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Working Paper 1439-12

Modal Identification from Sköll flight tests

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1.0 INTRODUCTION

Modal identification was performed on flight test data using the Curve Fitting Frequency Domain Decomposition (CFDD) method.[1] The emphasis is to identify aeroelastic modes rather than rigid body modes. Consequently, the aeroelastic short period mode was identified in addition to several higher frequency aeroelastic modes. All of the modes identified reflect complex-valued aeroelastic modes, as opposed to real-valued dry structural modes. The following flights were used for identification.

- Sköll Flight 3: 20 m/s flight condition. Data delivered on 7/2/2015
- Sköll Flight 4: 30 m/s flight condition. Data delivered on 7/12/2015.[2]

2.0 SKÖLL FLIGHT 3

A data segment was used where pitch excitation was present. Aeroelastic Short Period, SWB1, AWB1 and SWT1 modes were identified.

Table 1: Data Files

	Filenames
Data	C:\Users\cschulze\Toolboxes\MIST\trunk\demoInterface\CFDD_MatlabInterface\skoll_flight03_2015_07_02_MIST_data.mat
Sensor Locations	C:\Users\bdanowsky\Desktop\MIST_Skoll_1\Skoll_senslocs.mat
Interface	C:\Users\bdanowsky\Documents\My Stuff\1439 - PAAW\matlab\MIST_Skoll_1\MIST_Interface_skoll_flight03_2015_07_02_BPD.mat

Table 2: Sensor Information (sensors used highlighted in green)

Signal	x	y	z	Sensor Orientation	Sensor Connections
accel_cf	-15.55	0.000E+00	0.000E+00	Z+	3,5
accel_cr	18.00	0.000E+00	0.000E+00	Z+	4,6
accel_lf	21.04	-56.24	0.000E+00	Z+	4
accel_lr	23.62	-55.20	0.000E+00	Z+	
accel_rf	21.04	56.24	0.000E+00	Z+	6
accel_rr	23.62	55.20	0.000E+00	Z+	

