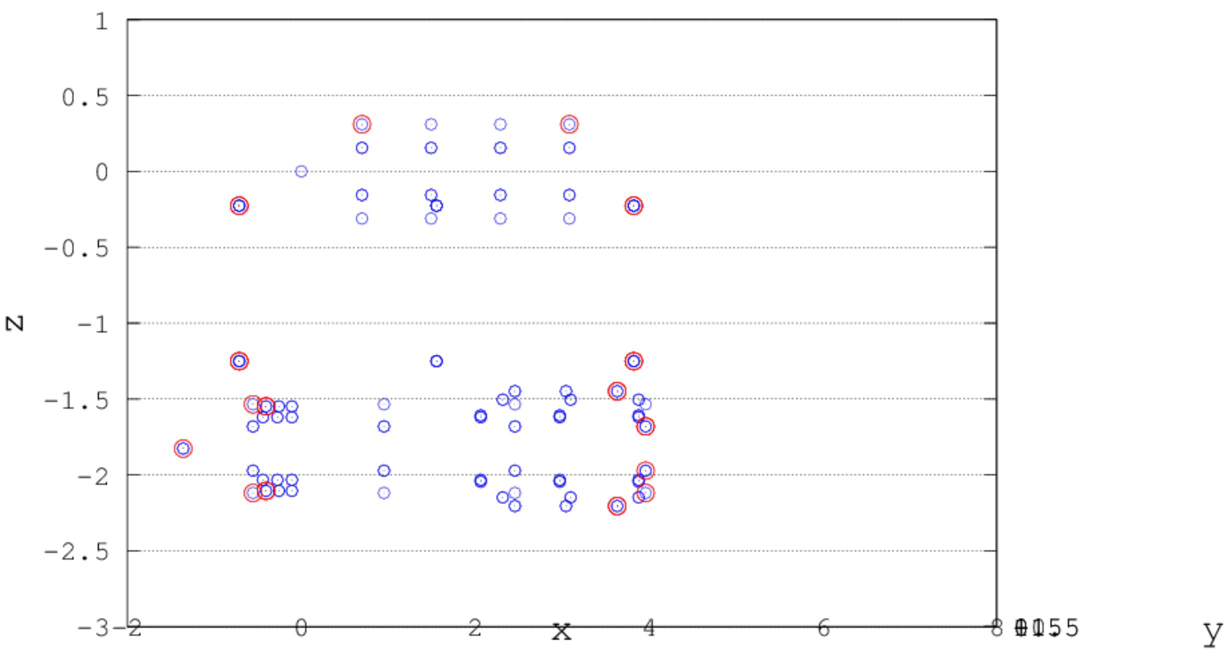


Figure 9. Example of point cloud representation for composite store 's2'. Top: front view. Bottom: side view. Red symbols denote the protruding vertices of the approximate encompassing surface.

An example time sequence of virtual lanyards computation is shown in **Figures 10-12**. In this example, the outboard store ('s3', c111) release is delayed with respect to the inboard store ('s2', c10010), and two aircraft components (indicated by the black symbols) are considered: a weapons pylon (located above the stores), and a portion of the fuselage (left-hand side of the figures). The shortest lanyards in each category (store-to-store, store-to-aircraft-component, etc.) are identified at each instant of the trajectory. The solid symbols represent the most forward positions of each object.

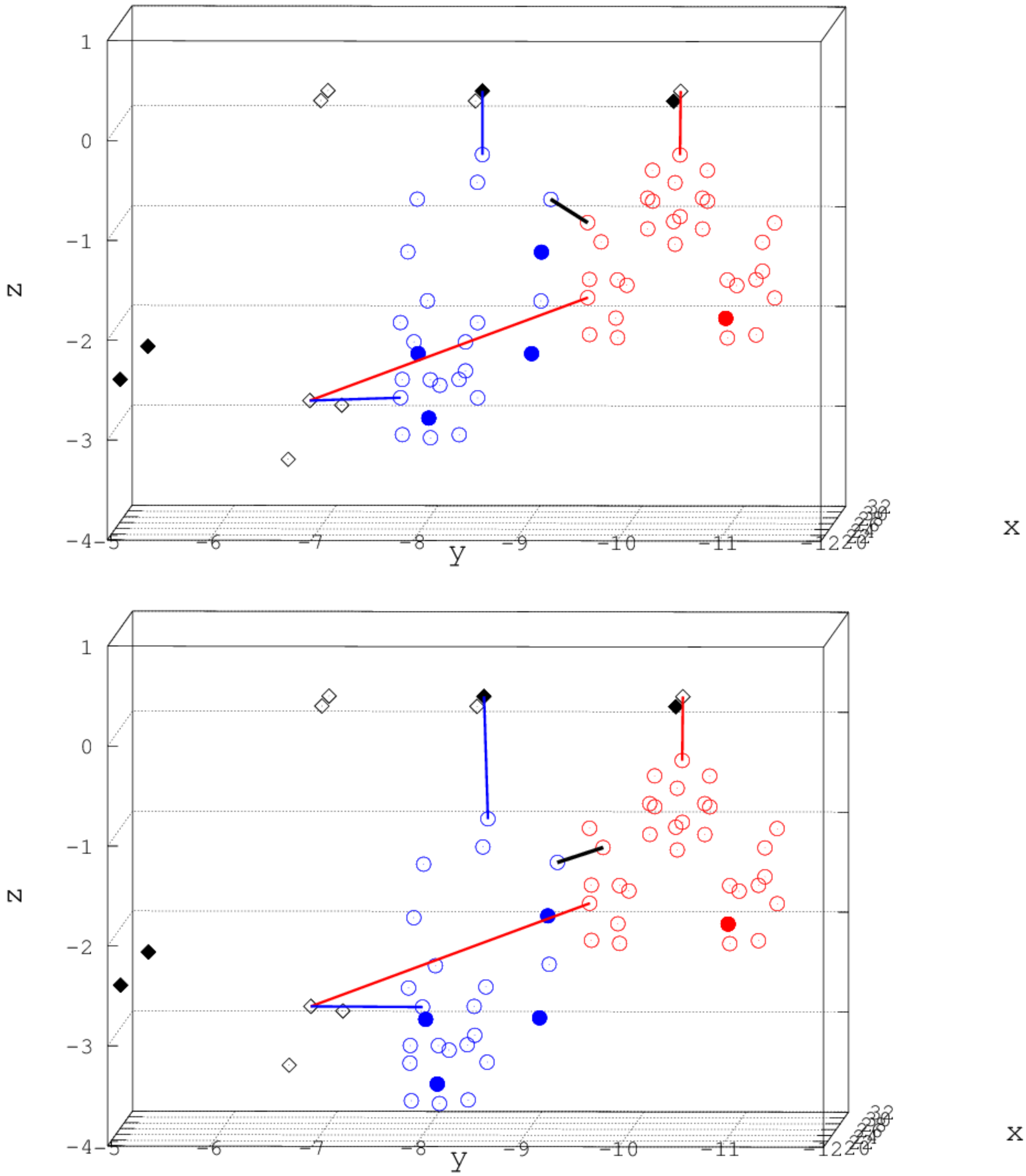
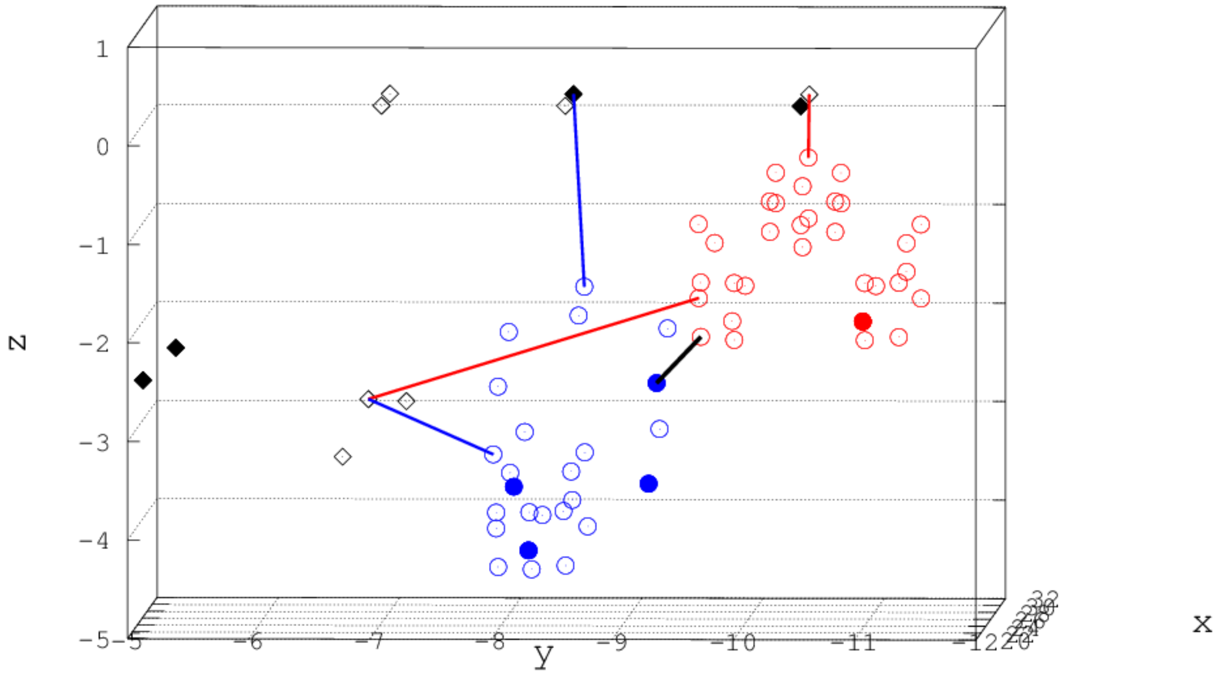


