Streamlining Store Separation Analysis with Missile Datcom and Aerodynamic Store Segmentation

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CSIR Aerospace Systems Impact Area

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Outline

- Background and overview
- Objectives
- Arnold Engineering Development Complex – AEDC-TR-73-87 Test Case
- Store Aerodynamics
- Results
- Conclusion

Background and Overview

- Aircraft/store integration
  - ❑ The process of integrating external stores, such as weapons, fuel tanks, electronics pod, or other equipment, onto an aircraft.
  - ❑ Ranging anywhere between 2.5 months to 4 years depending on complexity.

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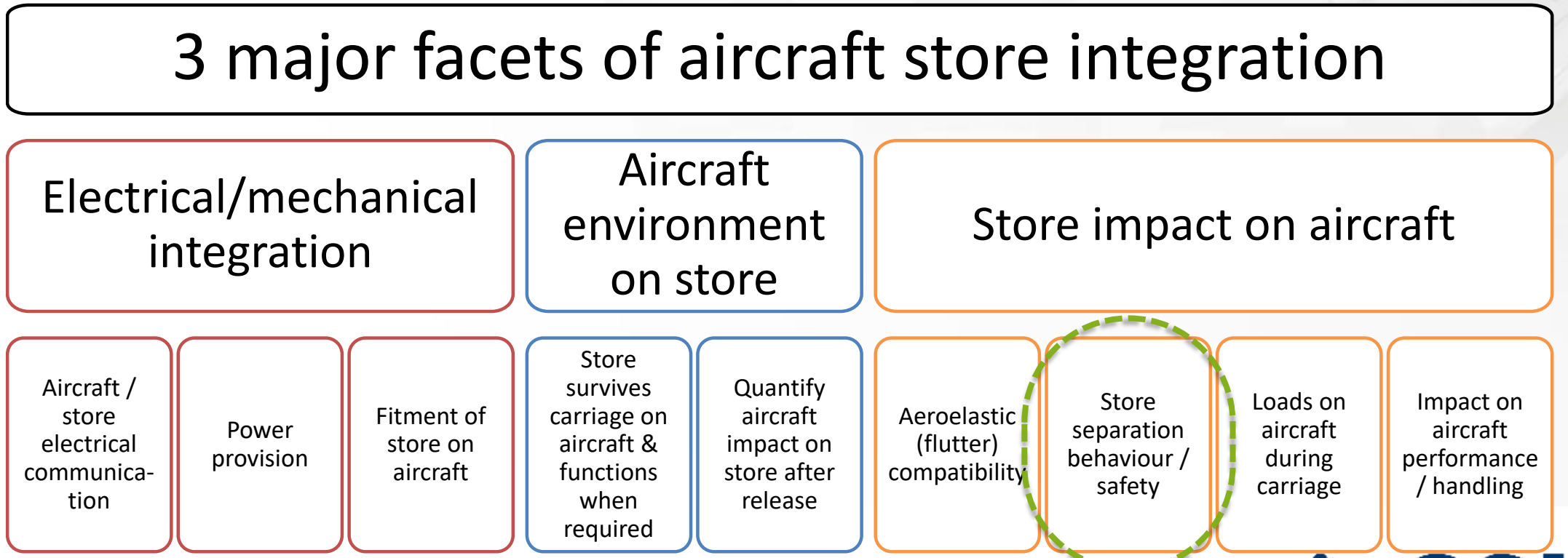
Background and Overview

- The key aspects of aircraft/store integration include (MIL-HDBK-1763):



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Background and Overview

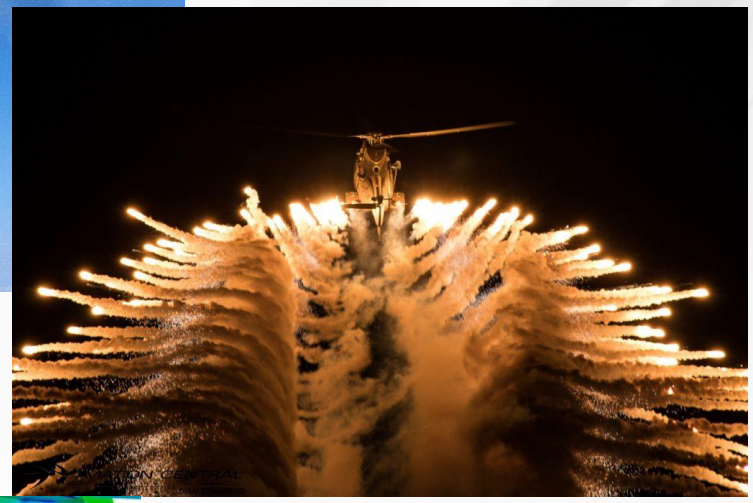
As defined in MIL-HDBK-1763

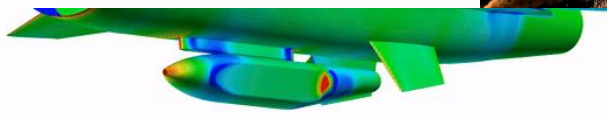
- **Separation**
  - ❑ The process of detaching or releasing external stores, such as missiles, bombs, or fuel tanks, from an aircraft during flight.
- **Safe separation**
  - ❑ The parting of store(s) from aircraft without
    - ✓ exceeding design limits of store or aircraft,
    - ✓ and without damage to,
    - ✓ contact with,
    - ✓ or unacceptable adverse effects

    on the aircraft, suspension equipment, or other store(s) both released and unreleased.