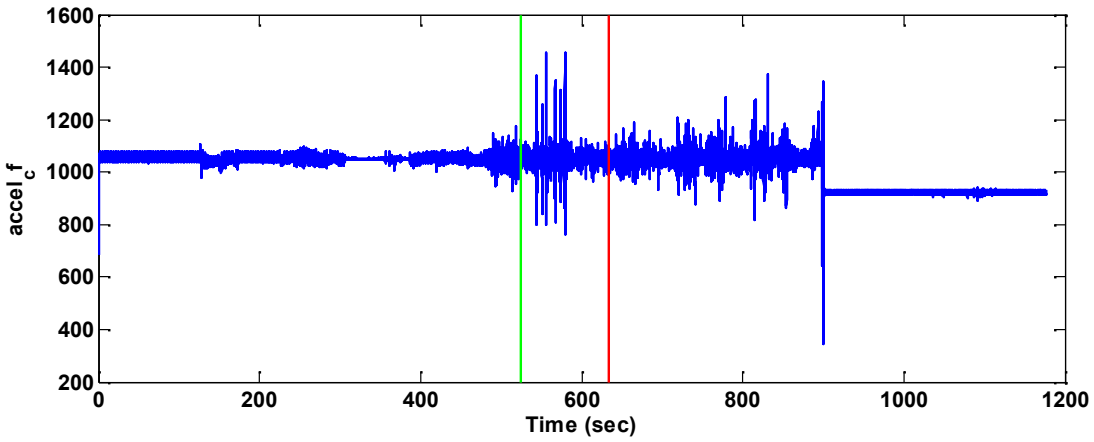

Figure 1: Time History - accel_cf

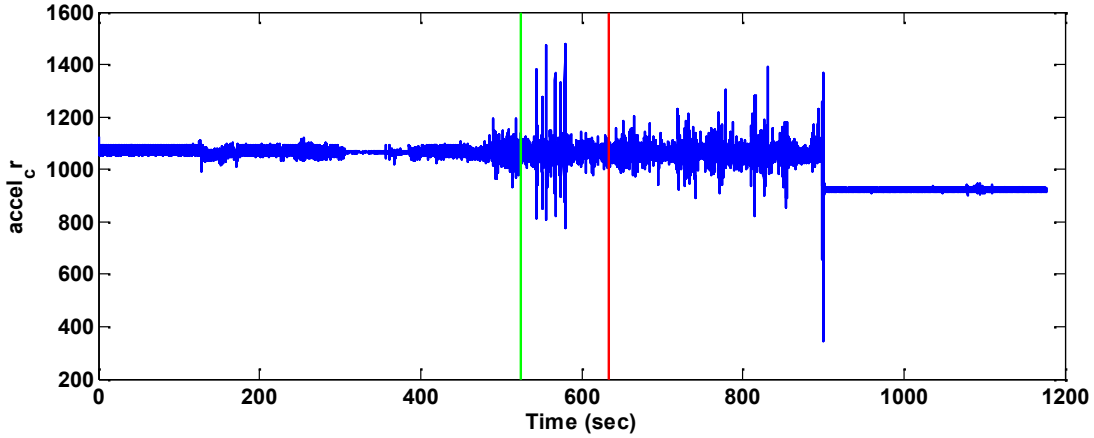

Figure 2: Time History - accel_cr

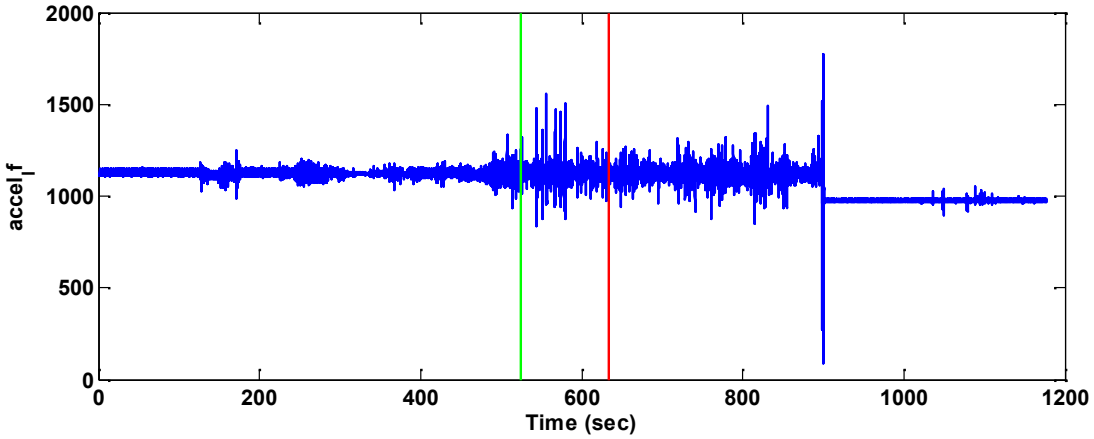

Figure 3: Time History - accel_lf

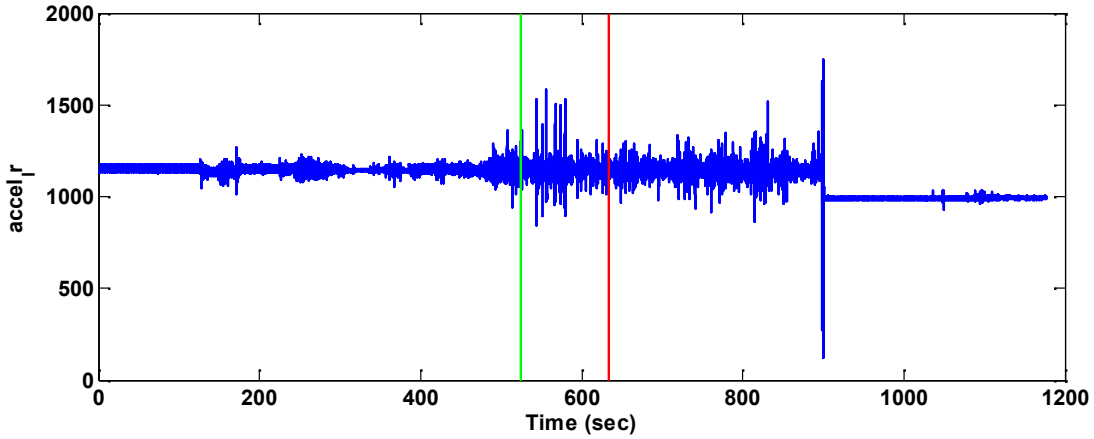

Figure 4: Time History - accel_lr

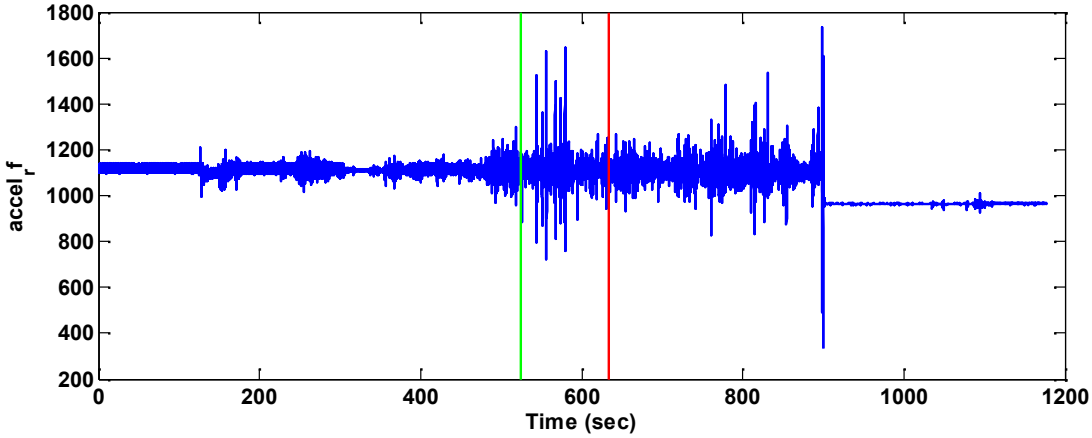

Figure 5: Time History - accel_rf

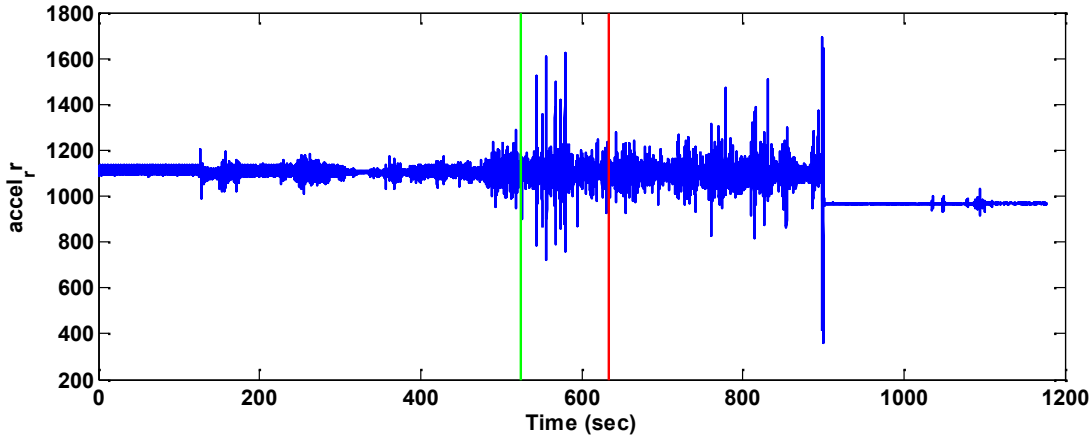

Figure 6: Time History - accel_rr

Table 3: CFDD Settings

	Value
Start time (sec)	523.80
End time (sec)	633.00
Window size (power of 2)	8.00
Window overlap (%)	5.000E-03
Low frequency bound (rad/s)	1.00
High frequency bound (rad/s)	200.00
Automatic peak selection	On

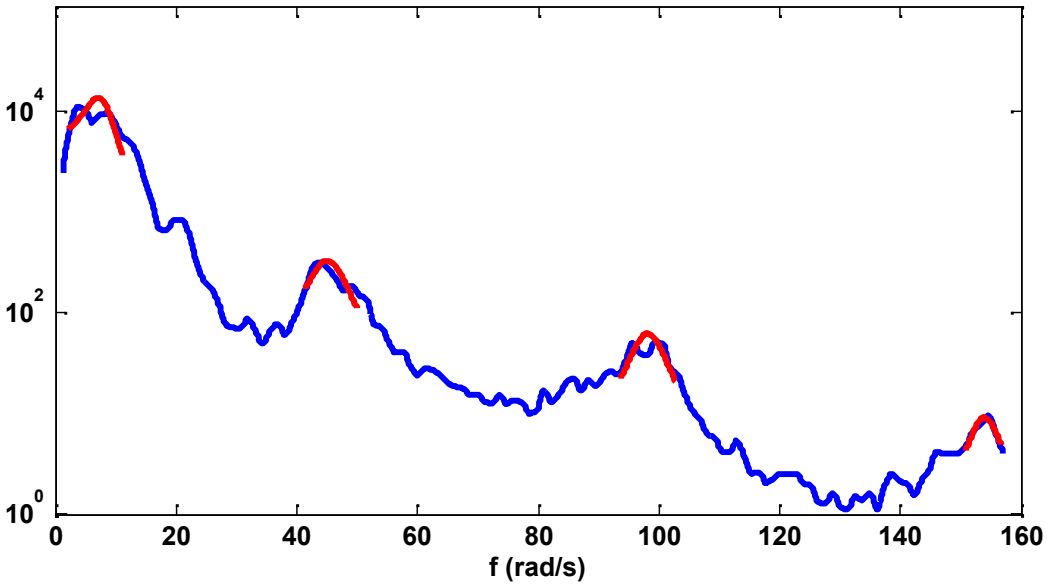

Figure 7: Singular Value Profile

Table 4: Identified Modes

Frequency (rad/s)	Damping
8.21	0.354
45.36	8.130E-02
98.28	3.391E-02
154.02	1.911E-02

