flatball (aka frisbee™) 6dof

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Validation exercise for implementation of Crowther and Potts 6dof equations of motion as a simulink model.

NOTES

- Frisbee.m modified to accept Y0 and dt as inputs to support testing

- running Frisbee @ 5Hz misses lots of dynamics

- running Frisbee @ 100Hz resembles flatball_6dof_eqom much closer

- flatball_6dof_eqom is an amalgamation of published papers by CandP as well as FrisbeeODE.m

- flatball_6dof is a simulink model that implements the same ODEs as flataball_6dof_eqom, uses table lookups for aero coefficients

- trajectory plots are ENU, state vector is NED

- [x y z, phi theta psi, u v w, p q r] - state vector

misc dot protolabs at gmail dot com

Begin simulations from scratch (i.e. clean workspace)

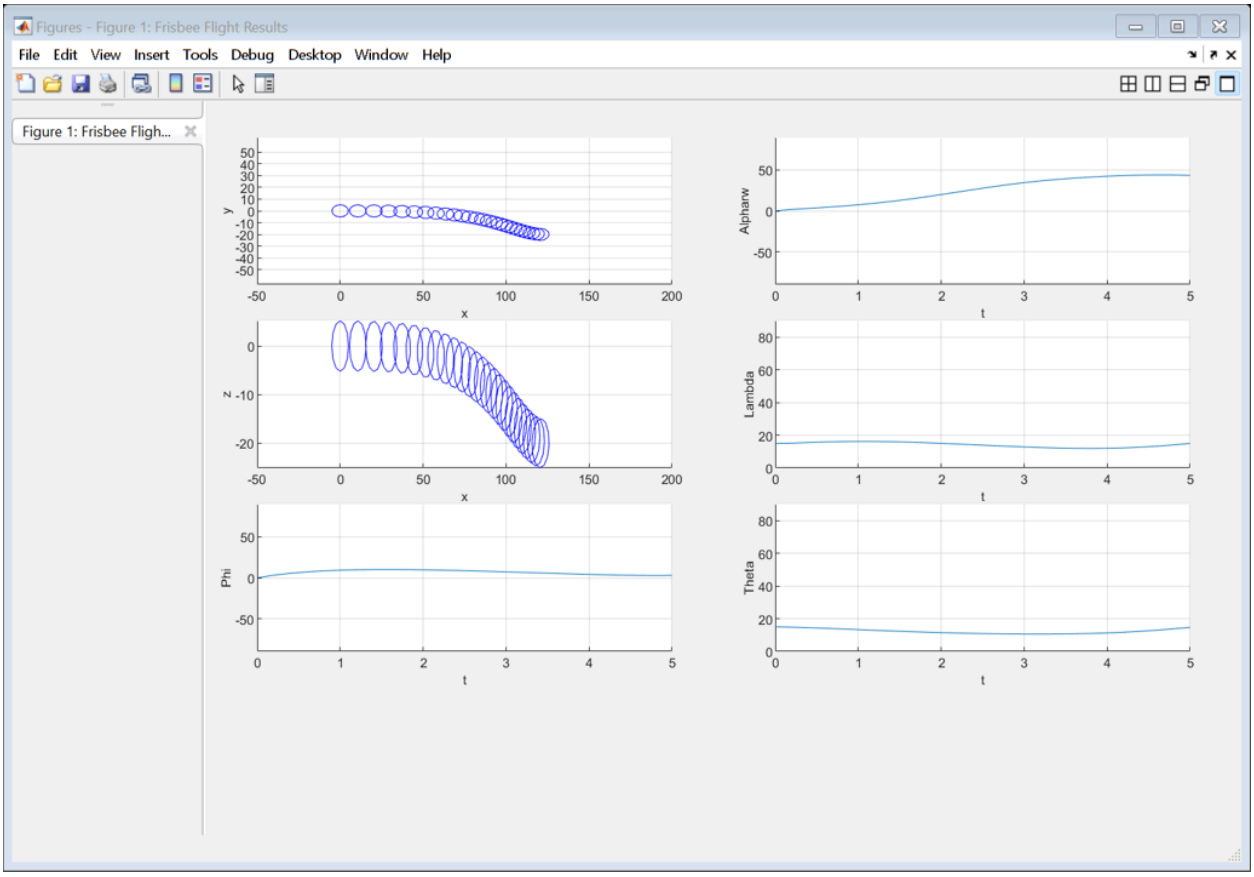
```
clc;
close all;
startup;

% initialize ambient conditions and disc properties
flatball_6dof_init;

misc: ... creating physical constants container C
misc: ... creating physical quantity container Q
misc: ... publish options set in pub_opts
misc: ... beep is off
```