Figure 10. **Illustration of virtual lanyards computation at time 0.000 (top) and time 0.200 (bottom). Red symbols represent outboard store. Blue symbols represent inboard store. Black symbols indicate parent aircraft (pylon and fuselage components). Only the shortest virtual lanyards in each category (store to pylon, store to fuselage, store to store) are shown.**



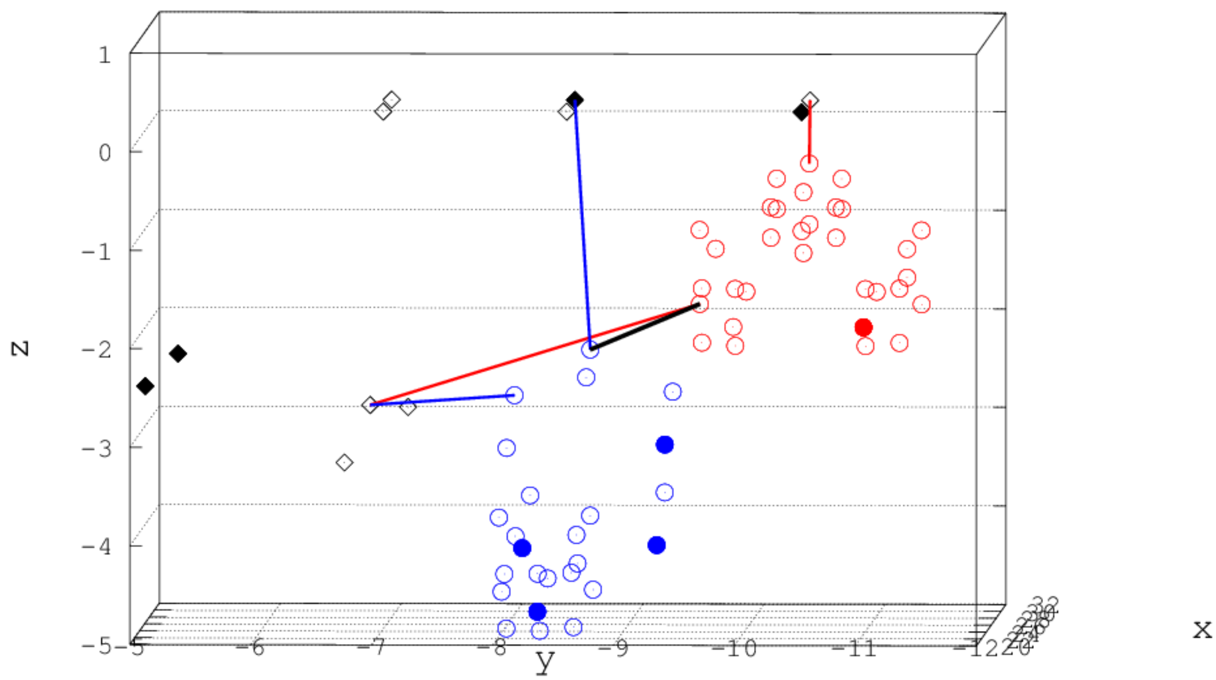


Figure 11. Illustration of virtual lanyards computation at time 0.300 (top) and time 0.360 (bottom). Red symbols represent outboard store. Blue symbols represent inboard store. Black symbols indicate parent aircraft (pylon and fuselage components). Only the shortest virtual lanyards in each category (store to pylon, store to fuselage, store to store) are shown.

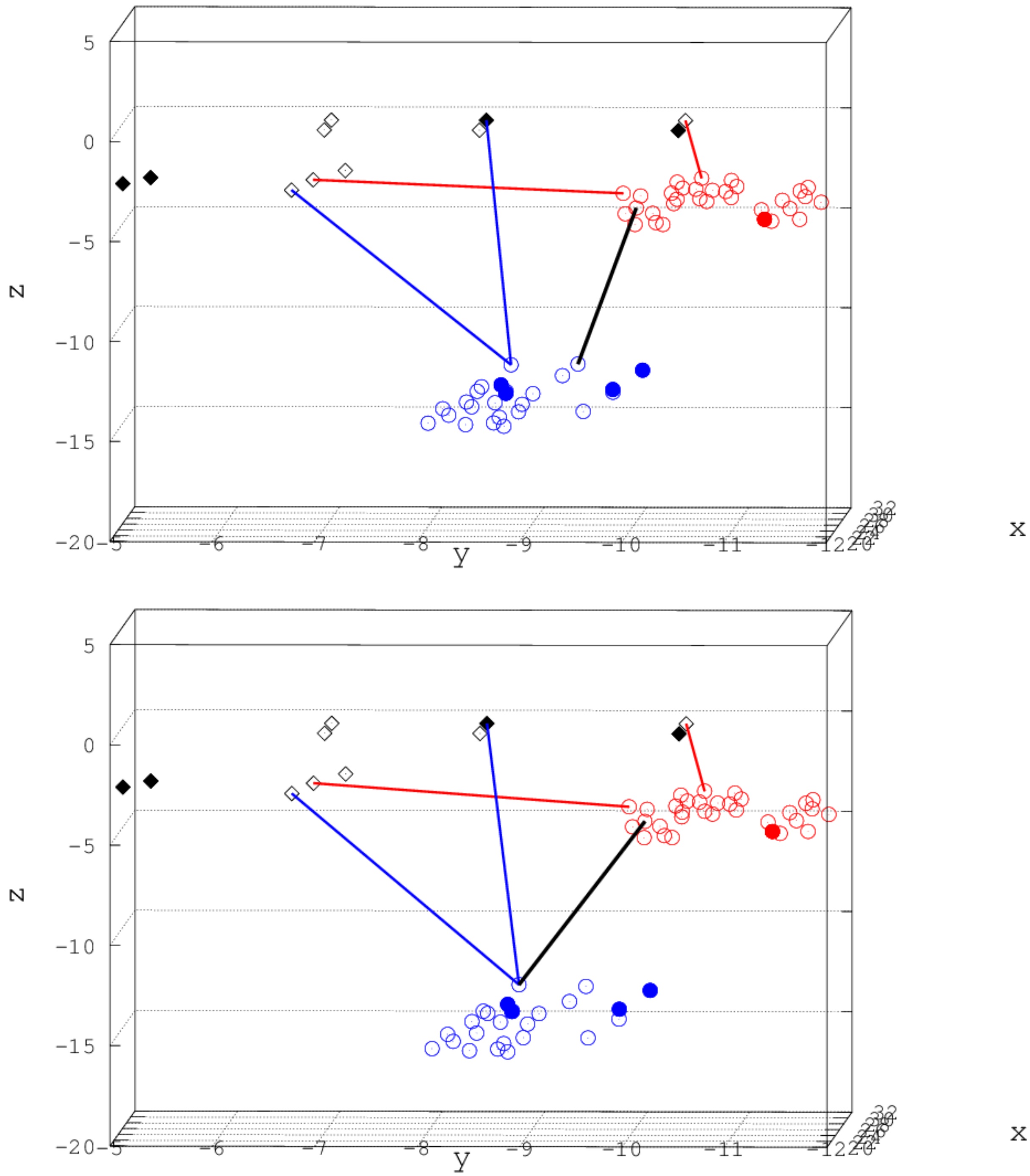


Figure 12. Illustration of virtual lanyards computation at time 0.900 (top) and time 0.940 (bottom). Red symbols represent outboard store. Blue symbols represent inboard store. Black symbols indicate parent aircraft (pylon and fuselage components). Only the shortest virtual lanyards in each category (store to pylon, store to fuselage, store to store) are shown.