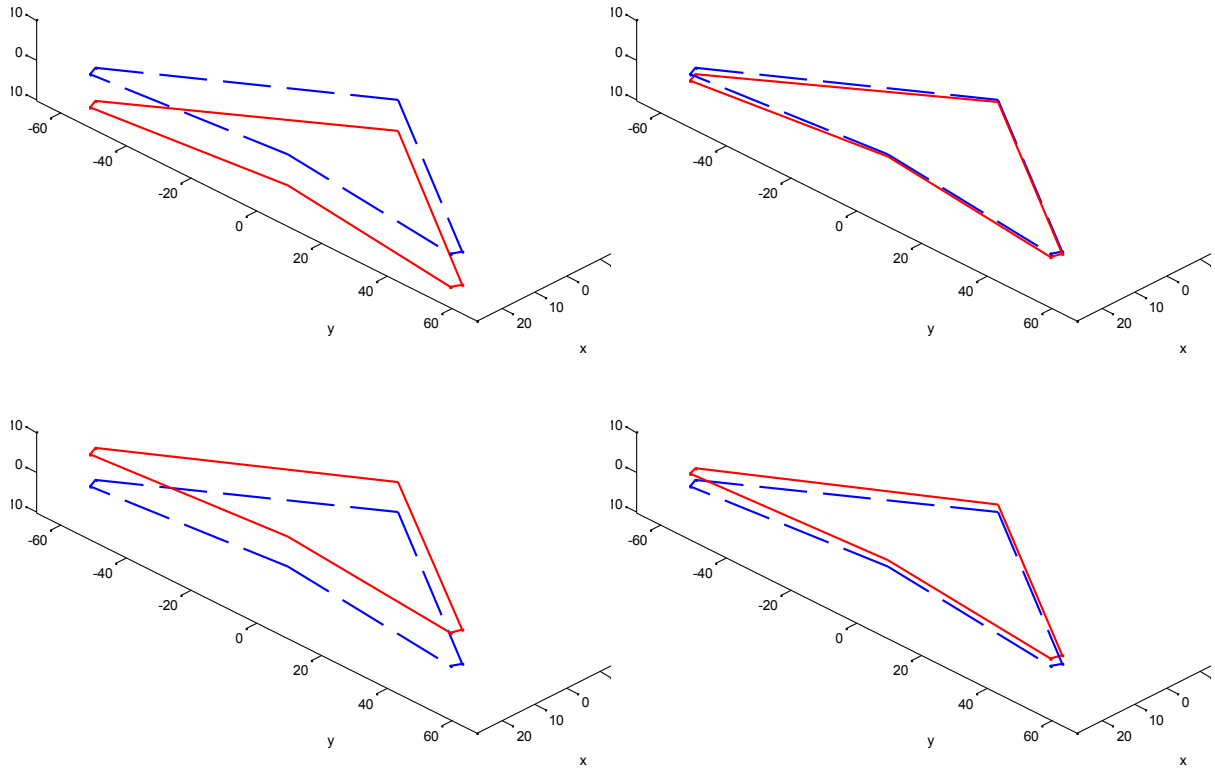

Figure 8: ID'd Shape, Mode 1: [0.3537, 8.208]

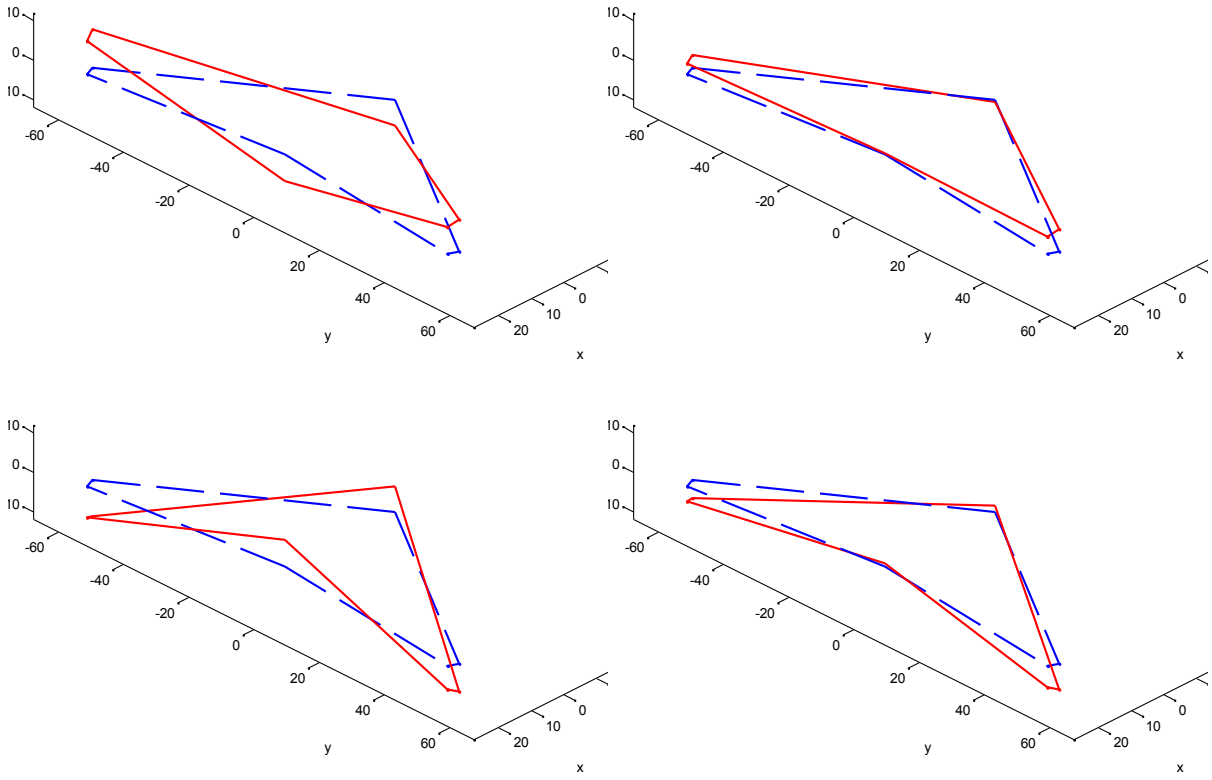

Figure 9: ID'd Shape, Mode 2: [0.0813, 45.36]