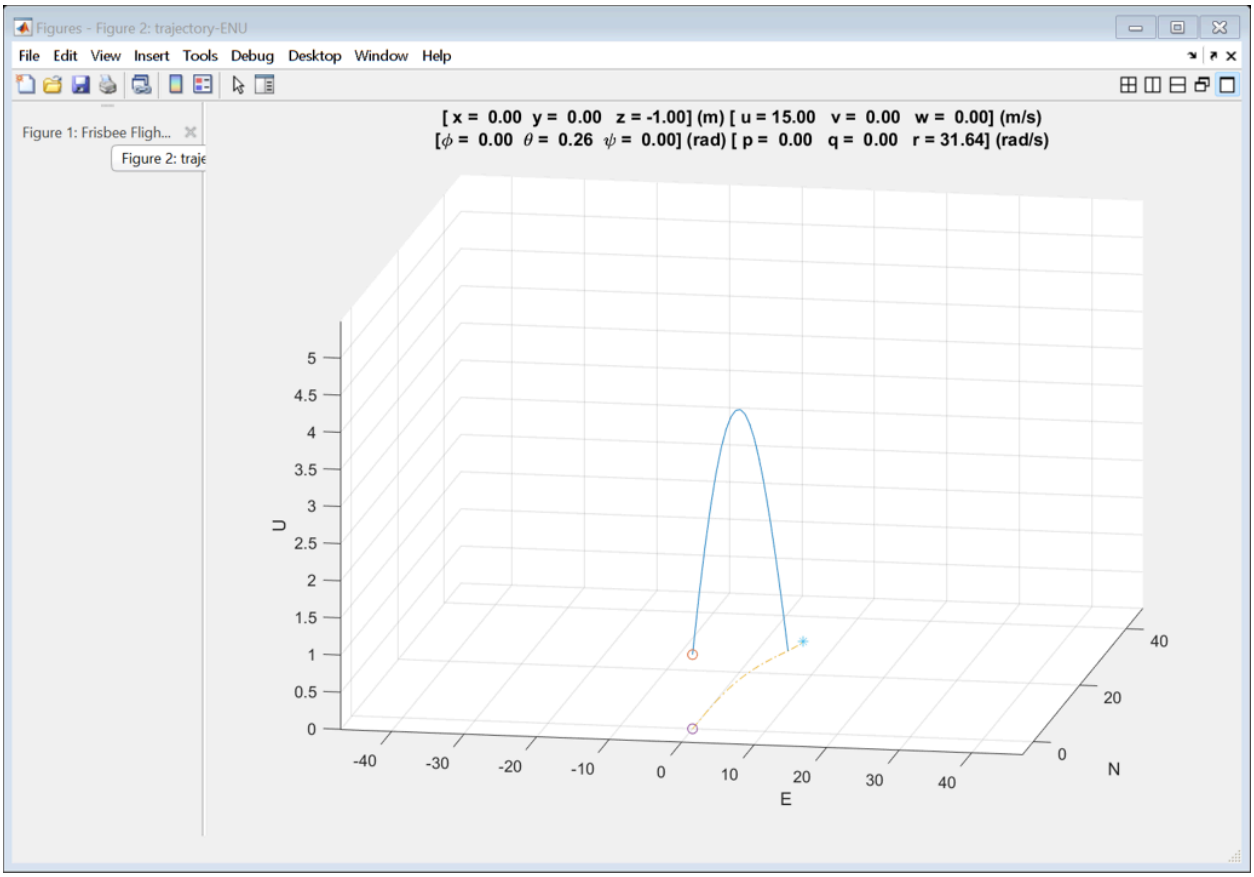
Initial conditions

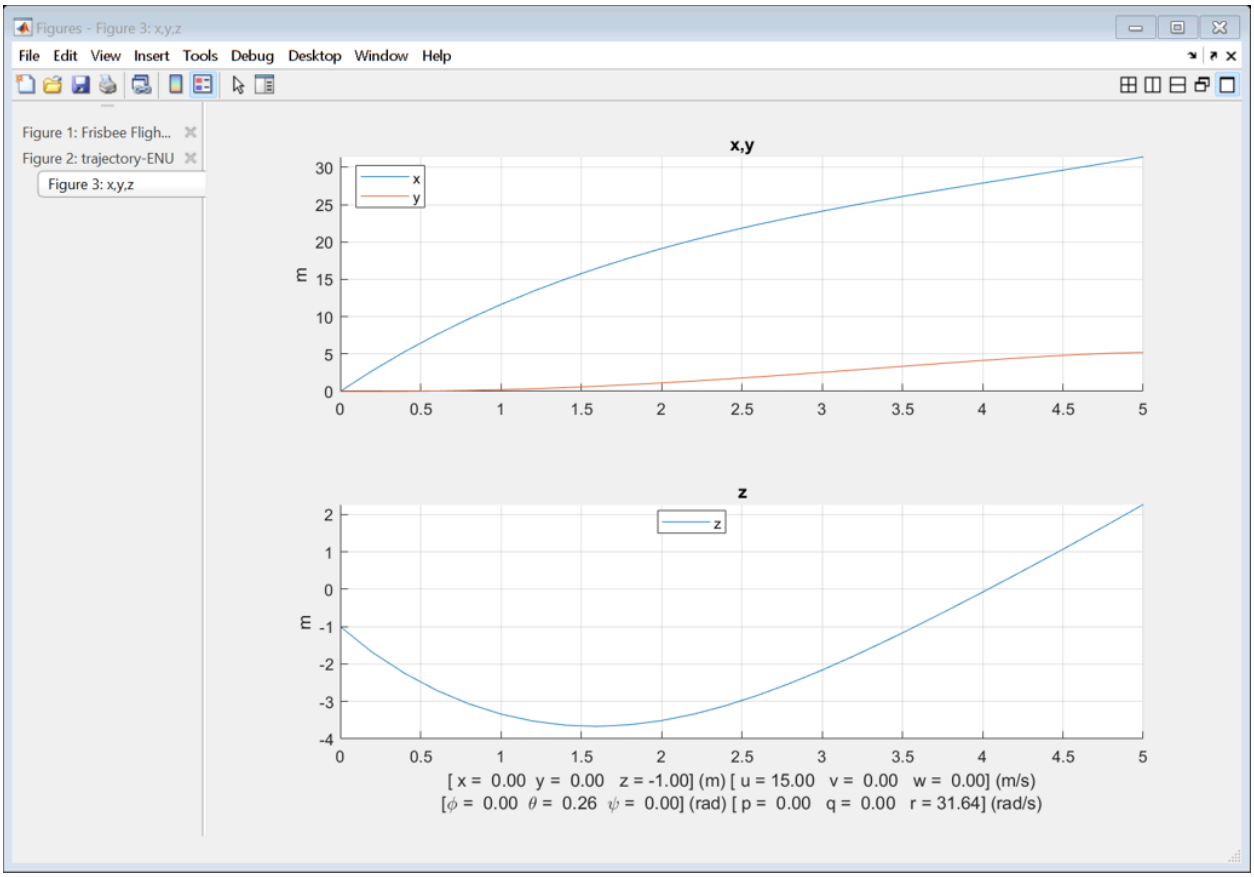
```
% f2302 per hummel MS Thesis - 2003
% https://www.researchgate.net/
publication/253842372_Simulation_of_Frisbee_Flight
% Y0 = [-0.90 -0.63 -0.91, -0.07 0.21 5.03, 13.42 -0.41 0.001, -14.94 -1.48
 54.25];

% f2302 per C&P ISEA 2007
% https://www.researchgate.net/
publication/225330184_Simulation_of_a_spinstabilised_sports_disc
% Y0 = [-0.90 -0.63 -0.91, -0.07 0.21 5.03, 4.48 12.52 1.84, -26.25 -5.19
 52.85];

% launch conditions per pg13 C&P ISEA 2007
% https://www.researchgate.net/
publication/225330184_Simulation_of_a_spinstabilised_sports_disc
Y0 = [0 0 -1, 0 15*C.DEG2RAD 0, 15 0 0, 0 0 (2*15*0.29/disc.d)];
```