Figures 9-12 illustrate the data reduction steps taken in SAJeS: solid geometry to point cloud, point cloud to protruding vertices, and selection of minimal length virtual lanyards in each category at each time step.

IV. Results

We first consider the case where the outboard store release is delayed with respect to the inboard store. The freestream conditions are $\alpha = 12°$, $\beta = 0°$, low-speed incompressible flow. **Figure 13** shows the minimum separation between the outboard stores and the pylon at each instant for all scenarios. The red line identifies the curve with the smallest minimum separation. **Figure 14** shows the corresponding probability distribution at time 0.66.

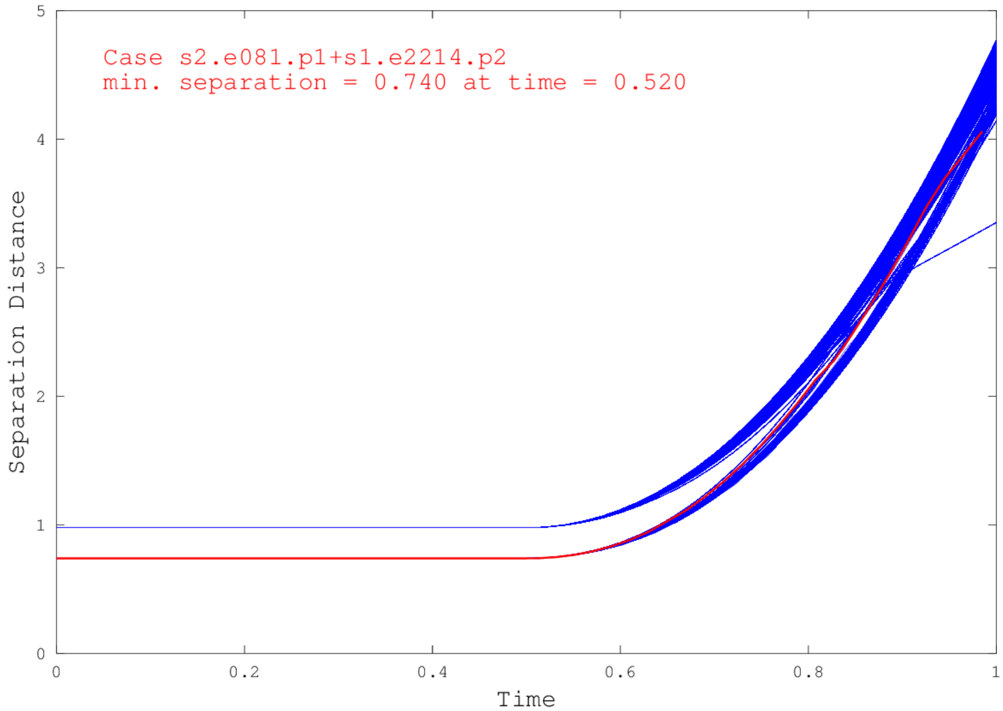


Figure 13. Outboard-store-to-pylon minimal separation distances.

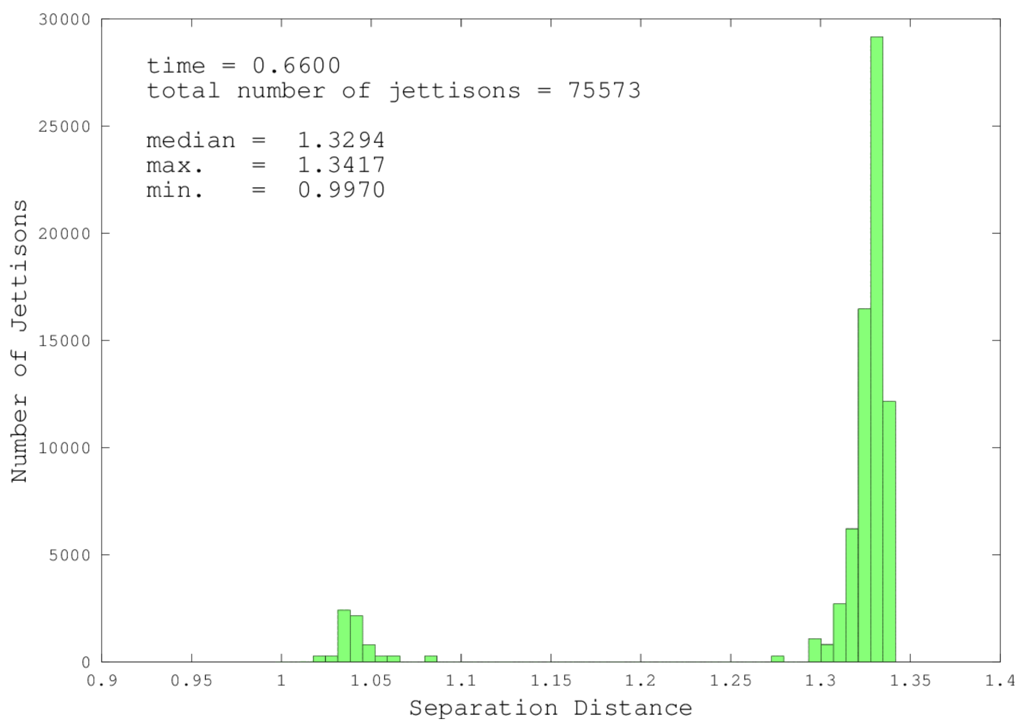


Figure 14. Outboard-store-to-pylon minimal separation distance distribution at time = 0.66.

The minimum separation for all scenarios between the inboard stores and the pylon is shown in **Figure 15** , with the corresponding probability distribution at time 0.66 shown in **Figure 16**.

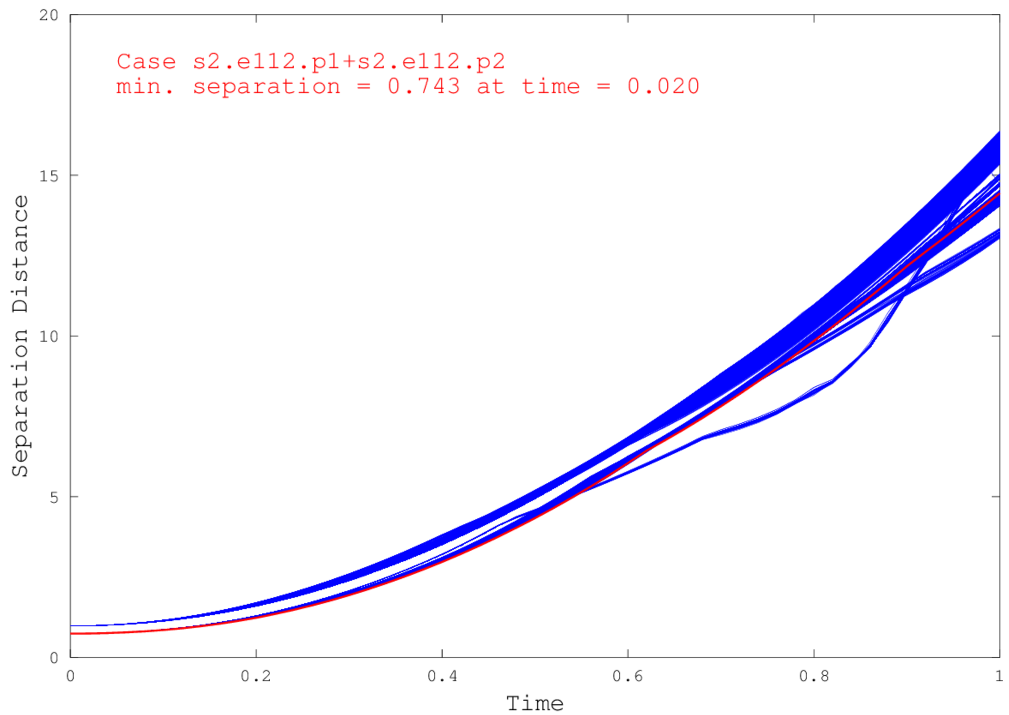


Figure 15. Inboard-store-to-pylon minimal separation distances.