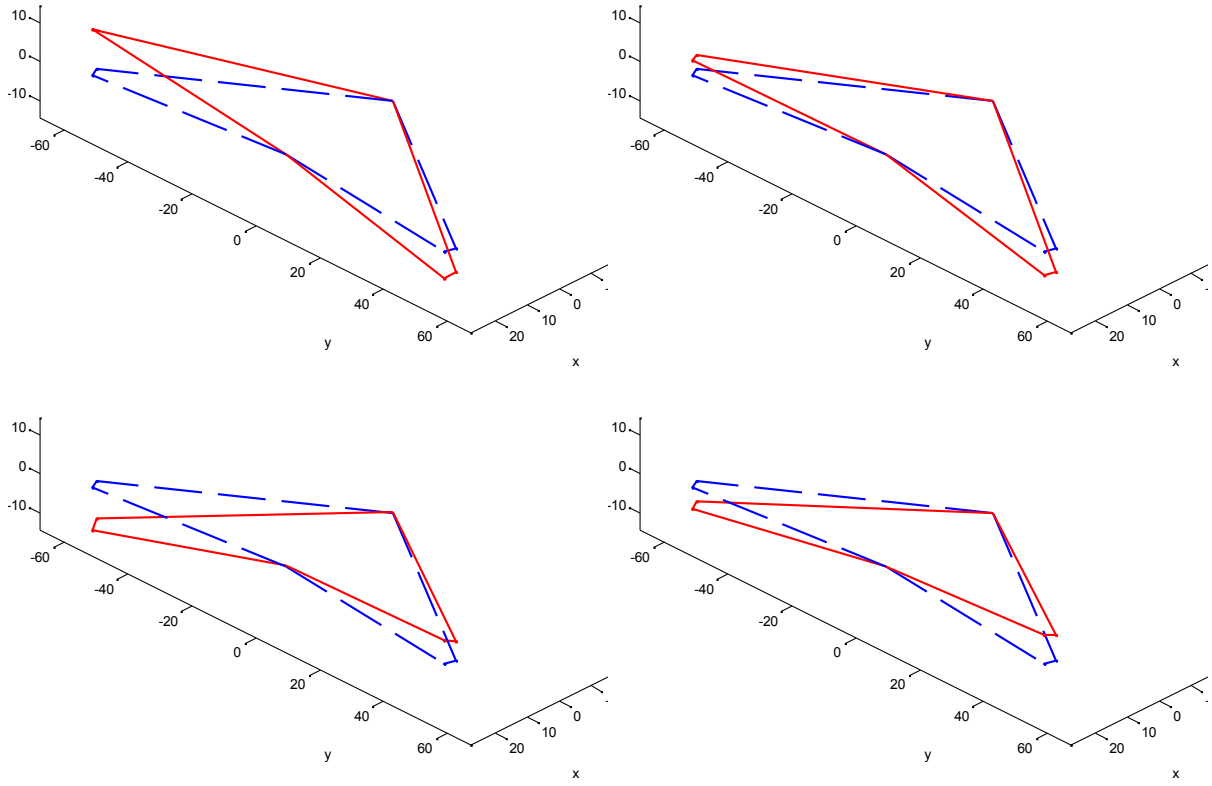

Figure 10: ID'd Shape, Mode 3: [0.03391, 98.28]

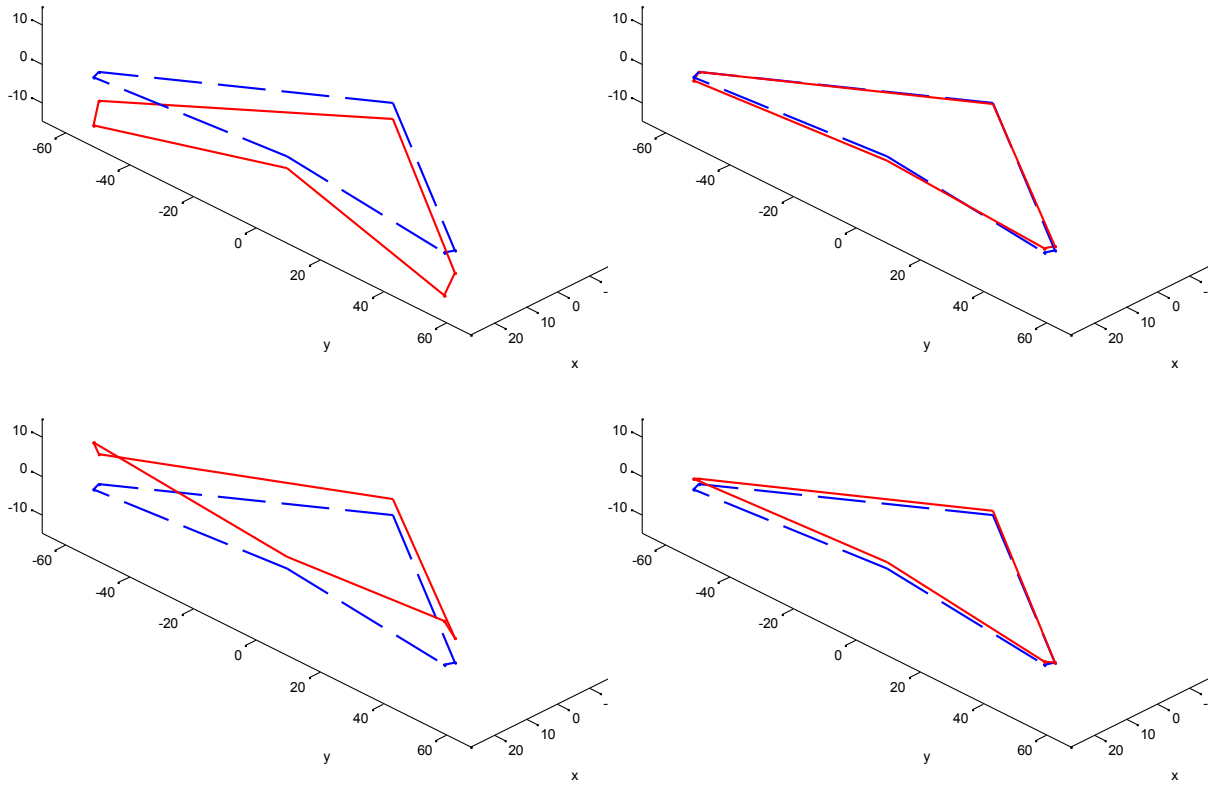

Figure 11: ID'd Shape, Mode 4: [0.01911, 154]

3.0 SKÖLL FLIGHT 4

A data segment was used where pitch excitation was present. Aeroelastic short period, SWB1, AWB1, SWT1, and AWT1 modes were identified.

Table 5: Data Files

	Filenames
Data	C:\Users\bdanowsky\Documents\My Stuff\1439 - PAAW\matlab\MIST_Skoll_Flight4\skoll_flight04_MIST.mat
Sensor Locations	C:\Users\bdanowsky\Documents\My Stuff\1439 - PAAW\matlab\MIST_Skoll_Flight4\Skoll_senslocs.mat
Interface	C:\Users\bdanowsky\Documents\My Stuff\1439 - PAAW\matlab\MIST_Skoll_Flight4\ID_skoll4_pitch_excite_2.mat

Table 6: Sensor Information (sensors used highlighted in green)

Signal	x	y	z	Sensor Orientation	Sensor Connections
accel_cf	-15.55	0.000E+00	0.000E+00	Z+	3,5,2
accel_cr	18.00	0.000E+00	0.000E+00	Z+	4,6
accel_lf	21.04	-56.24	0.000E+00	Z+	4
accel_lr	23.62	-55.20	0.000E+00	Z+	
accel_rf	21.04	56.24	0.000E+00	Z+	6
accel_rr	23.62	55.20	0.000E+00	Z+	