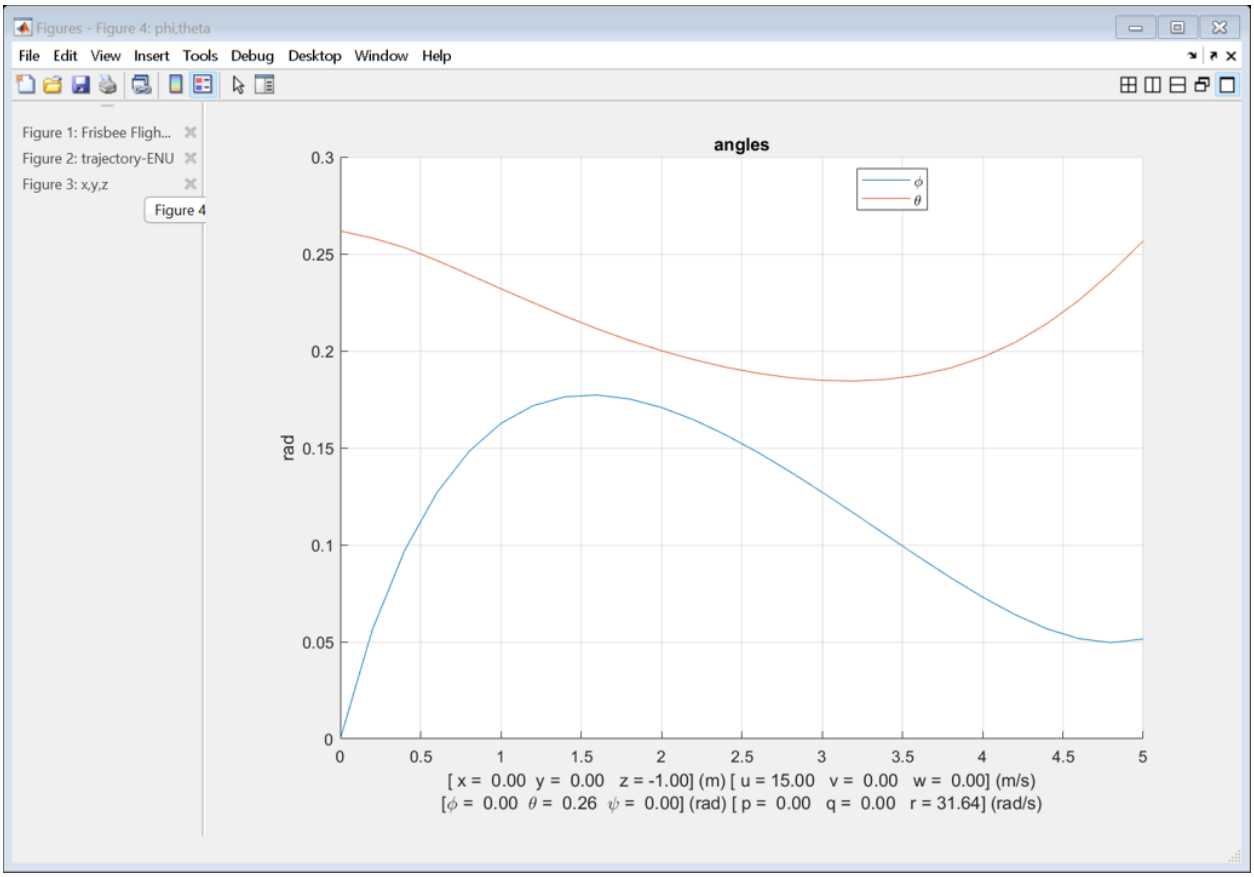
FrisbeeODE.m @ 5Hz - CandP ~2003

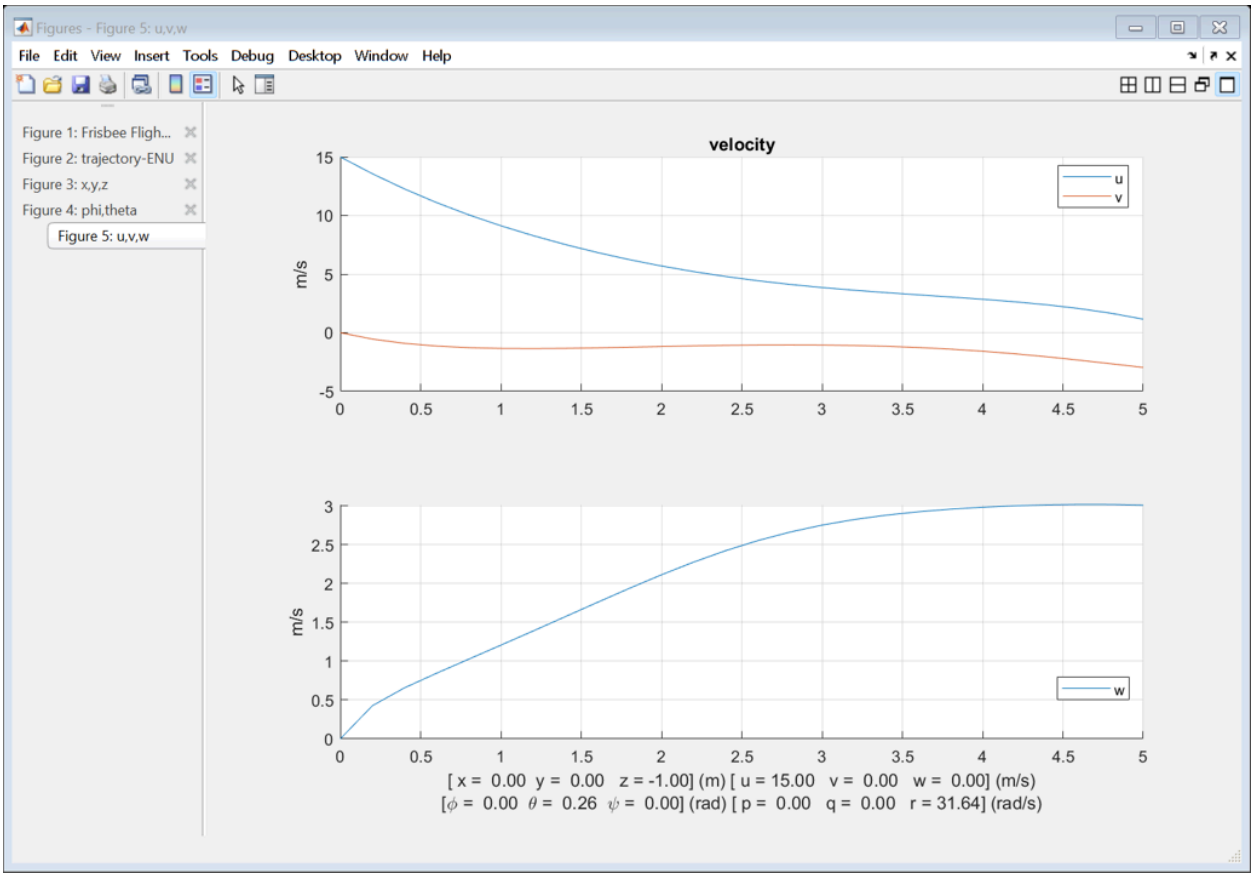
```
Frisbee( Y0, 0.20);
toc( tic0);
close all;
```