Alex Chenko on "Store Separation Lessons Learned"

- "Store Separation is a complex process that every new aircraft/weapon combination has to follow before the store is first released from the aircraft. There are numerous things that can go wrong with serious consequences to the aircraft and pilot."
- "The greatest mistake one can make is to try to hide/cover-up the mistake, and not learn any lessons in the process."





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Objective

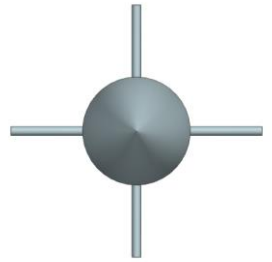
- Focus of the presentation is in the process taken in developing a methodology for subsonic flow store separation to quicky generate extensive segmented lookup tables using Missile Datcom to support the fast store trajectory calculation using an inhouse six-degree-of-freedom (6-dof) solver called ARUV.
  - ❑ Missile Datcom was used to estimate the aerodynamic properties of the store.
    - ➢ Missile Datcom is a widely used semi-empirical software tool for the analysis of aerodynamic properties of axisymmetric missiles and aircraft.

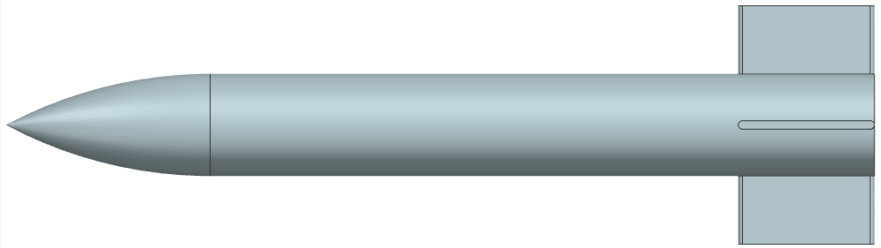
How does all these fit in the bigger picture?

- ❑ Aerodynamic properties of the store can, in this case, be used together with CFD flow-field and 6-dof solver to calculate store trajectories.

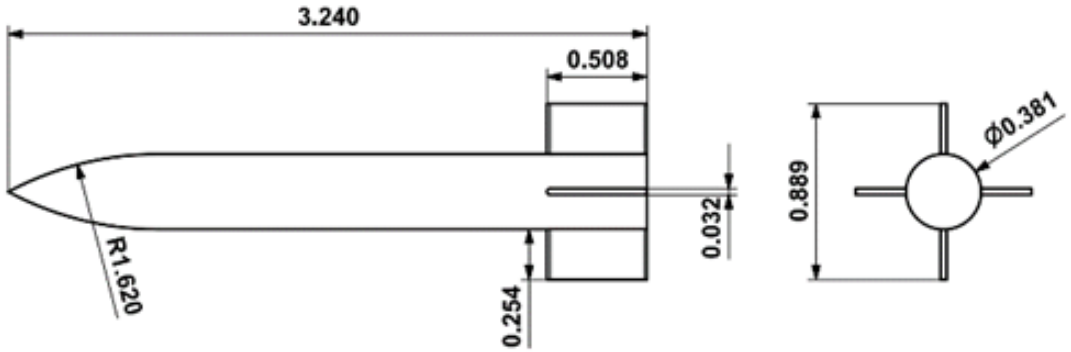
AEDC-TR-73-87 Test Case - Roberts and Myers

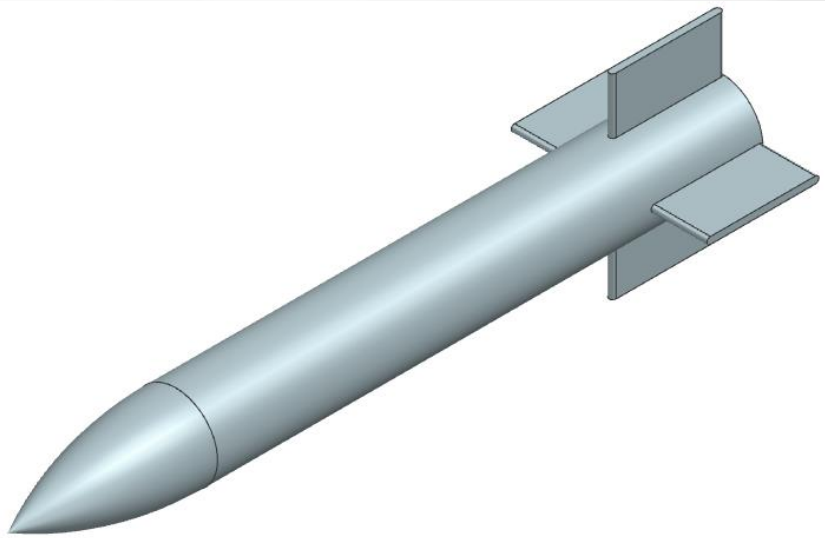
The proposed methodology was validated using the AEDC-TR-73-87 wind tunnel trajectory test cases conducted by Robert and Myers.