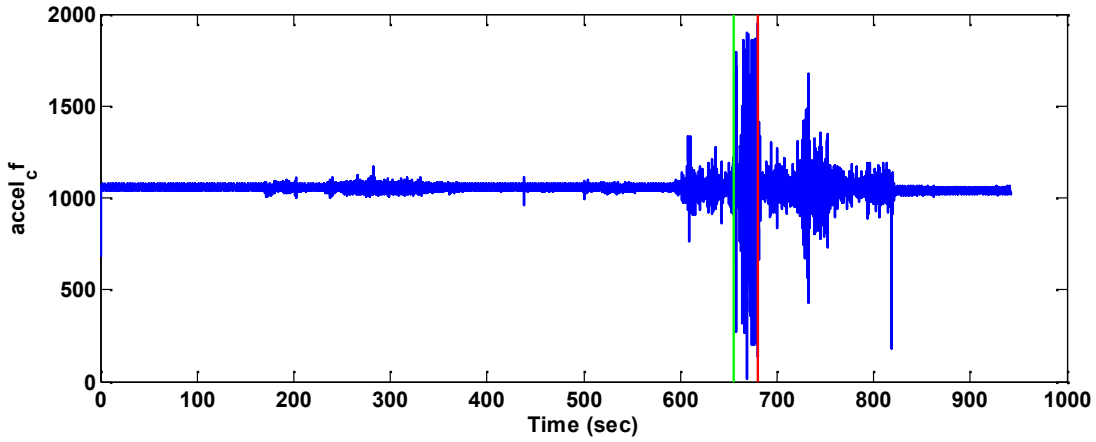

Figure 12: Time History - accel_cf

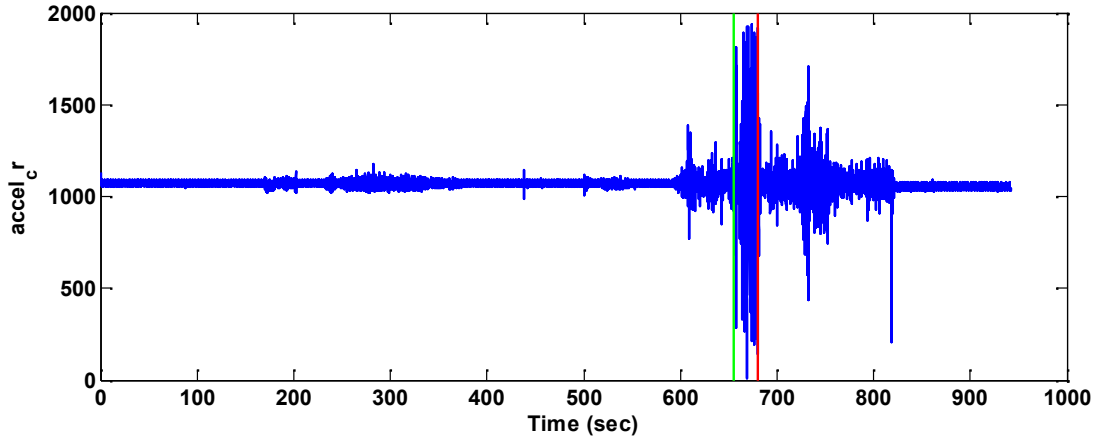

Figure 13: Time History - accel_cr

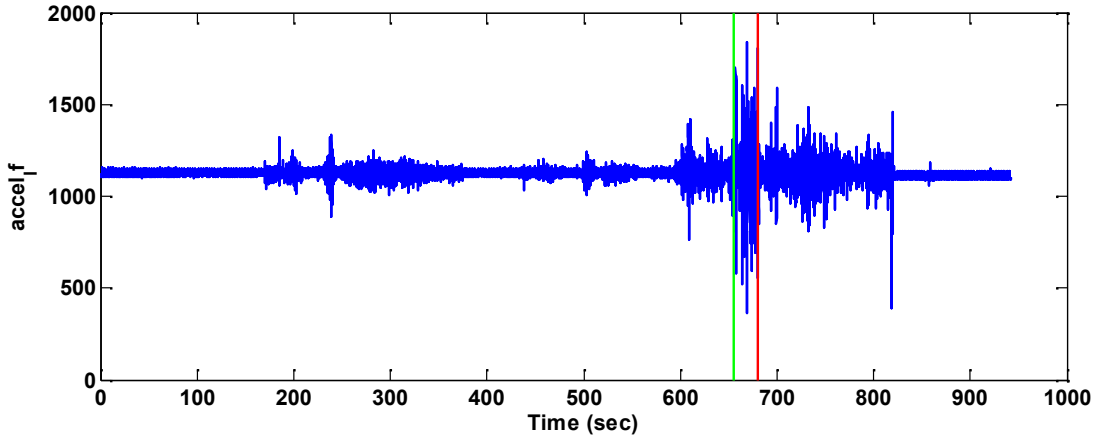

Figure 14: Time History - accel_lf

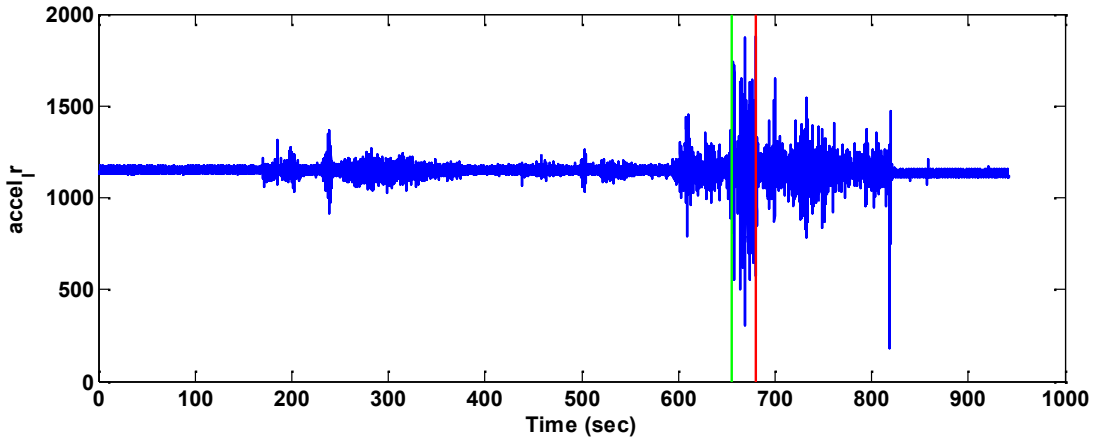

Figure 15: Time History - accel_lr

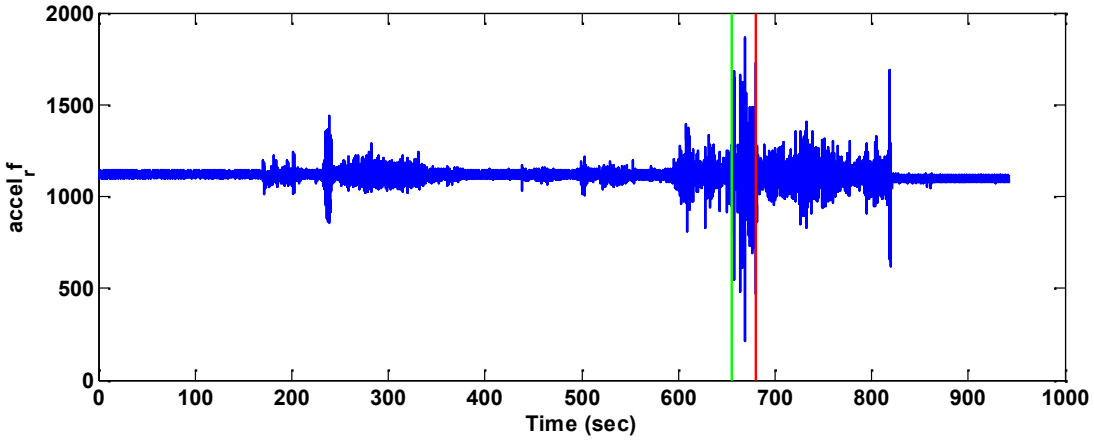

Figure 16: Time History - accel_rf

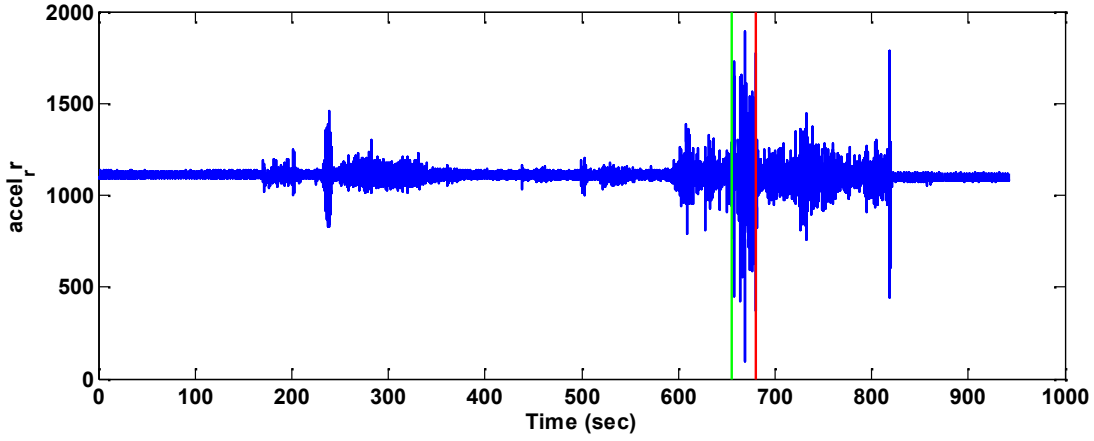

Figure 17: Time History - accel_rr

Table 7: CFDD Settings

	Value