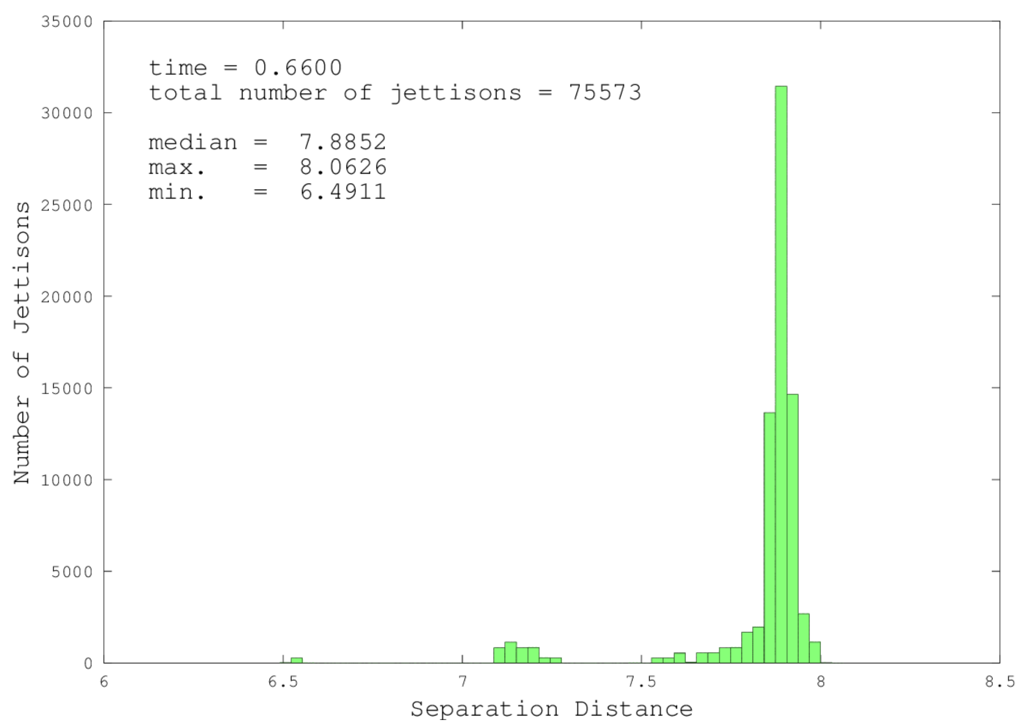


Figure 16. Inboard-store-to-pylon minimal separation distance distribution at time = 0.66.

The outboard-store-to-fuselage characteristics are shown in **Figures 17** and **18**.

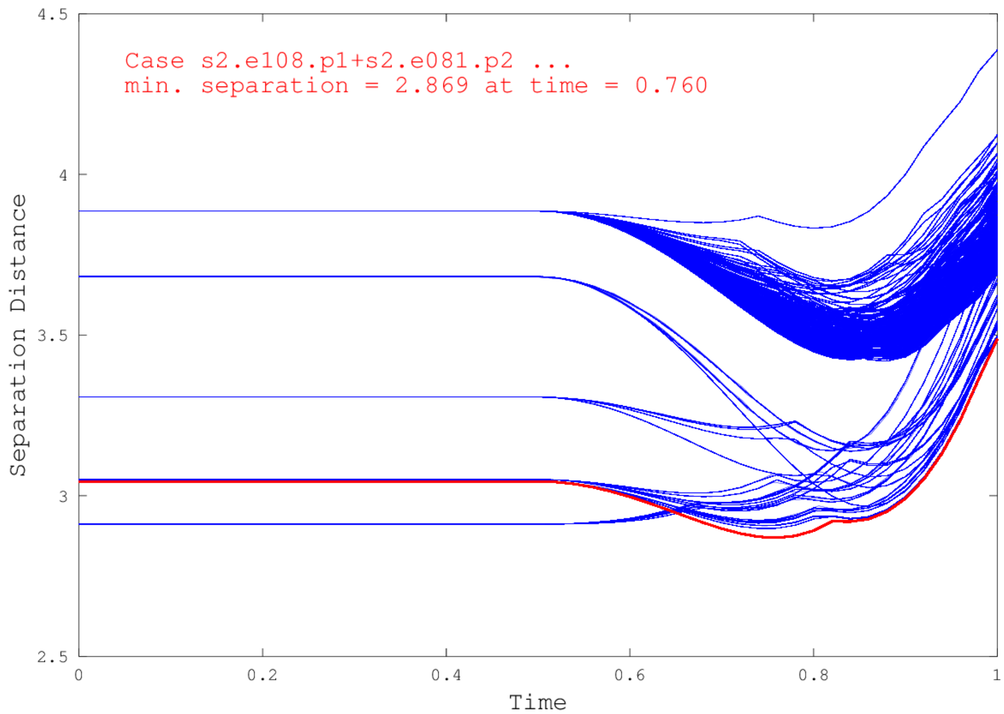


Figure 17. Outboard-store-to-fuselage minimal separation distances.

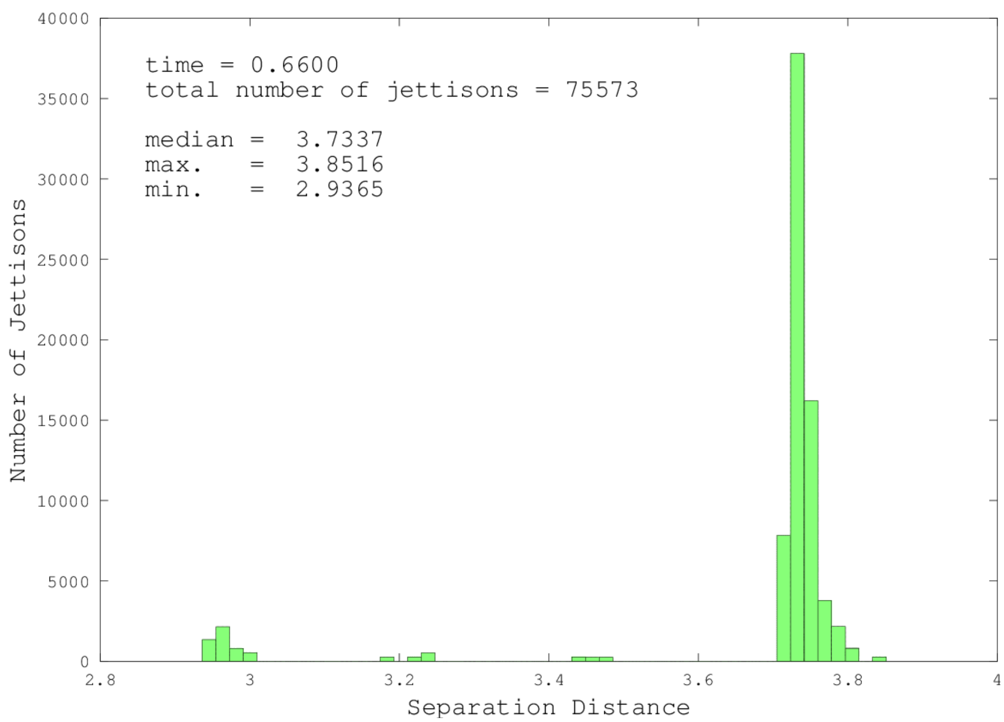


Figure 18. Outboard-store-to-fuselage minimal separation distance distribution at time = 0.66.