Full scale CAD model of the Large Force Finned (LFF) store model





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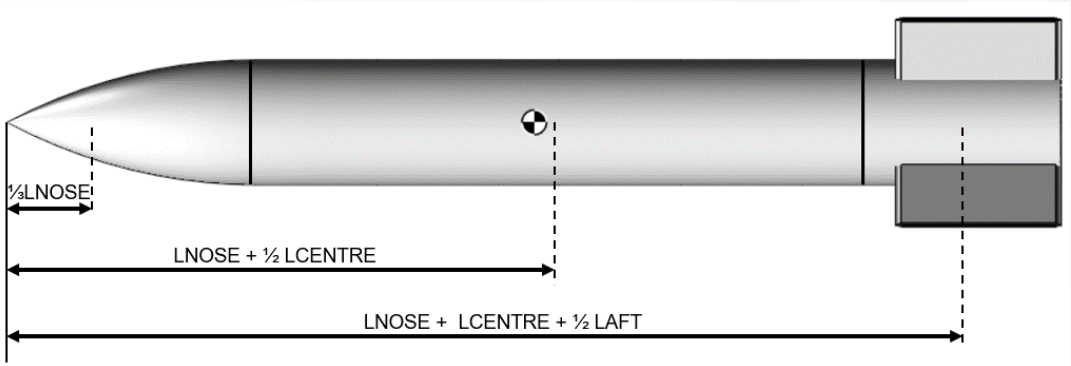
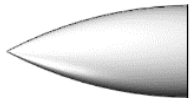
AEDC-TR-73-87 Test Case - Roberts and Myers

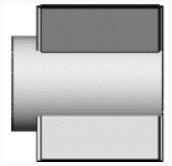
- Store segmentation – the Roberts and Myers store has been split into the nose cone, the centre body, and the aft body.





Nose Cone

Centre Body



Aft Body

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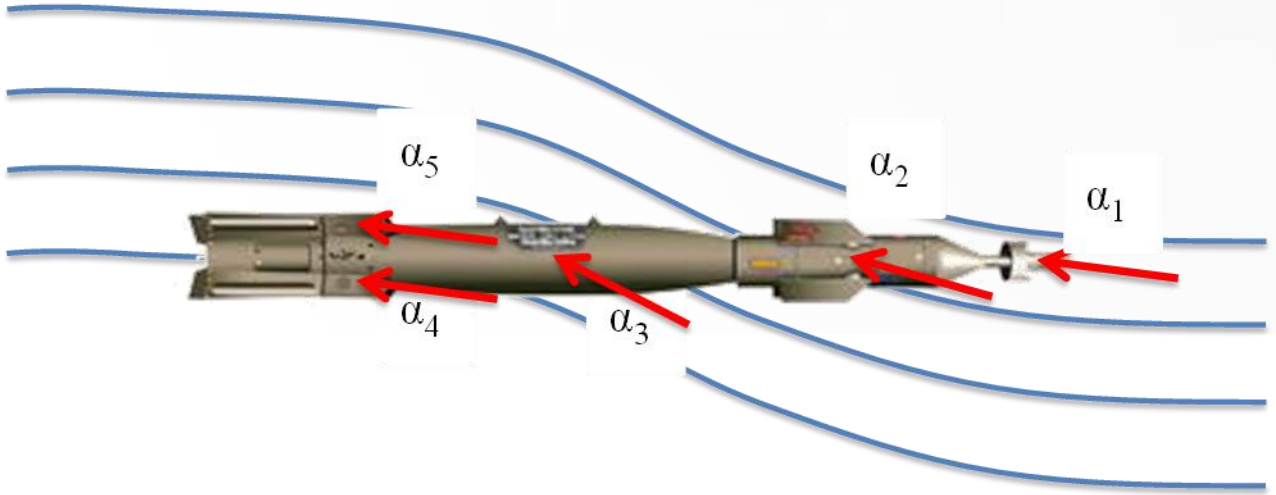
Store Aerodynamics

- Store aerodynamic database supplied by the store OEM (Starting point).
- Or use tools that can analyse high angle of attack (AOA) aerodynamics (e.g. Missile Datcom).

- Why segmented store?
  - ❑ Segmentation captures variation in aircraft flow field along length of the store
  - ❑ Also captures local AOA variations due to store dynamics – models damping effects



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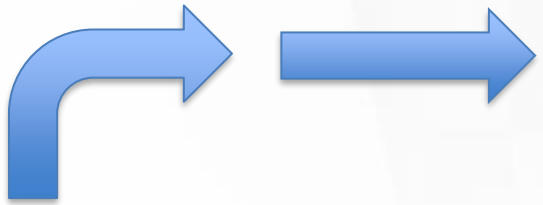
AEDC-TR-73-87 Test Case



Segment Designation Name	Segment Designation	Model Segment	X reference [m]
Aft Body	C = 1 – 2		2.934
Centre Body	B = 2 – 3		1.696
Nose Cone	A = 3		0.254

X Designation	Sub-Model Designation	Sub-Model	X termination [m]
Full Store LNOSE +LCENTRE+LAFT	1		3.2385
LNOSE+LCENTR	2		2.6305
LNOSE	3		0.762