Start time (sec)	655.00
End time (sec)	680.00

Window size (power of 2)	8.00
Window overlap (%)	20.00
Low frequency bound (rad/s)	0.100
High frequency bound (rad/s)	200.00
Automatic peak selection	On

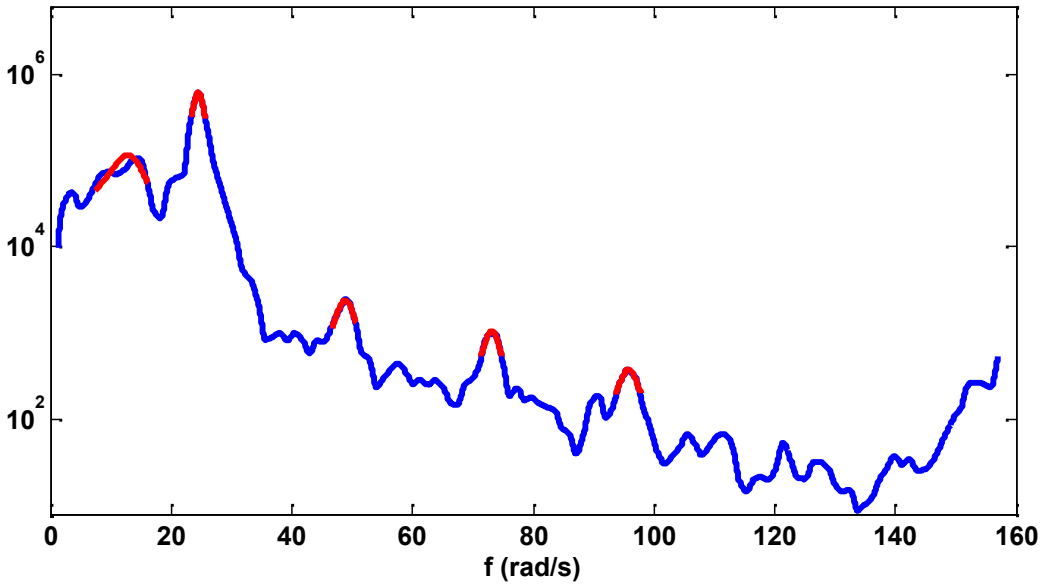

Figure 18: Singular Value Profile

Table 8: Identified Modes

Frequency (rad/s)	Damping
24.58	4.789E-02
13.72	0.242
48.93	4.078E-02
73.17	2.384E-02
95.85	2.235E-02

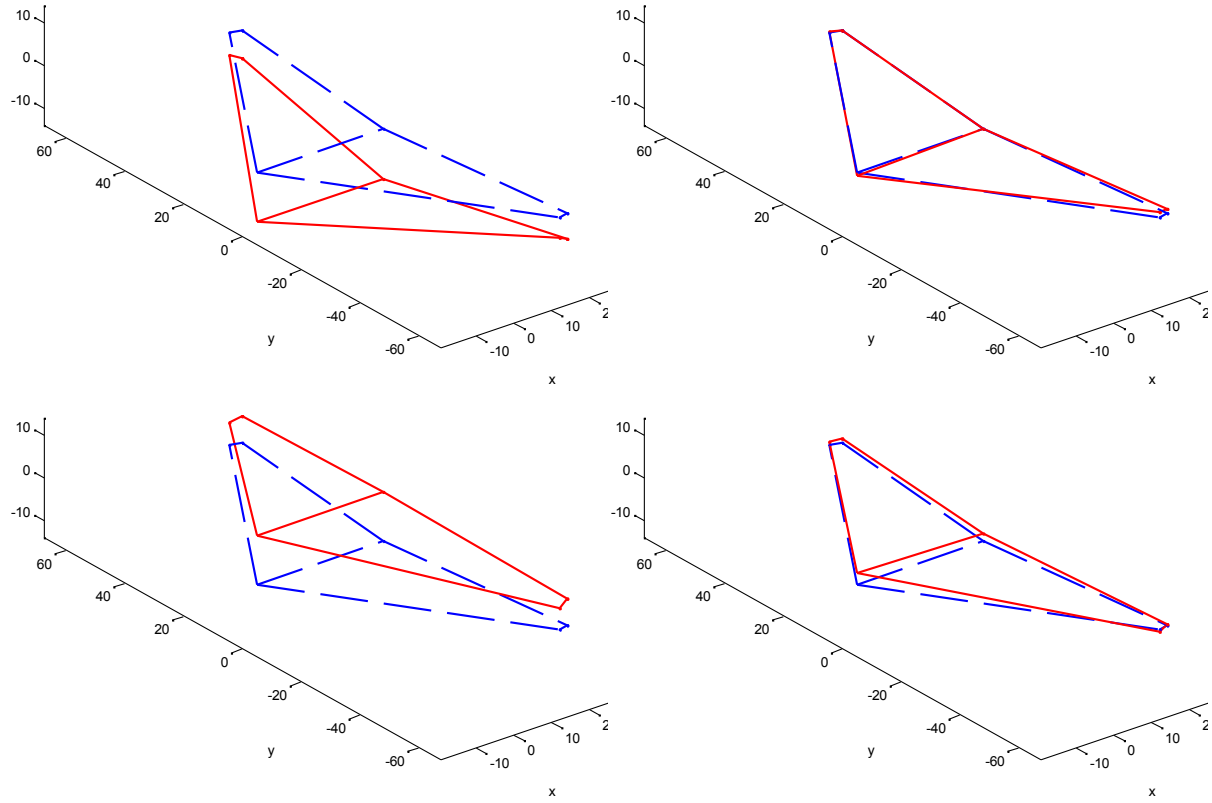

Figure 19: ID'd Shape, Mode 1: [0.04789, 24.58]