Figures 19 and **20** show the characteristics of the minimum distance between the inboard composite store and the parent aircraft fuselage.

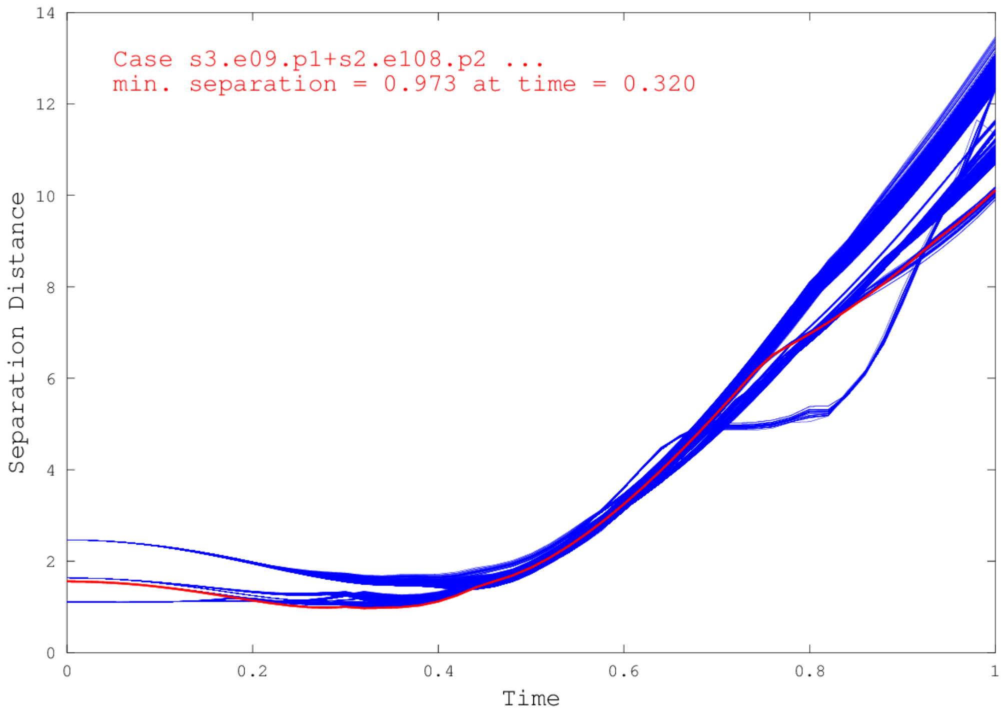


Figure 19. Inboard-store-to-fuselage minimal separation distances.

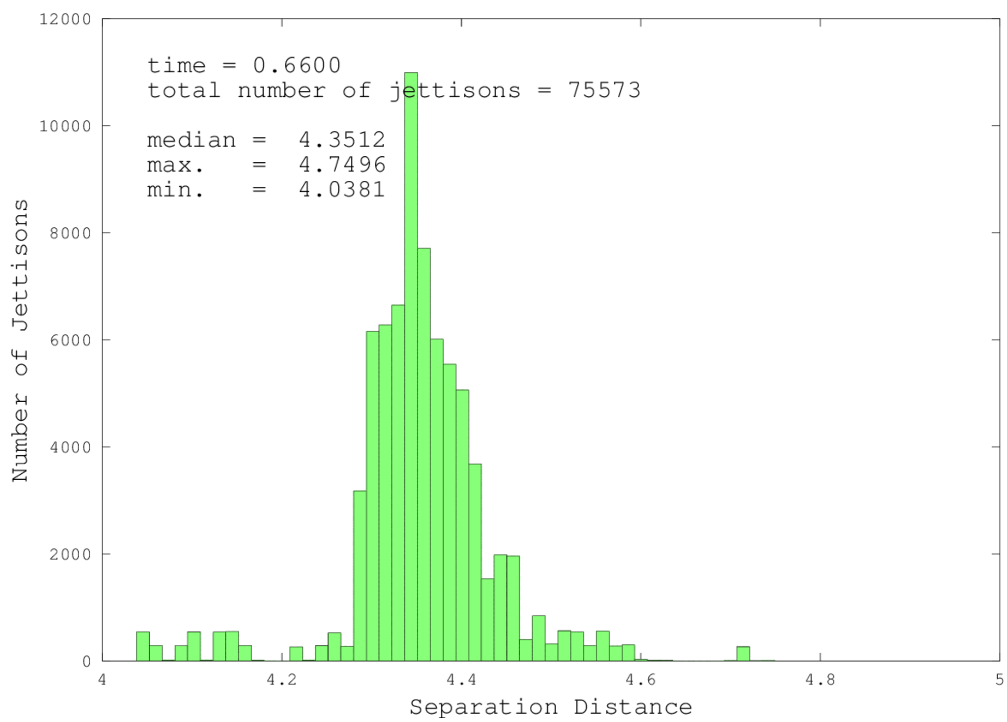


Figure 20. Inboard-store-to-fuselage minimal separation distance distribution at time = 0.66.

Time histories of the store-to-store separation distances are shown in **Figure 21**, followed by a time sequence of the corresponding separation distributions (**Figures 22** through **24**).

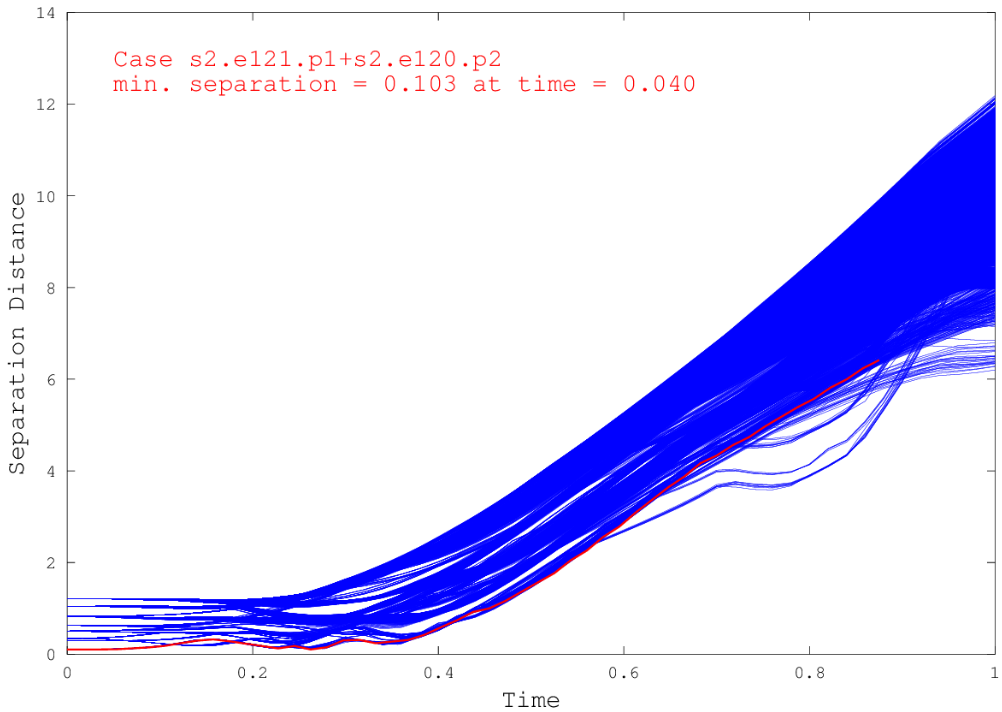


Figure 21. Store-to-store minimal separation distances (with outboard delay).