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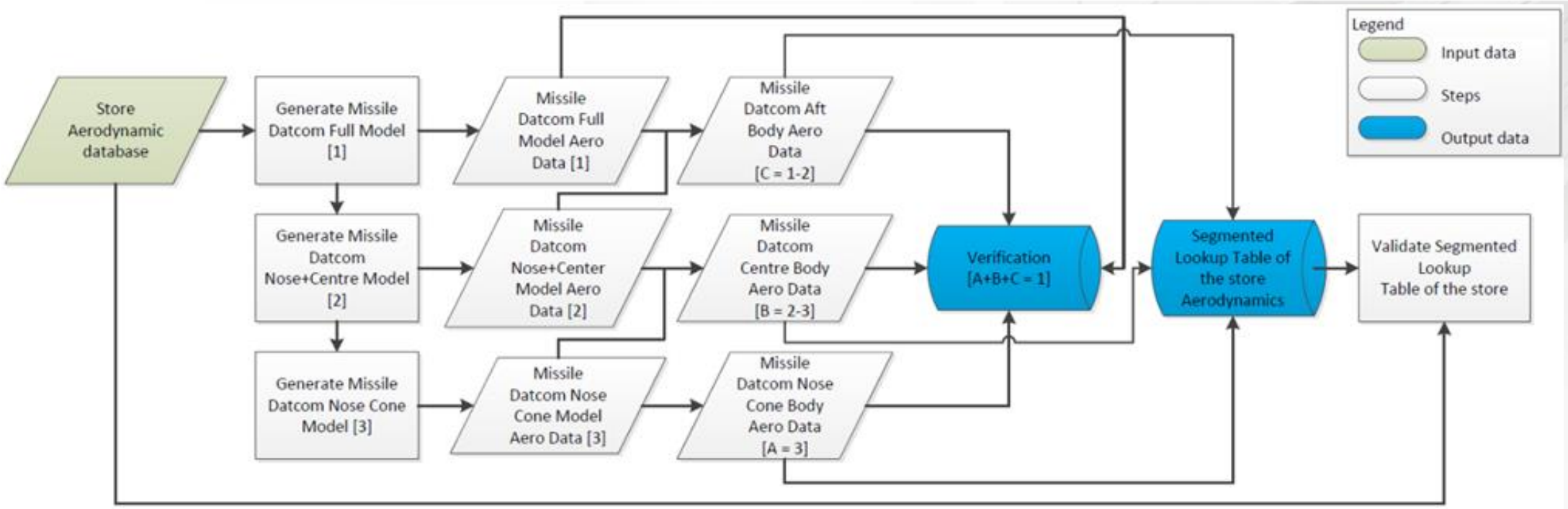
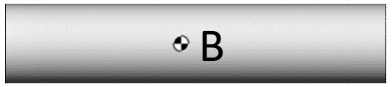
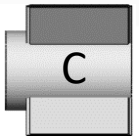
Store Segmented Lookup Table Generation Procedure







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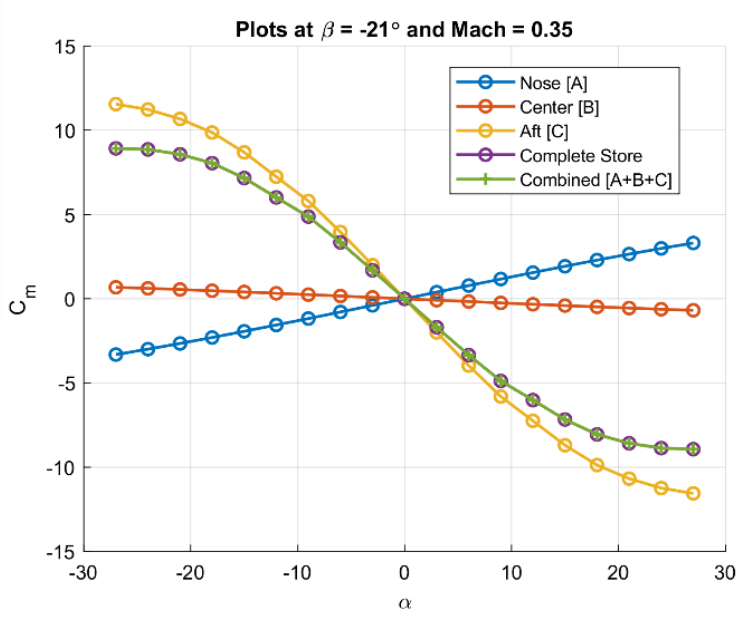
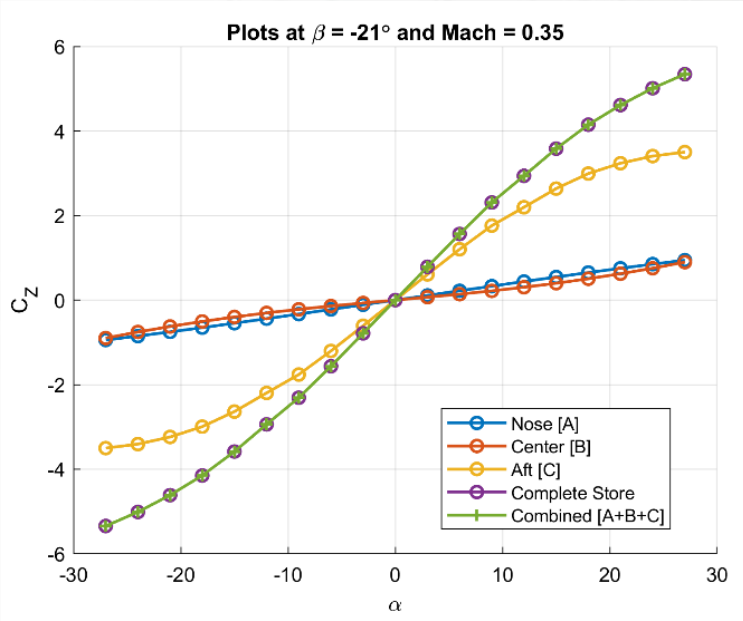
Results - Validation