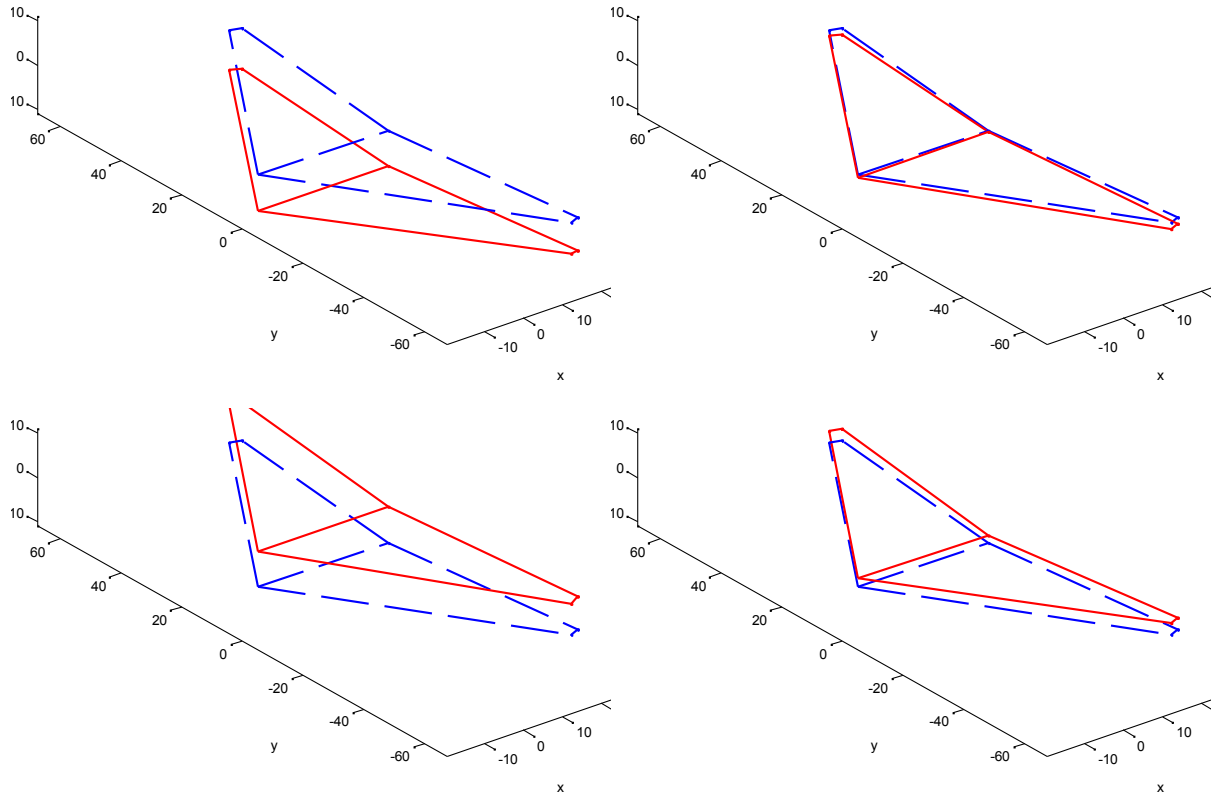

Figure 20: ID'd Shape, Mode 2: [0.2419, 13.72]

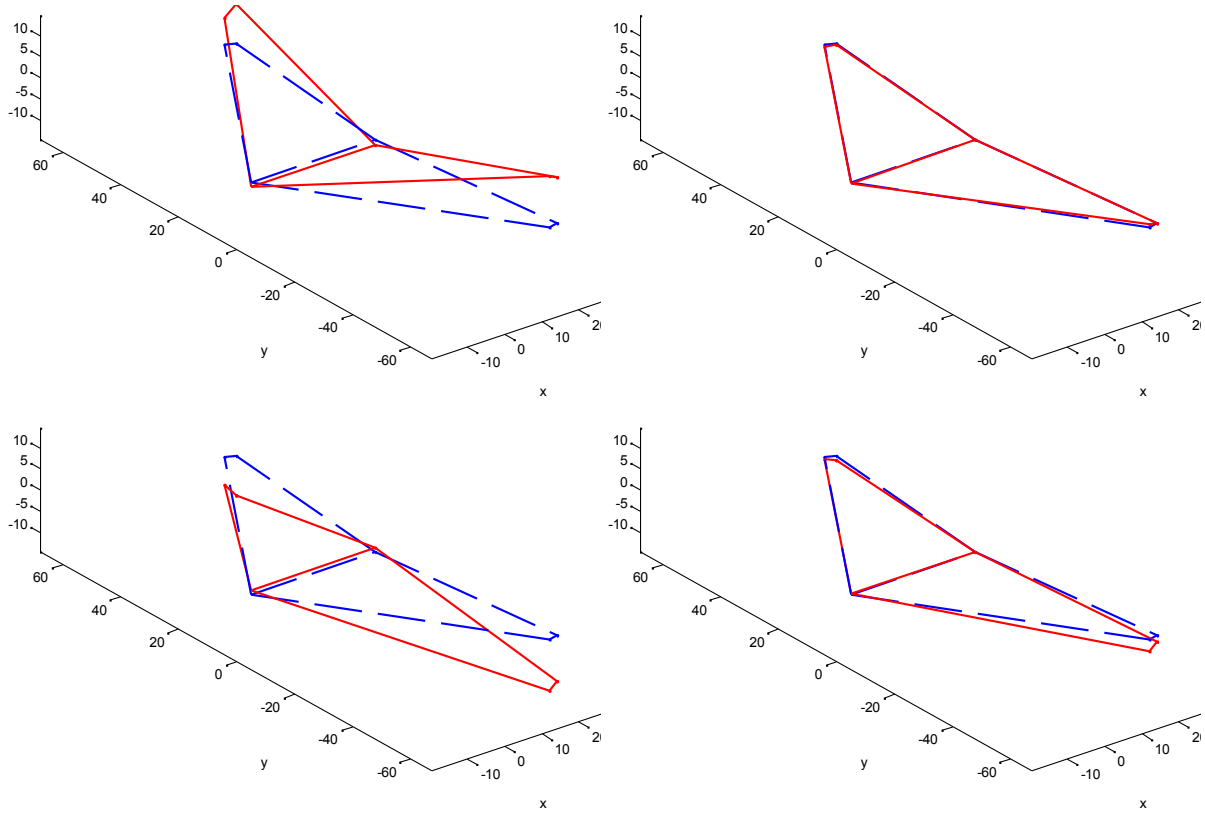

Figure 21: ID'd Shape, Mode 3: [0.04078, 48.93]