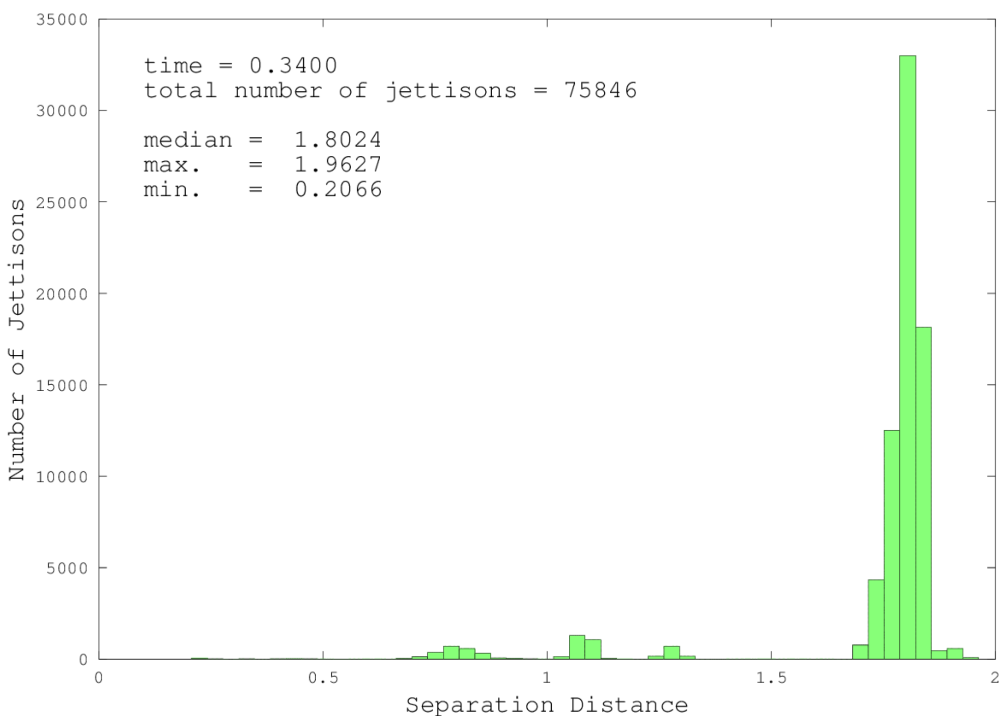


Figure 22. Store-to-store minimal separation distance distribution at time = 0.34 (with outboard delay).

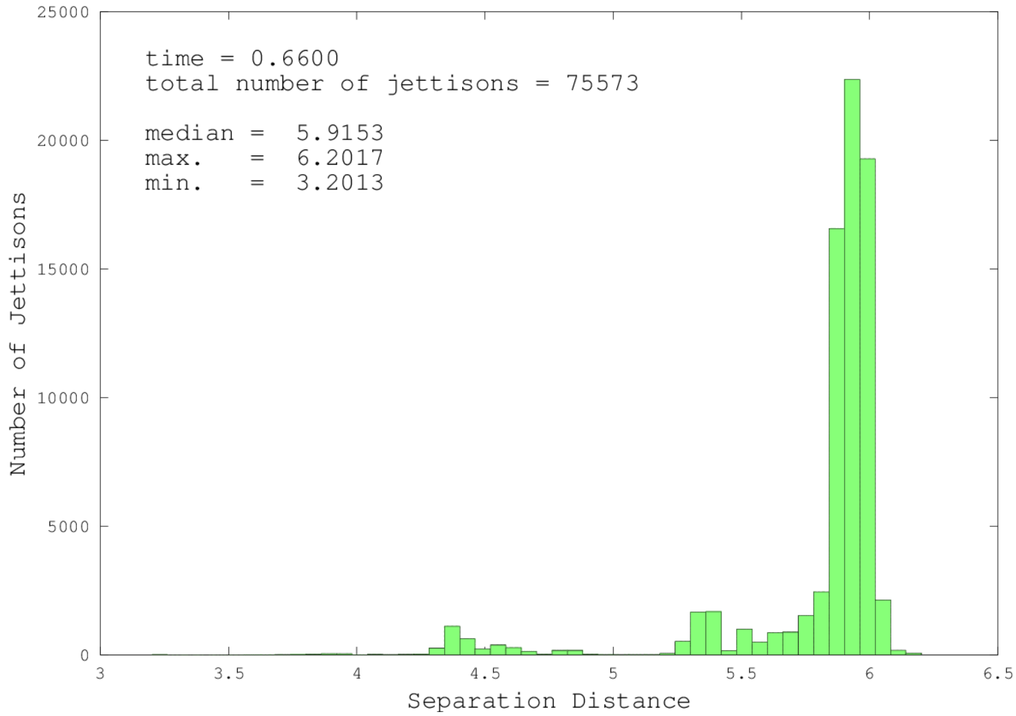


Figure 23. Store-to-store minimal separation distance distribution at time = 0.66 (with outboard delay).

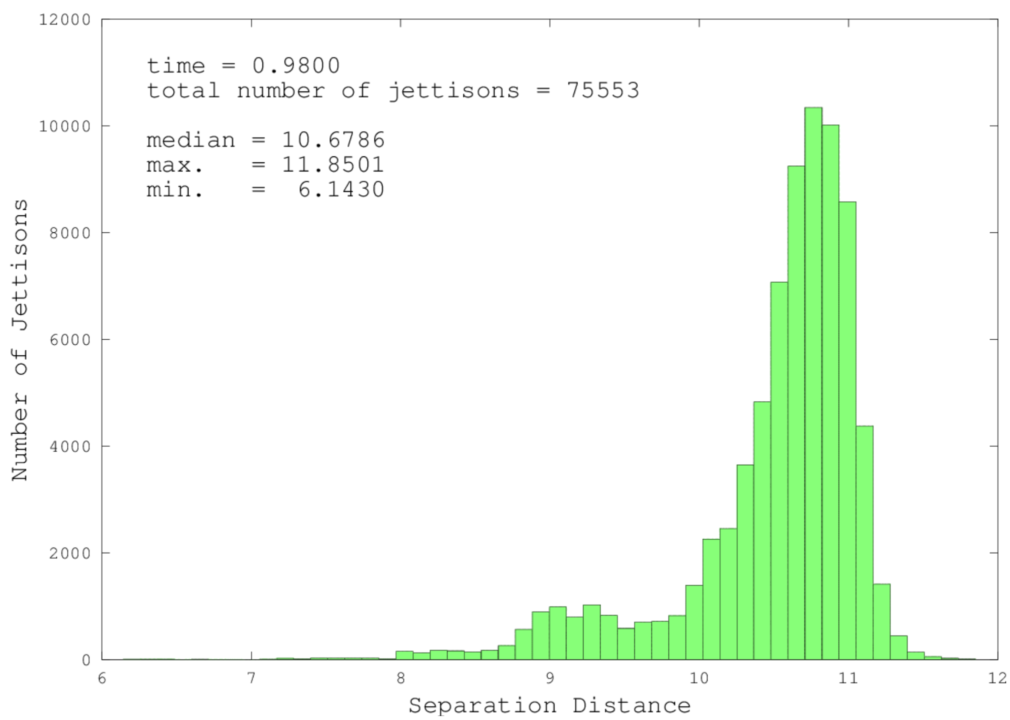


Figure 24. Store-to-store minimal separation distance distribution at time = 0.98 (with outboard delay).

For the outboard delay case, the minimum inter-store distance occurs near the beginning of the jettison sequence, and increases thereafter. At time 0.98 (**Figure 24**), the minimum separation distance is 6.14. By contrast, the minimum distance for the zero delay case (**Figures 25** and **26**) is less than 0.1, which indicates the possibility of contact between the stores.