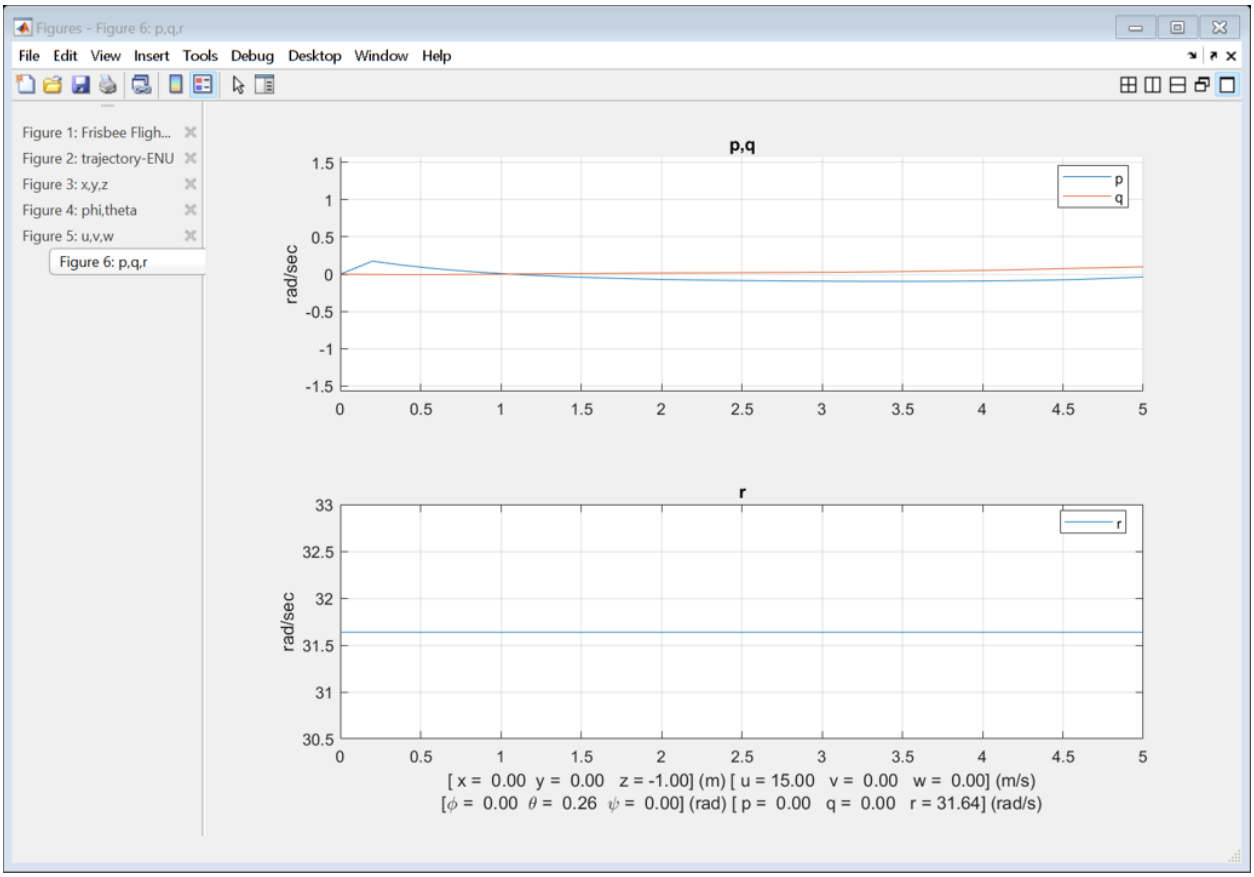



Figures - Figure 2: trajectory-ENU
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: Frisbee Fligh...
Figure 2: traje
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)
U
E
N


Figures - Figure 3: x,y,z
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: Frisbee Fligh...
Figure 2: trajectory-ENU
Figure 3: x,y,z
x,y
x
y
m
z
z
m
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)


Figures - Figure 4: phi,theta
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: Frisbee Fligh...
Figure 2: trajectory-ENU
Figure 3: x,y,z
Figure 4
angles
rad
0.3
0.25
0.2
0.15
0.1
0.05
0
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)

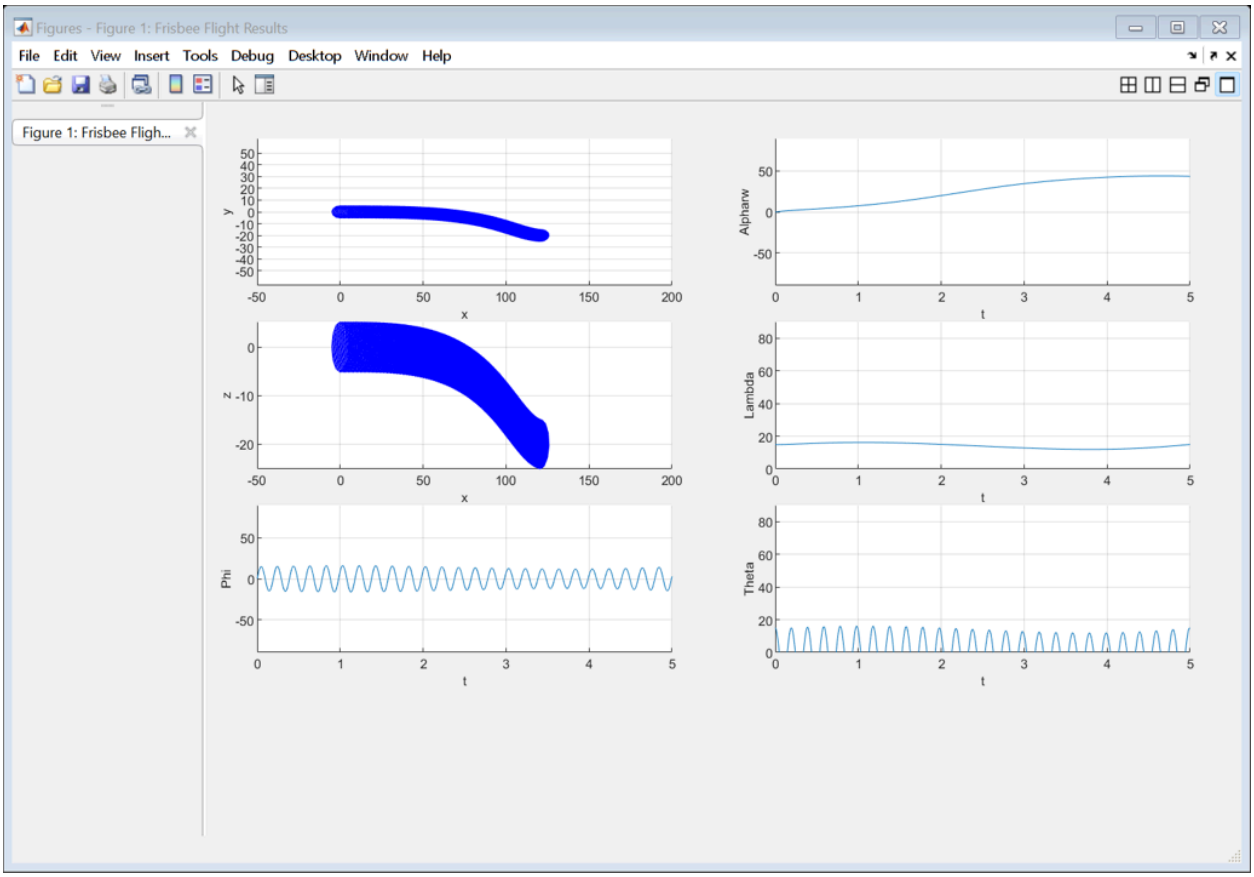

Figures - Figure 5: u,v,w
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: Frisbee Fligh...
Figure 2: trajectory-ENU
Figure 3: x,y,z
Figure 4: phi,theta
Figure 5: u,v,w
velocity
m/s
u
v
w
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)