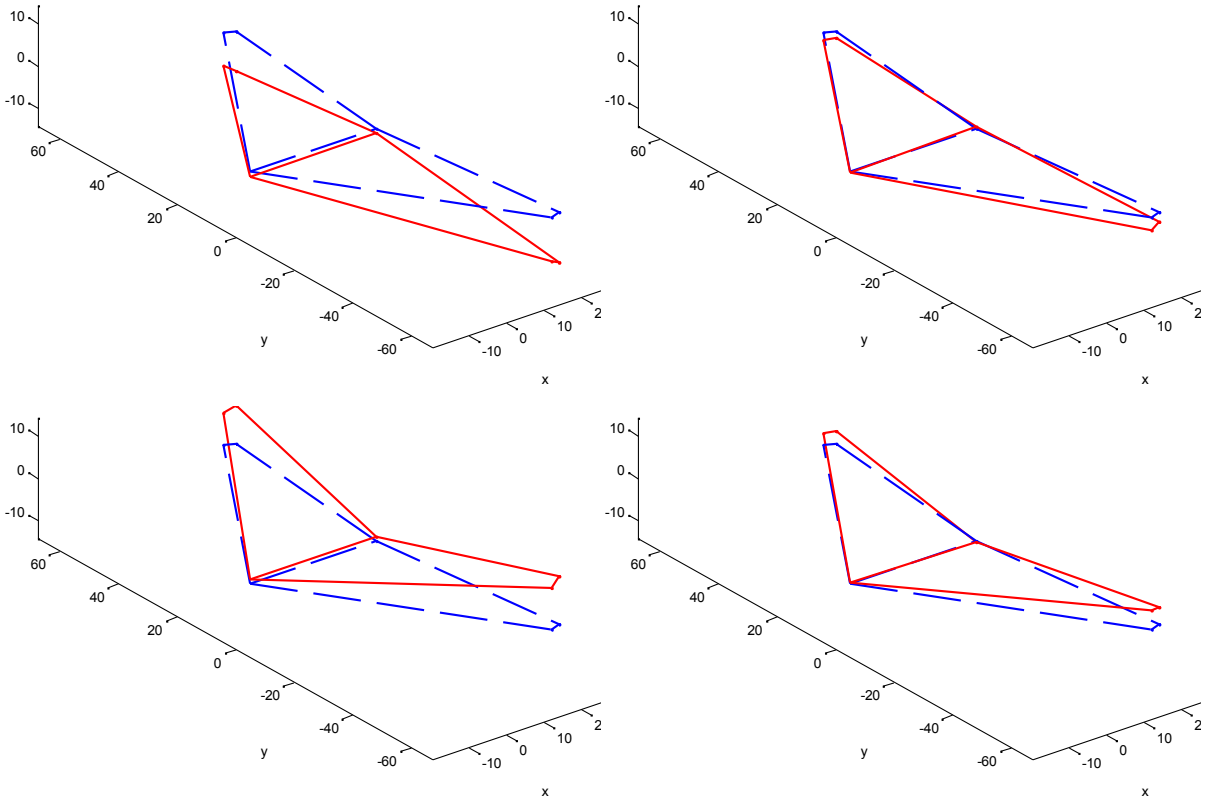

Figure 22: ID'd Shape, Mode 4: [0.02384, 73.17]

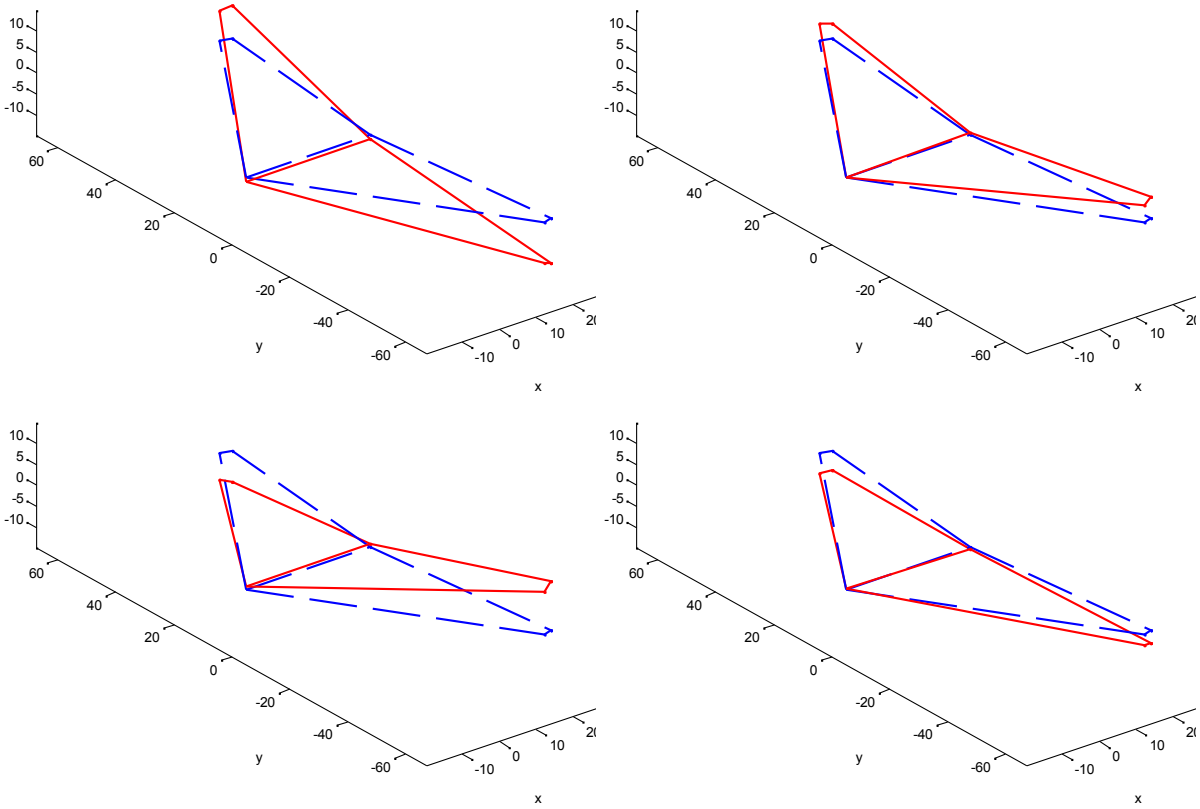

Figure 23: ID'd Shape, Mode 5: [0.02235, 95.85]

4.0 CONCLUSIONS

- The short period mode and the SWB1 mode approach each other in frequency as speed increases. This is consistent with the expected behavior of the vehicle which is expected to flutter via the body freedom flutter mechanism where these modes couple.
- The SWB1 and SWT1 modes decrease in frequency magnitude as speed increases. Their frequencies drop in magnitude significantly (SWB1 drops ~20 rad/s and SWT1 drops ~80 rad/s). Their magnitudes remain relatively proportional (SWT1/SWB1 at 20 m/s = 3.4, SWT1/SWB1 at 30 m/s = 3.0).
- The AWB1 mode does not change significantly in frequency magnitude as a function of airspeed.
- Both the SWT1 and AWT1 mode look to have coupled with the SWB1 mode at 30 m/s.
- The AWB1 mode was not identified at 20 m/s but it was at 30 m/s. Reasoning behind this could be due to the mode energy not being significant enough for CFDD to capture it. This could also be due to modes being close in frequency vicinity. From the models, the SWT1 and AWT1 dry structural modes are very near each other in frequency. Modes with close frequency vicinity have been traditionally difficult to identify with CFDD. At the lower airspeed, the modes may not have separated enough for CFDD to identify two distinct modes.

REFERENCES

[1] Schulze, P. M., Thompson, P. M., Danowsky, B. P., Lee, D. C. and Harris, C., "System Identification and Modal Extraction from Response Data," *AIAA Atmospheric Flight Mechanics Conference*, AIAA Paper 2013-4919, August 2013.

[2] Taylor, B., "Sköll Flight 4 Flight Report," *University of Minnesota*, July 2015.