- The individual behaviour of the store segment was analysed to confirm data validity
- The stability analysis showed that the store behaved as expected; for example, the data indicated that the store nose had a destabilising effect on the full store, while the aft body had a stabilising effect as expected.



a) Individual contribution C_m vs α plots



b) Individual contribution C_Z vs α plots

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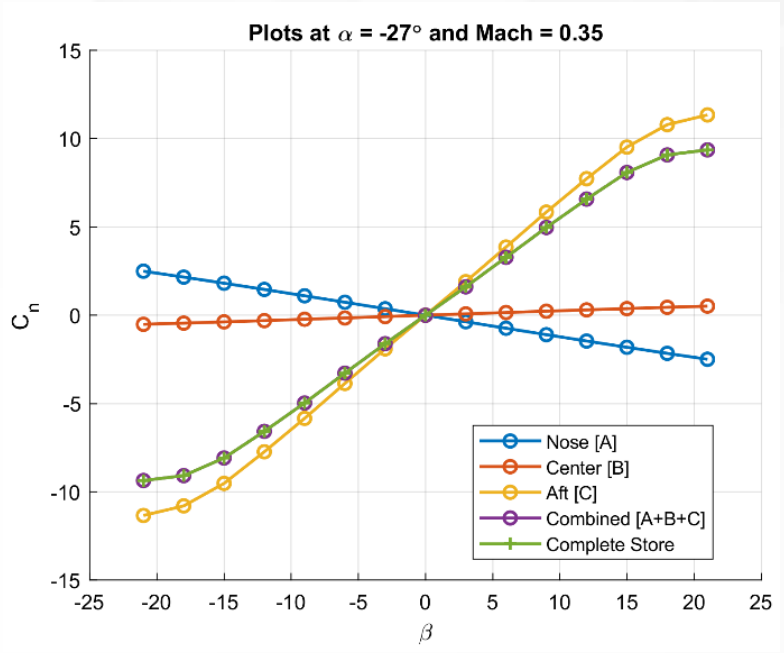
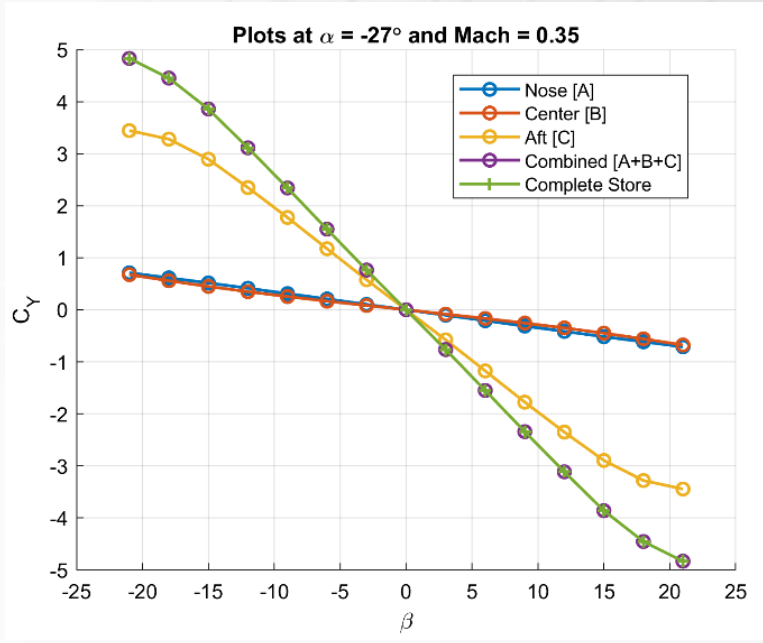
Results - Validation

- The individual store segments add up to the complete store.