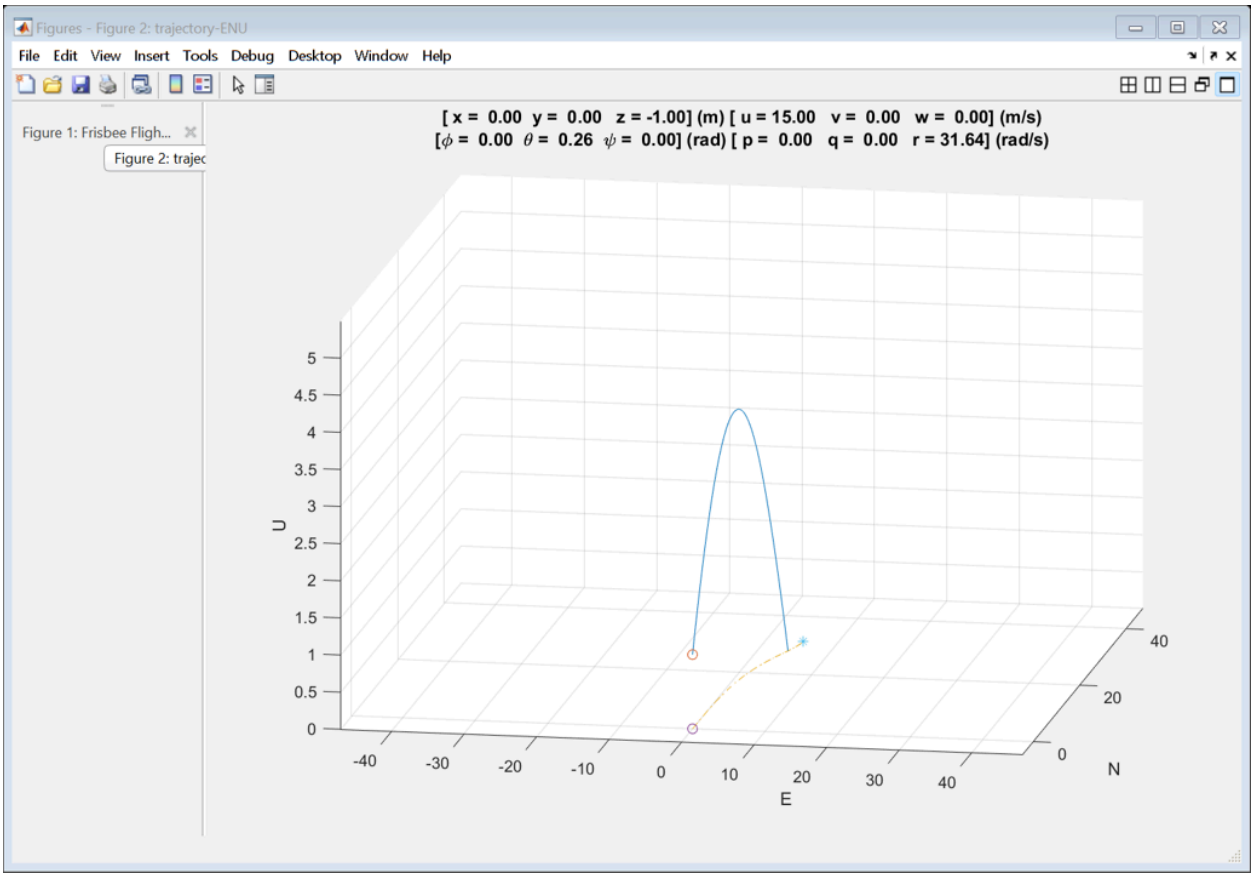


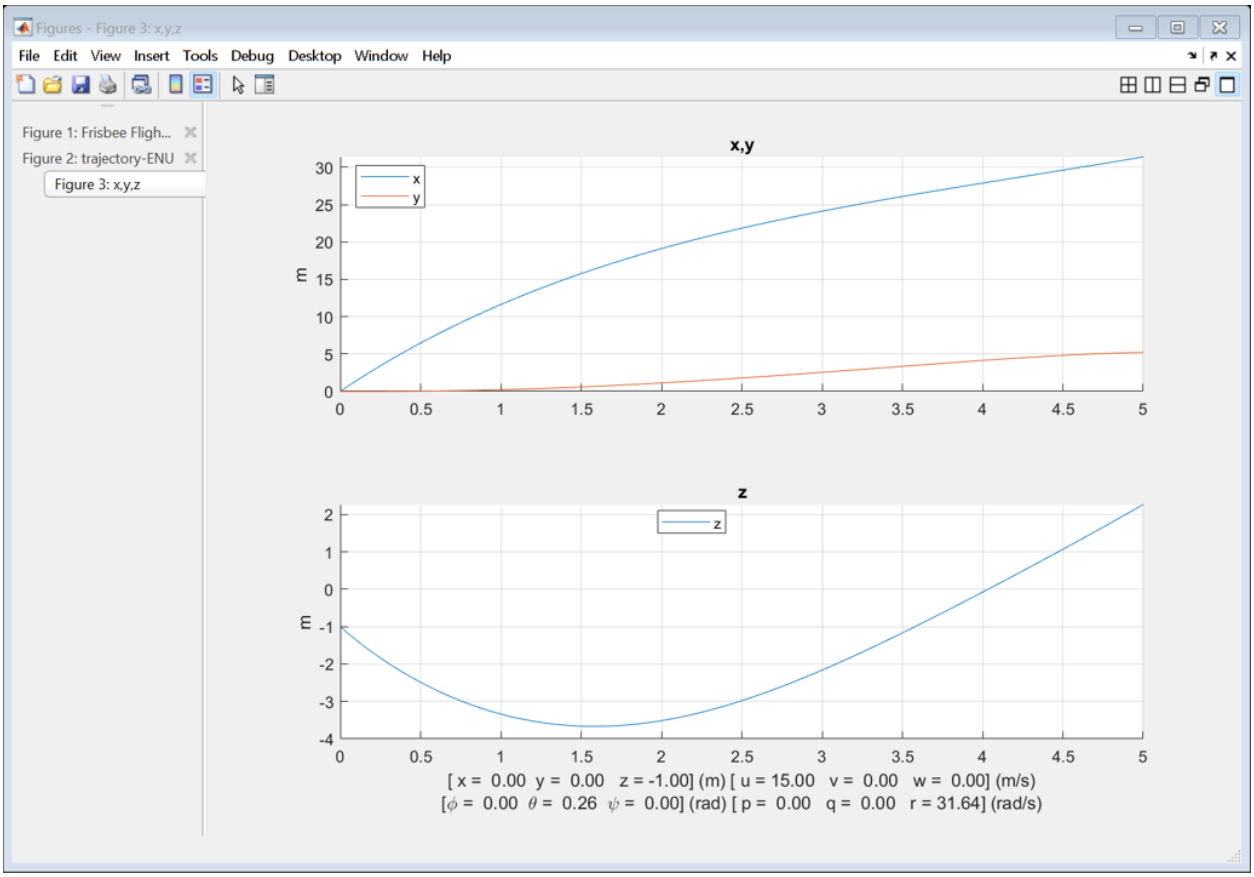
Elapsed time is 4.362109 seconds.