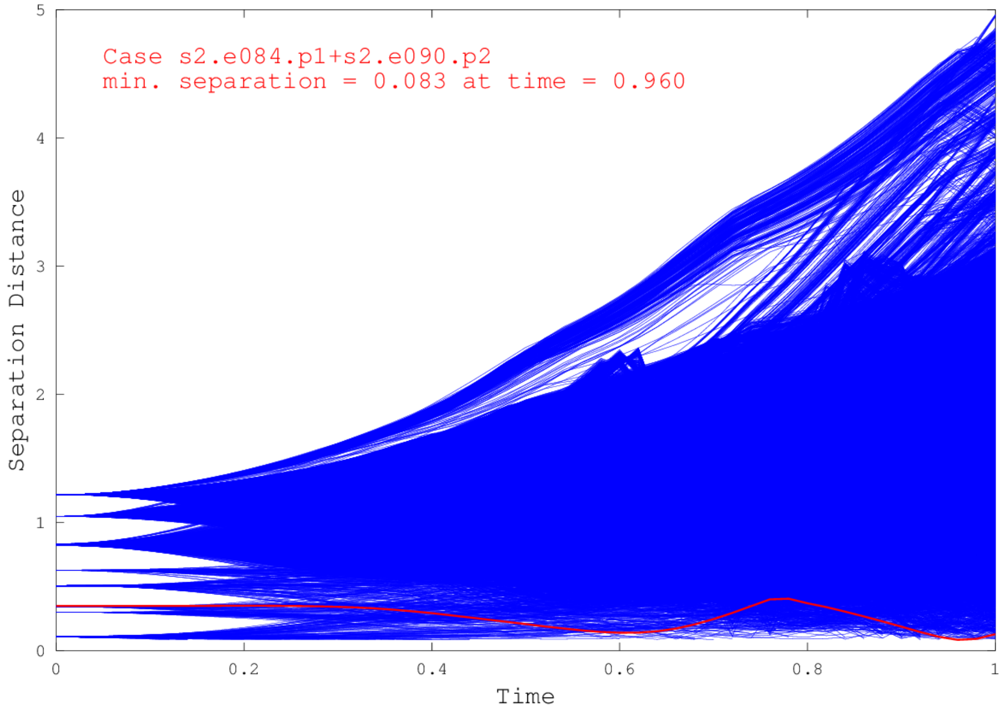


Figure 25. Store-to-store minimal separation distances (no outboard delay).

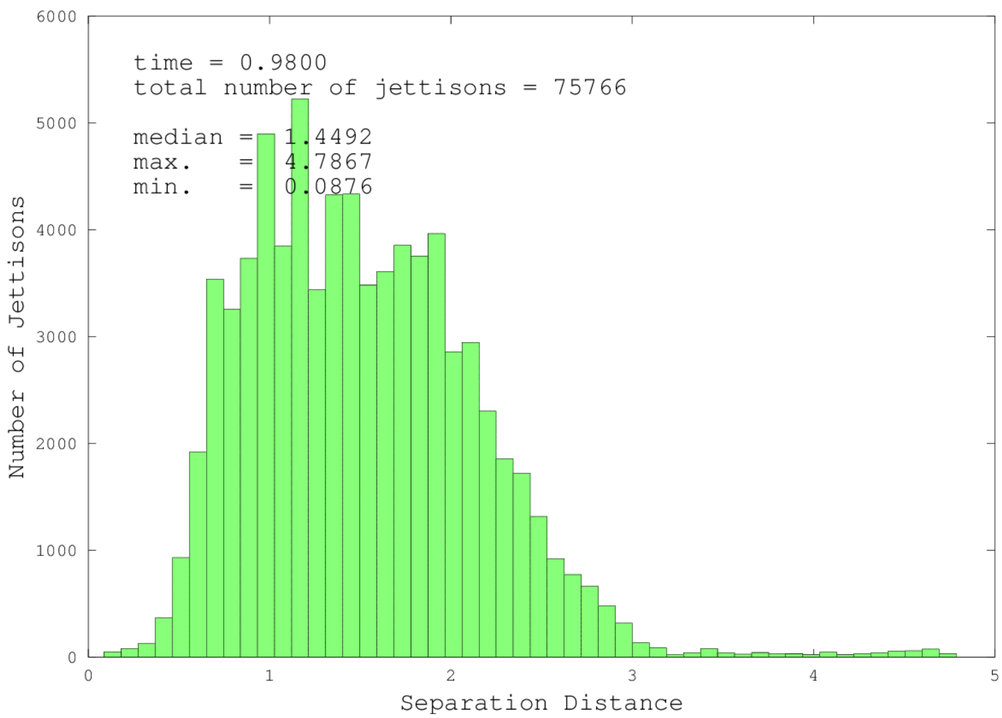


Figure 26. Store-to-store minimal separation distance distribution at time = 0.98 (no outboard delay).

In addition to the above statistics, SAJeS generates a scoring of each trajectory based not only on minimum distance but also on how long and how close two stores dwell next to each other over the length of the trajectory. Using these metrics, an automated report is produced, which ranks the most dangerous scenarios within each contact category (i.e., store to pylon, store to fuselage, or store to store).

A high-level summary of the data mining analysis produced by SAJeS is shown below:

```
> weighted distance scoring (with outboard delay):

s2.e120.p1 + s2.e121.p2  inboard config '11111'    outboard config '11110' score = 2.2e-1 S1-S2
s3.e12.p1  + s1.e2431.p2 inboard config '10100001' outboard config '110'   score = 1.2e-2 S1-A1
s2.e112.p1 + s2.e112.p2  inboard config '11011'    outboard config '11011' score = 1.7e-3 S2-A1
s3.e09.p1  + s2.e112.p2  inboard config '11011'    outboard config '100'   score = 9.5e-4 S2-A2
s2.e112.p1 + s2.e081.p2  inboard config '10000'    outboard config '11011' score = 3.8e-8 S1-A2
```

The above summary pinpoints jettison cases which may be deserving of further (i.e., higher fidelity) analysis. The report identifies the cases by name, including their store configurations, and lists their relative scores. The weighed distance scoring is calculated as the average over the calculated trajectory of the exponentially weighted minimum distance:

$$\text{weighted distance score} \;=\; \mathit{average}\left(\exp\left(-\lambda \frac{d-d_{\text{contact}}}{d_{\text{contact}}}\right)\right) \qquad \textbf{(1)}$$

where d is the instantaneous minimum distance, $d_{contact}$ is the operational definition used for detecting contact, and λ is a user-defined parameter. Thus, the weighted distance score is 1.0 for a continuously grazing contact. In the present study, λ was chosen to be 0.5. With the chosen values, scores of 0.8, 0.5 and 0.2 correspond to $d/d_{contact} \approx$ 1.4, 2.4, and 4.2, respectively.

The top entry in the above table identifies the closest store-to-store ('S1-S2') distance metric as one associated with a fully loaded ('11111') four-missile launcher ('s2') in the inboard position ('p2'), and a partially loaded ('11110') four-missile launcher ('s2') in the outboard position ('p1'). The base-3 decoding of the composite store configurations 'e120' and 'e121' correspond to the bit-wise expanded store configurations '11110' and '11111'. The presence of only ones and zeros indicates that the outboard store includes 'missile_type_1' in three of the four positions (upper inboard and outboard, and lower inboard).

The second entry in the above report identifies the closest outboard-store-to-pylon ('S1-A1') distance metric as one associated with a partially loaded ('10100001') seven-rocket launcher ('s1') in the inboard position ('p2'), and an asymmetrically loaded ('110') two-missile launcher ('s3') in the outboard position ('p1'). The base-3 decoding of the composite store configurations 'e12' and 'e2431' correspond to the bit-wise expanded store configurations '110' and '10100001', respectively. The presence of only ones and zeros indicates that neither 'missile_type_2' nor 'rocket_type_2' are part of this configuration. Furthermore, the outboard store has 'missile_type_1' in the inboard position only. The inboard store is loaded with two 'rocket_type_1' components, one in the upper outboard position, the other in the lower outboard position.

Similar interpretations can readily be made from the summary report for the other contact categories, i.e., inboard-store-to-pylon ('S2-A1'), inboard-store-to-fuselage ('S2-A2'), and outboard-store-to-fuselage ('S1-A2').

The case of zero outboard delay is illustrated in **Figure 26**, which shows the separation statistics at time 0.98, with a median separation of approximately 1.45 and a minimum separation of less than 0.1, indicating the existence of store-to-store contacts. The corresponding high-level data mining summary produced by SAJeS is shown below:

```
> weighted distance scoring (zero outboard delay):

s2.e112.p1 + s2.e121.p2  inboard config '11111'    outboard config '11011' score = 8.0e-1 S1-S2
s3.e17.p1  + s2.e081.p2  inboard config '10000'    outboard config '122'   score = 2.3e-3 S1-A1
s2.e112.p1 + s2.e112.p2  inboard config '11011'    outboard config '11011' score = 2.2e-3 S2-A1
s3.e09.p1  + s2.e112.p2  inboard config '11011'    outboard config '100'   score = 9.4e-4 S2-A2
s2.e111.p1 + s2.e121.p2  inboard config '11111'    outboard config '11010' score = 2.1e-8 S1-A2
```

The top entry identifies the closest store-to-store ('S1-S2') distance metric as one associated with a fully loaded ('11111') four-missile launcher ('s2') in the inboard position ('p2'), and a partially loaded ('11011') four-missile launcher ('s2') in the outboard position ('p1'). The base-3 decoding of the composite store configuration 'e112' corresponds to the bit-wise expanded store configuration '11011'. For this configuration, the outboard store includes 'missile_type_1' in three of the four positions (lower inboard and outboard, and upper inboard).