a) Individual contribution C_n vs β plots



b) Individual contribution C_Y vs β plots

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Results - Verification

[A]+[B]+[C]; BETA = -21 and Mach = 0.35

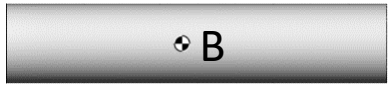
α	Cx	Cy	Cz	Cmx	Cmy	Cmz
-27.000	0.249	0.711	-0.944	0.000	-3.308	2.492
-24.000	0.257	0.733	-0.851	0.000	-2.988	2.576
-21.000	0.232	0.752	-0.752	0.000	-2.650	2.650
-18.000	0.247	0.769	-0.651	0.000	-2.296	2.713
-15.000	0.259	0.782	-0.546	0.000	-1.930	2.765
-12.000	0.268	0.792	-0.439	0.000	-1.554	2.807
-9.000	0.275	0.800	-0.330	0.000	-1.172	2.839
-6.000	0.279	0.806	-0.221	0.000	-0.784	2.862
-3.000	0.282	0.809	-0.110	0.000	-0.393	2.875
0.000	0.283	0.810	0.000	0.000	0.000	2.880
3.000	0.282	0.809	0.110	0.000	0.393	2.875
6.000	0.279	0.806	0.221	0.000	0.784	2.862
9.000	0.275	0.800	0.330	0.000	1.172	2.839
12.000	0.268	0.792	0.439	0.000	1.554	2.807
15.000	0.259	0.782	0.546	0.000	1.930	2.765
18.000	0.247	0.769	0.651	0.000	2.296	2.713
21.000	0.232	0.752	0.752	0.000	2.650	2.650
24.000	0.257	0.733	0.851	0.000	2.988	2.576
27.000	0.249	0.711	0.944	0.000	3.308	2.492

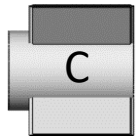
+

α	Cx	Cy	Cz	Cmx	Cmy	Cmz
-27.000	-0.065	0.676	-0.898	0.000	0.685	-0.516
-24.000	-0.068	0.651	-0.754	0.000	0.621	-0.536
-21.000	-0.129	0.624	-0.624	0.000	0.553	-0.553
-18.000	-0.118	0.597	-0.505	0.000	0.481	-0.568
-15.000	-0.110	0.572	-0.399	0.000	0.405	-0.580
-12.000	-0.105	0.549	-0.304	0.000	0.327	-0.591
-9.000	-0.101	0.529	-0.218	0.000	0.247	-0.598
-6.000	-0.099	0.514	-0.140	0.000	0.166	-0.604
-3.000	-0.098	0.504	-0.069	0.000	0.083	-0.607
0.000	-0.098	0.501	0.000	0.000	0.000	-0.609
3.000	-0.098	0.504	0.069	0.000	-0.083	-0.607
6.000	-0.099	0.514	0.140	0.000	-0.166	-0.604
9.000	-0.101	0.529	0.218	0.000	-0.247	-0.598
12.000	-0.105	0.549	0.304	0.000	-0.327	-0.591
15.000	-0.110	0.572	0.399	0.000	-0.405	-0.580
18.000	-0.118	0.597	0.505	0.000	-0.481	-0.568
21.000	-0.129	0.624	0.624	0.000	-0.553	-0.553
24.000	-0.068	0.651	0.754	0.000	-0.621	-0.536
27.000	-0.065	0.676	0.898	0.000	-0.685	-0.516

+

α	Cx	Cy	Cz	Cmx	Cmy	Cmz
-27.000	0.044	3.444	-3.501	-0.342	11.559	-11.343
-24.000	0.045	3.319	-3.406	-0.133	11.242	-10.943
-21.000	0.031	3.237	-3.237	0.000	10.682	-10.682
-18.000	0.035	3.203	-2.993	0.082	9.874	-10.580
-15.000	0.038	3.263	-2.637	0.110	8.698	-10.782
-12.000	0.041	3.360	-2.196	0.110	7.246	-11.101
-9.000	0.041	3.312	-1.761	0.157	5.806	-10.949
-6.000	0.043	3.415	-1.203	0.117	3.965	-11.289
-3.000	0.043	3.500	-0.607	0.066	2.000	-11.565
0.000	0.044	3.536	0.000	0.000	0.000	-11.684
3.000	0.043	3.500	0.607	-0.066	-2.000	-11.565
6.000	0.043	3.415	1.203	-0.117	-3.965	-11.289
9.000	0.041	3.312	1.761	-0.157	-5.806	-10.949
12.000	0.041	3.360	2.196	-0.110	-7.246	-11.101
15.000	0.038	3.263	2.637	-0.110	-8.698	-10.782
18.000	0.035	3.203	2.993	-0.082	-9.874	-10.580
21.000	0.031	3.237	3.237	0.000	-10.682	-10.682
24.000	0.045	3.319	3.406	0.133	-11.242	-10.943
27.000	0.044	3.444	3.501	0.342	-11.559	-11.343