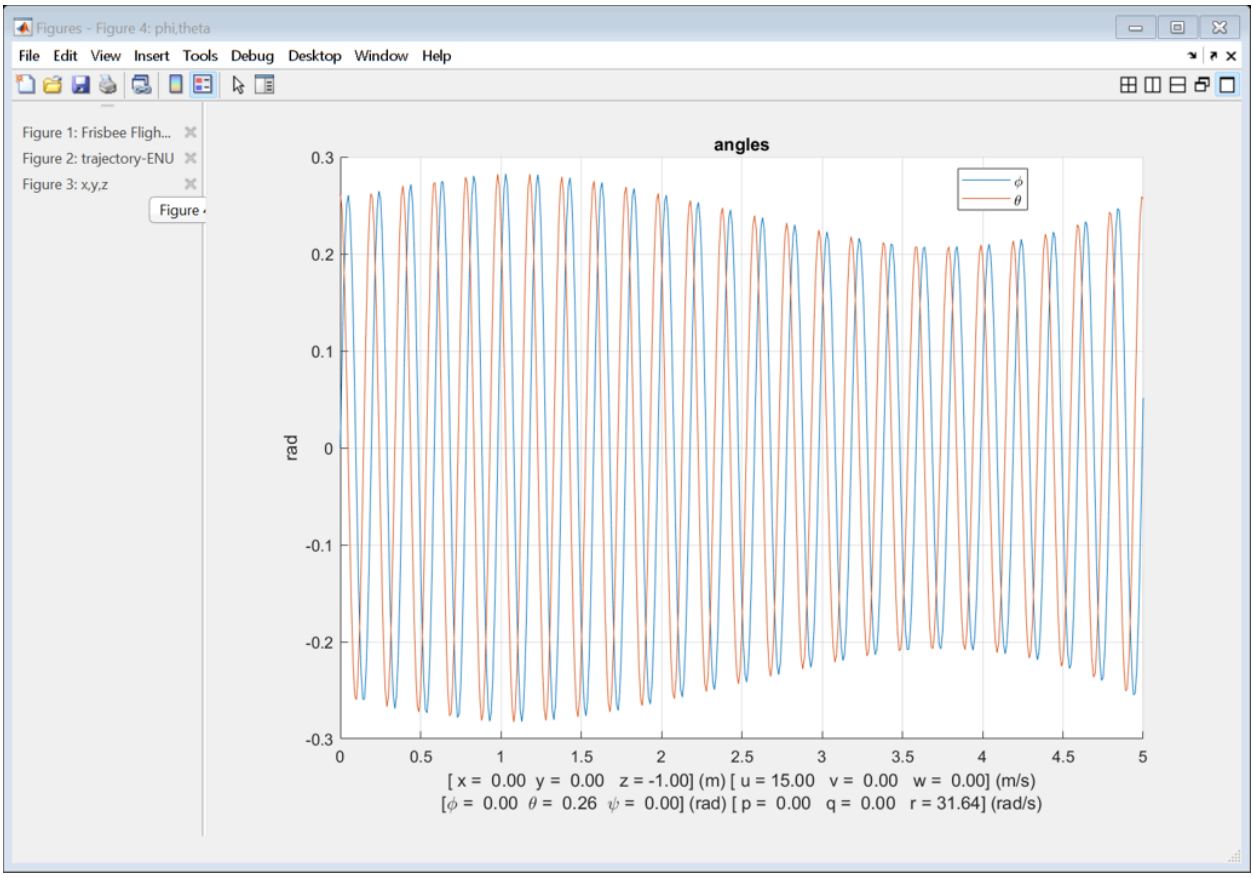
FrisbeeODE.m @ 100Hz - CandP ~2003

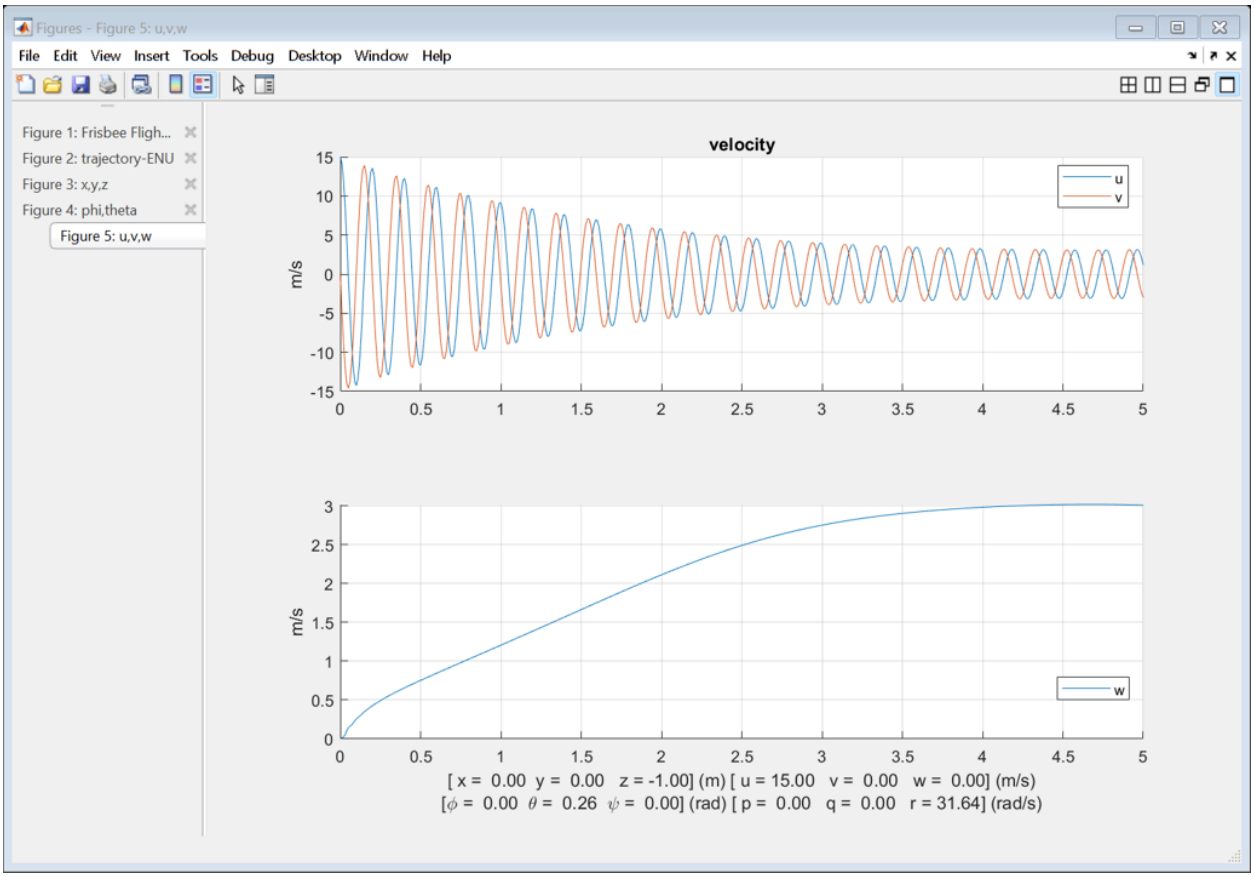
```
Frisbee( Y0, 1e-2);
toc( tic0);
close all;
```

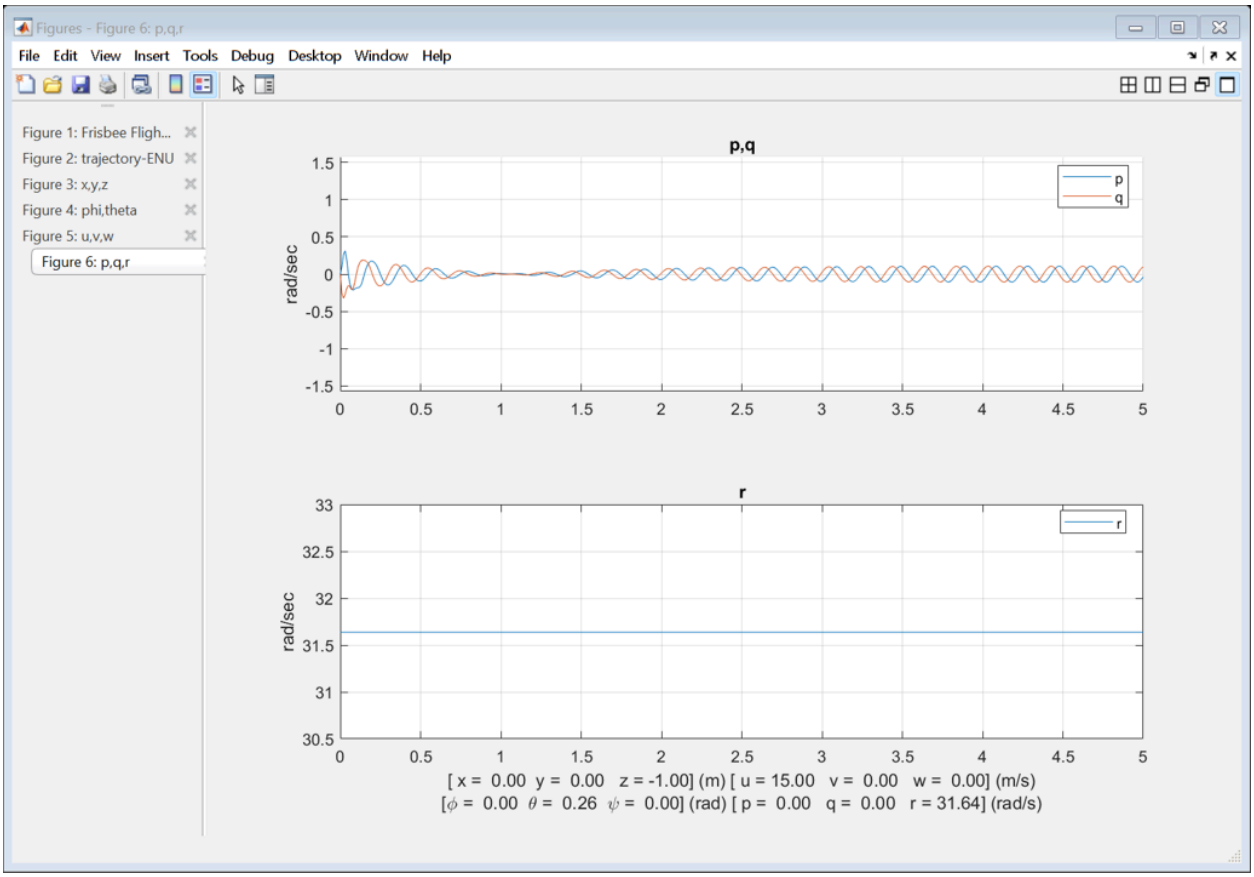

Figures - Figure 1: Frisbee Flight Results
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: Frisbee Fligh...
y
x
z
x
Phi
t
Alpharw
t
Lambda
t
Theta
t


Figures - Figure 2: trajectory-ENU
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: Frisbee Fligh...
Figure 2: trajec
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)
U
E
N


Figures - Figure 3: x,y,z
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: Frisbee Fligh...
Figure 2: trajectory-ENU
Figure 3: x,y,z
x,y
x
y
m
z
z
m
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)


Figures - Figure 4: phi,theta
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: Frisbee Fligh...
Figure 2: trajectory-ENU
Figure 3: x,y,z
Figure 4
angles
rad
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
ϕ
θ
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)