Of the various contact categories, the most interesting to analyze is the store-to-store distance in the case of zero outboard delay. For this category, SAJeS identifies a total of 69 cases in which contact is made between stores within the one second simulation. Contact cases are ranked according to a separate “contact time scoring” metric, defined as

$$\text{contact time score} = \frac{t_{\text{sim}} - t_{\text{contact}}}{t_{\text{sim}}} \quad \textbf{(2)}$$

where t_{sim} is the total simulation time, and $t_{contact}$ is the time at which the two composite stores first make contact. Thus, a contact time score approaching 1.0 represents an almost immediate contact, while a score of, say, 0.05 represents a later contact (0.95 seconds into the simulation, in this case). A partial output of the SAJeS report for this contact category is shown in the table below.

rank	jettison scenario	inboard config	outboard config	contact time score
1	s2.e108.p1 + s2.e121.p2	11111	11000	8.58E-01
2	s2.e108.p1 + s2.e094.p2	10111	11000	8.55E-01
3	s2.e108.p1 + s2.e093.p2	10110	11000	8.34E-01
4	s2.e108.p1 + s2.e118.p2	11101	11000	8.31E-01
5	s2.e108.p1 + s2.e120.p2	11110	11000	8.30E-01
6	s2.e108.p1 + s2.e117.p2	11100	11000	7.69E-01
7	s2.e112.p1 + s2.e120.p2	11110	11011	7.30E-01
8	s2.e112.p1 + s2.e093.p2	10110	11011	6.90E-01
9	s2.e112.p1 + s2.e117.p2	11100	11011	6.43E-01
10	s2.e121.p1 + s2.e120.p2	11110	11111	6.35E-01
⋮	⋮	⋮	⋮	⋮
31	s3.e13.p1 + s1.e2916.p2	11000000	111	1.57E-01
32	s2.e121.p1 + s1.e2916.p2	11000000	11111	1.52E-01
33	s1.e2915.p1 + s2.e091.p2	10101	10222222	1.28E-01
34	s2.e121.p1 + s2.e091.p2	10101	11111	1.20E-01
35	s1.e2753.p1 + s2.e091.p2	10101	10202222	1.14E-01
36	s1.e4349.p1 + s2.e091.p2	10101	12222002	1.10E-01
37	s1.e4317.p1 + s2.e091.p2	10101	12220220	1.03E-01
38	s1.e2429.p1 + s2.e091.p2	10101	10022222	9.85E-02
39	s2.e081.p1 + s1.e2349.p2	10020000	10000	9.84E-02
40	s1.e4365.p1 + s2.e091.p2	10101	12222200	9.81E-02
⋮	⋮	⋮	⋮	⋮

The observations listed below are based on the 69 contact cases listed in the SAJeS report of which the above table is a subset. Because these represent instances of store-to-store contact shortly after release, additional detailed analysis of the trajectory characteristics would be recommended for a safe clearance study. For example, plots or animations of store trajectories should be used to provide additional insight.

As background, the stores are released from an initial position where the fuselage is expanding radially, creating a sizable outflow. The above table indicates that the first six (6) contact cases share the same outboard composite store: a 4-missile launcher with a single missile on the upper inboard rail next to the inboard composite store. This is a lighter configuration with asymmetric mass properties and three exposed rails which produce aerodynamic forces. The inboard composite store has either two, three or four missiles, but all six configurations have in common the presence of one missile located on the upper outboard rail next to the outboard composite store. The mass is greater for the inboard composite store, and its configurations exhibit more symmetry than the outboard one. The missile configurations of the first six combinations are shown in the front view diagrams below, where 'o' indicates the presence of a missile, and '-' its absence but the presence of a launch rail.

o o	o -	- o	o -	- o	o -	o o	o -	o o	o -	o o	o -
o o	- -	o o	- -	o -	- -	- o	- -	o -	- -	- -	- -

Contact is likely between the two adjacent missiles on the inboard and outboard composite stores. The lighter mass, asymmetry, and three lifting rails of the outboard store make it very susceptible to the nonuniform aircraft and store flowfield, resulting in quicker translations and rotations. The heavier inboard store can be expected to react slower. Because contact occurs quickly, the nature of the contact is likely to be between the adjacent missiles on the two composite stores.

The outboard store for the contact cases ranked 7 through 9 has three missiles with two on the inboard rails and one on the lower outboard rail. For these cases the inboard store has either two or three missiles, with one always located on the upper outboard rail adjacent to the outboard composite store. The corresponding contact case geometries are depicted in the following diagrams.

o o o -	o - o o

- o o -	o - o o

o o - -	o - o o

As before, early contact is likely between adjacent missiles. Ranked case #9 makes contact at 0.357 seconds. As contact time increases, it is difficult to know how contact is made, but there are few interesting cases. For example, the 4-launcher configuration '`10101`' released from the inboard pylon (missiles on the outboard rails next to the outboard composite store) makes contact with 31 outboard pylon configurations, 29 of which correspond to the 7-tube rocket launcher with different permutations of '`rocket_type_2`' loadings. These rocket launcher contacts happen after 0.872 seconds.

The non-contact cases are ranked according to the weighted distance metric (Equation 1) discussed earlier. For reference, the top 10 non-contact scenarios are given below.

rank	jettison scenario	inboard config	outboard config	weighted distance score
1	s2.e112.p1 + s2.e121.p2	11111	11011	7.99E-01
2	s2.e120.p1 + s2.e117.p2	11100	11110	7.83E-01
3	s2.e111.p1 + s2.e118.p2	11101	11010	7.58E-01
4	s2.e112.p1 + s2.e094.p2	10111	11011	7.29E-01
5	s2.e112.p1 + s2.e091.p2	10101	11011	7.08E-01
6	s2.e111.p1 + s2.e094.p2	10111	11010	7.07E-01
7	s2.e121.p1 + s2.e118.p2	11101	11111	7.04E-01
8	s2.e120.p1 + s2.e121.p2	11111	11110	6.96E-01
9	s2.e111.p1 + s2.e091.p2	10101	11010	6.90E-01
10	s2.e111.p1 + s2.e121.p2	11111	11010	6.78E-01
⋮	⋮	⋮	⋮	⋮

Top ranking cases based on the weighted distance metric involve 4-missile launchers and several 2-missile launchers. Of the top 69 cases, 54 involve adjacent 4-missile launchers, and 15 involve a 4-missile launcher on the inboard pylon and a 2-missile launcher on the outboard pylon. For all of these cases except one, there is at least one missile on the outboard rail of the inboard composite store and at least one missile on the inboard rail of the outboard composite store. This places adjacent missiles is close proximity at the time of release, especially the missile fin tips. Of the top 16 cases (including nine of the top ten in the above table), all but two cases (ranks #2, and #13) exhibit two pairs of adjacent missiles: top and bottom outboard missiles on the inboard launcher, and top and bottom inboard missiles on the outboard one. For these cases involving two adjacent pairs, there are only 16 possible configurations. Fourteen of those figure into the top 16 list of the weighted distance metric. The remaining two configurations are contact cases (discussed above), with contact time rankings of 16 and 34. The fact that only 2 of the 16 possible cases involving two adjacent missiles pairs are contact cases is interesting and not intuitive.

V. Concluding Remarks

This paper presents sample results from a statistical analysis of jettisoned store scenarios. The value of the proposed new tool, named SAJeS, is that critical ejection configurations for complex stores can be rapidly and systematically identified, which is especially useful in the case of aerodynamically unstable stores where trajectories are unintuitive.

Of the 75,880 jettison configurations studied, 69 were identified as making store to store contact within one second of the simultaneous inboard and outboard composite store release. Critical cases and groups of cases which would warrant further review for safe separation clearance were also identified.

Acknowledgments

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References

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