Results - Verification

[A]+[B]+[C] = [1]; BETA = -21 and Mach = 0.35

α	Cx	Cy	Cz	Cmx	Cmy	Cmz
-27.000	0.228	4.831	-5.343	-0.342	8.936	-9.367
-24.000	0.234	4.703	-5.011	-0.133	8.875	-8.903
-21.000	0.134	4.613	-4.613	0.000	8.585	-8.585
-18.000	0.164	4.569	-4.149	0.082	8.059	-8.435
-15.000	0.187	4.617	-3.582	0.110	7.173	-8.597
-12.000	0.204	4.701	-2.939	0.110	6.019	-8.885
-9.000	0.215	4.641	-2.309	0.157	4.881	-8.708
-6.000	0.223	4.735	-1.564	0.117	3.347	-9.031
-3.000	0.227	4.813	-0.786	0.066	1.690	-9.297
0.000	0.229	4.847	0.000	0.000	0.000	-9.413
3.000	0.227	4.813	0.786	-0.066	-1.690	-9.297
6.000	0.223	4.735	1.564	-0.117	-3.347	-9.031
9.000	0.215	4.641	2.309	-0.157	-4.881	-8.708
12.000	0.204	4.701	2.939	-0.110	-6.019	-8.885
15.000	0.187	4.617	3.582	-0.110	-7.173	-8.597
18.000	0.164	4.569	4.149	-0.082	-8.059	-8.435
21.000	0.134	4.613	4.613	0.000	-8.585	-8.585
24.000	0.234	4.703	5.011	0.133	-8.875	-8.903
27.000	0.228	4.831	5.343	0.342	-8.936	-9.367

=

α	Cx	Cy	Cz	Cmx	Cmy	Cmz
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-21.000	0.134	4.613	-4.613	0.000	8.585	-8.585
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-15.000	0.187	4.617	-3.582	0.110	7.173	-8.597
-12.000	0.204	4.701	-2.939	0.110	6.019	-8.885
-9.000	0.215	4.641	-2.309	0.157	4.881	-8.708
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-3.000	0.227	4.813	-0.786	0.066	1.690	-9.297
0.000	0.229	4.847	0.000	0.000	0.000	-9.413
3.000	0.227	4.813	0.786	-0.066	-1.690	-9.297
6.000	0.223	4.735	1.564	-0.117	-3.347	-9.031
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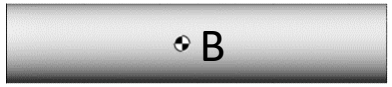
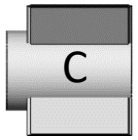
18.000	0.164	4.569	4.149	-0.082	-8.059	-8.435
21.000	0.134	4.613	4.613	0.000	-8.585	-8.585
24.000	0.234	4.703	5.011	0.133	-8.875	-8.903
27.000	0.228	4.831	5.343	0.342	-8.936	-9.367





Results - Verification

Difference = [A]+[B]+[C] - 1; **BETA = -21 and Mach = 0.35**

α	Cx	Cy	Cz	Cmx	Cmy	Cmz
-27.000	0.000	0.000	0.000	0.000	0.000	0.000
-24.000	0.000	0.000	0.000	0.000	0.000	0.000
-21.000	0.000	0.000	0.000	0.000	0.000	0.000
-18.000	0.000	0.000	0.000	0.000	0.000	0.000
-15.000	0.000	0.000	0.000	0.000	0.000	0.000
-12.000	0.000	0.000	0.000	0.000	0.000	0.000
-9.000	0.000	0.000	0.000	0.000	0.000	0.000
-6.000	0.000	0.000	0.000	0.000	0.000	0.000
-3.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000
3.000	0.000	0.000	0.000	0.000	0.000	0.000
6.000	0.000	0.000	0.000	0.000	0.000	0.000
9.000	0.000	0.000	0.000	0.000	0.000	0.000
12.000	0.000	0.000	0.000	0.000	0.000	0.000
15.000	0.000	0.000	0.000	0.000	0.000	0.000
18.000	0.000	0.000	0.000	0.000	0.000	0.000
21.000	0.000	0.000	0.000	0.000	0.000	0.000
24.000	0.000	0.000	0.000	0.000	0.000	0.000
27.000	0.000	0.000	0.000	0.000	0.000	0.000

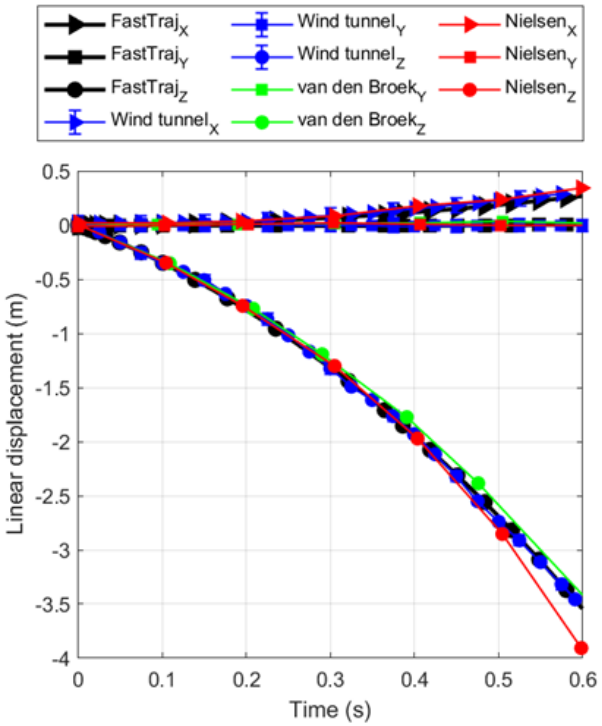
A

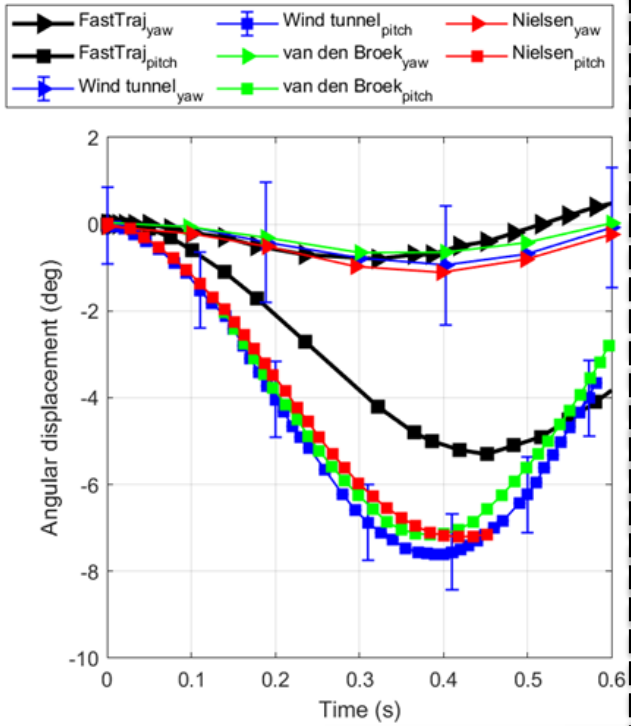
B

C

Results – Trajectory – Non-Segmented Store

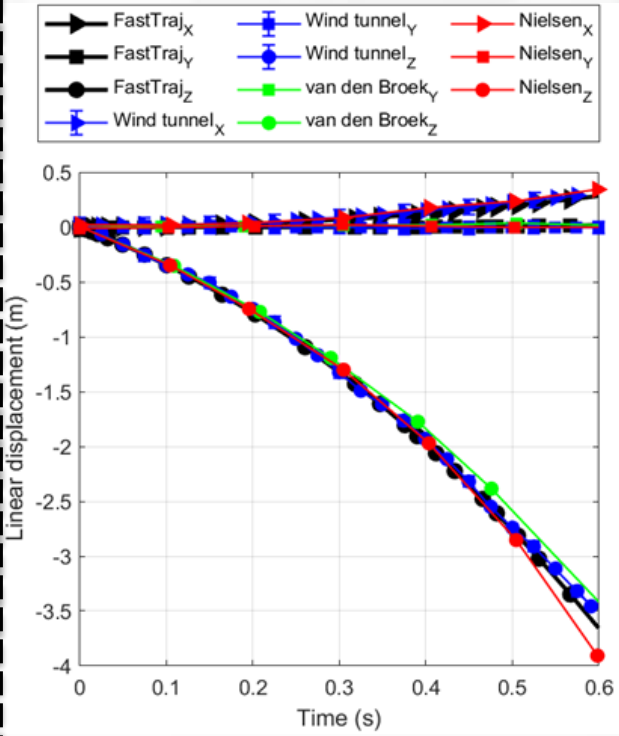
Non-Segmented Store

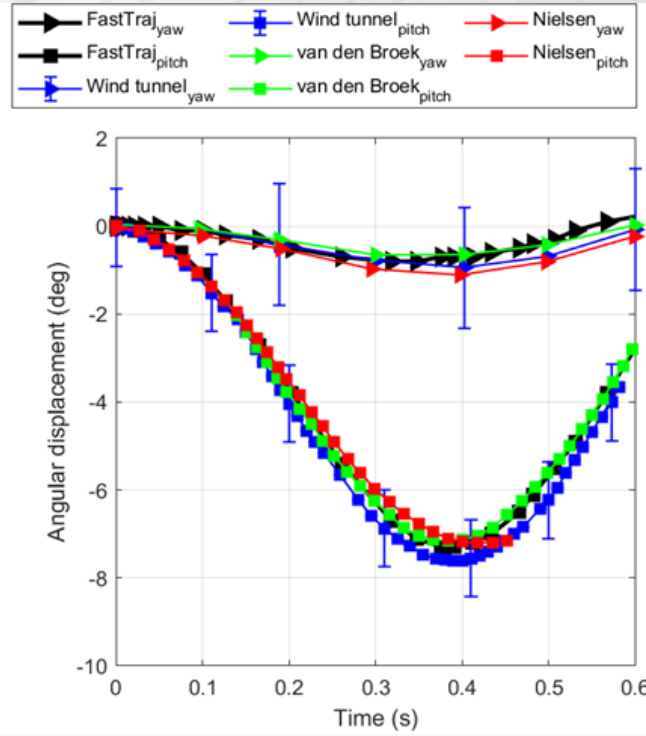




- The store angular displacement is not correctly captured for a non-segmented store.

Segmented Store





- The store angular displacement is correctly captured for a segmented store.

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Conclusion

The store trajectories were compared to wind tunnel results. Missile Datcom was used as a tool to facilitate the store segmentation. And the conclusions are as follows:

- The differences between the trajectories of the segmented and non-segmented models showed the importance of capturing the changes in the aircraft flow field along the length of the store.
- The segmented model matched closely with the wind tunnel results when compared to the non-segmented model.
- This result emphasises the need to segment the aerodynamics look-up table to better capture the store's angular dynamics as the effect of the flow field variations along the length of the store are significant.


Thank you.