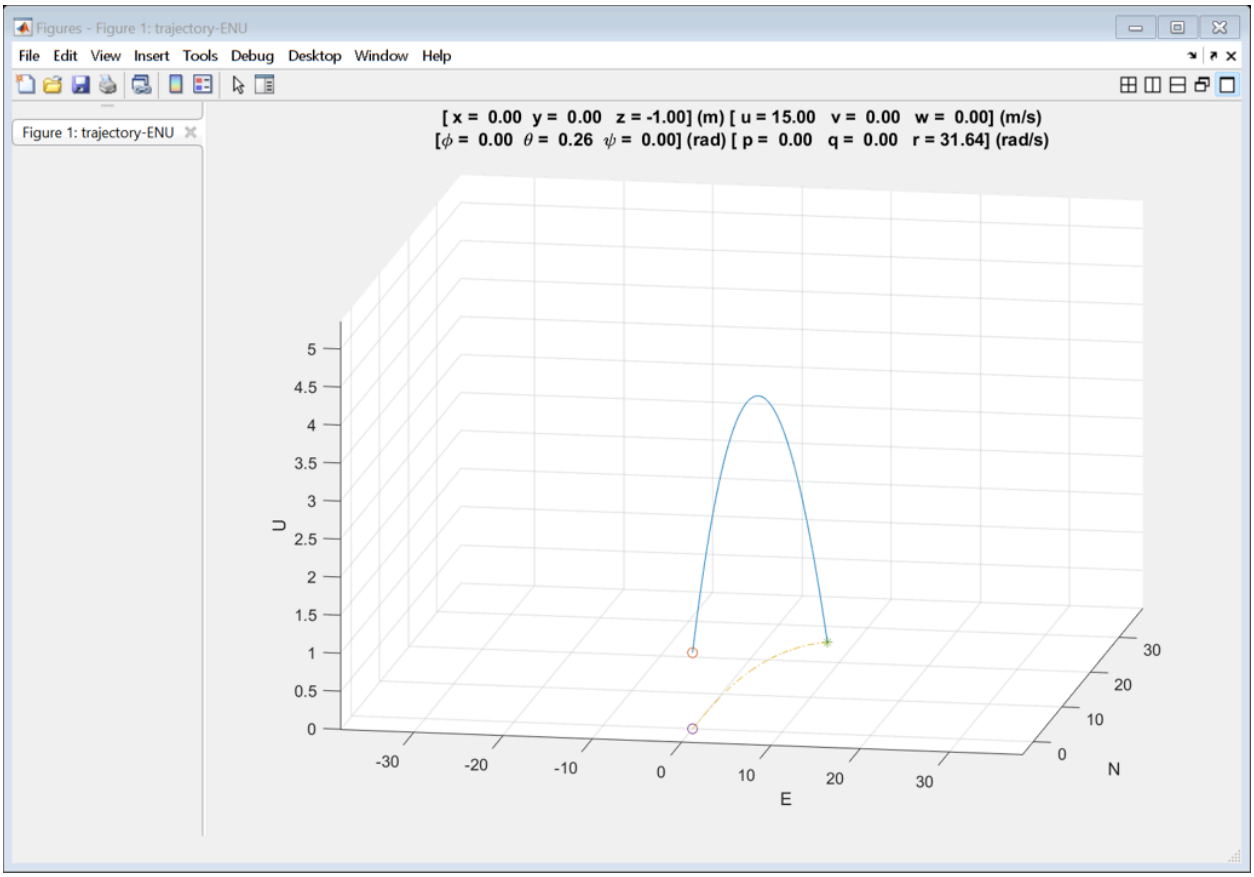

Figures - Figure 5: u,v,w
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: Frisbee Fligh...
Figure 2: trajectory-ENU
Figure 3: x,y,z
Figure 4: phi,theta
Figure 5: u,v,w
velocity
m/s
u
v
w
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)

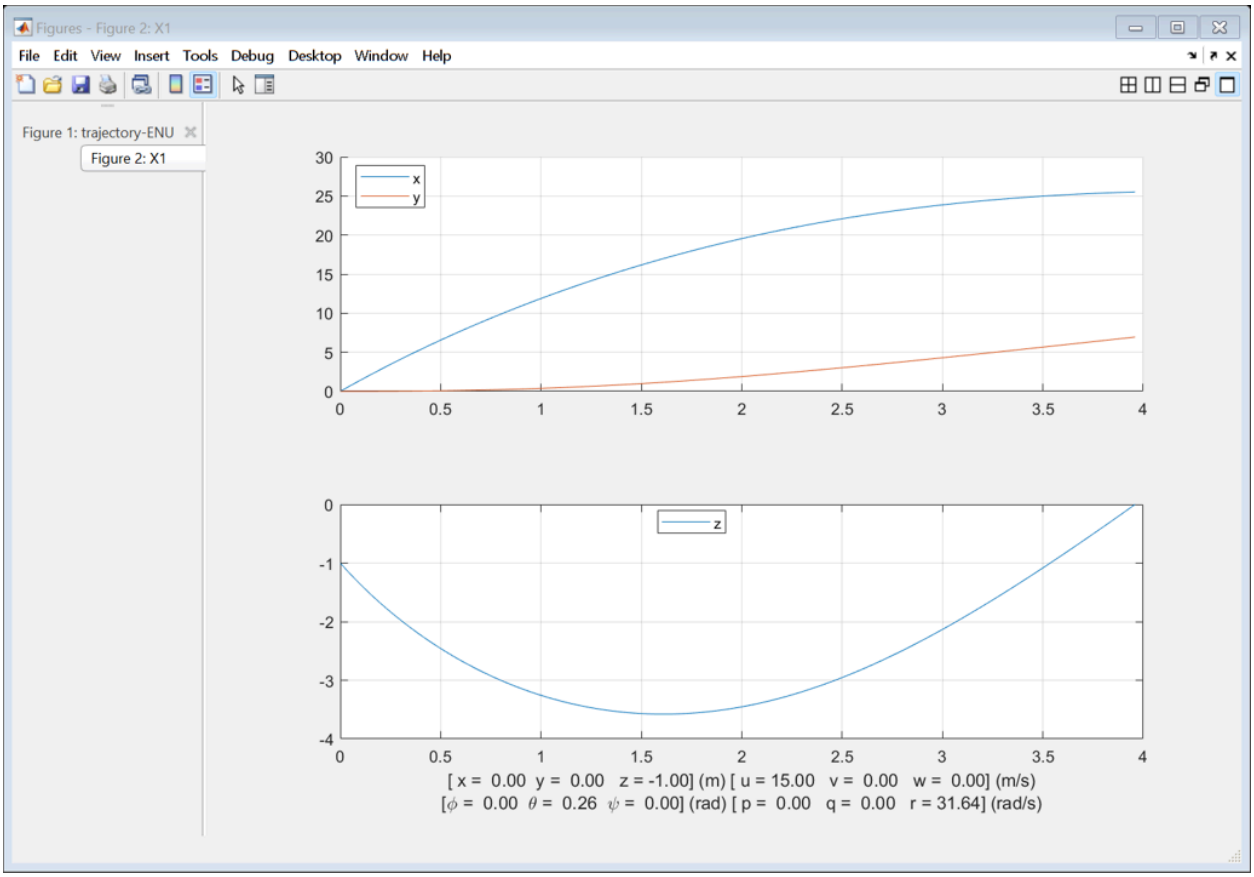


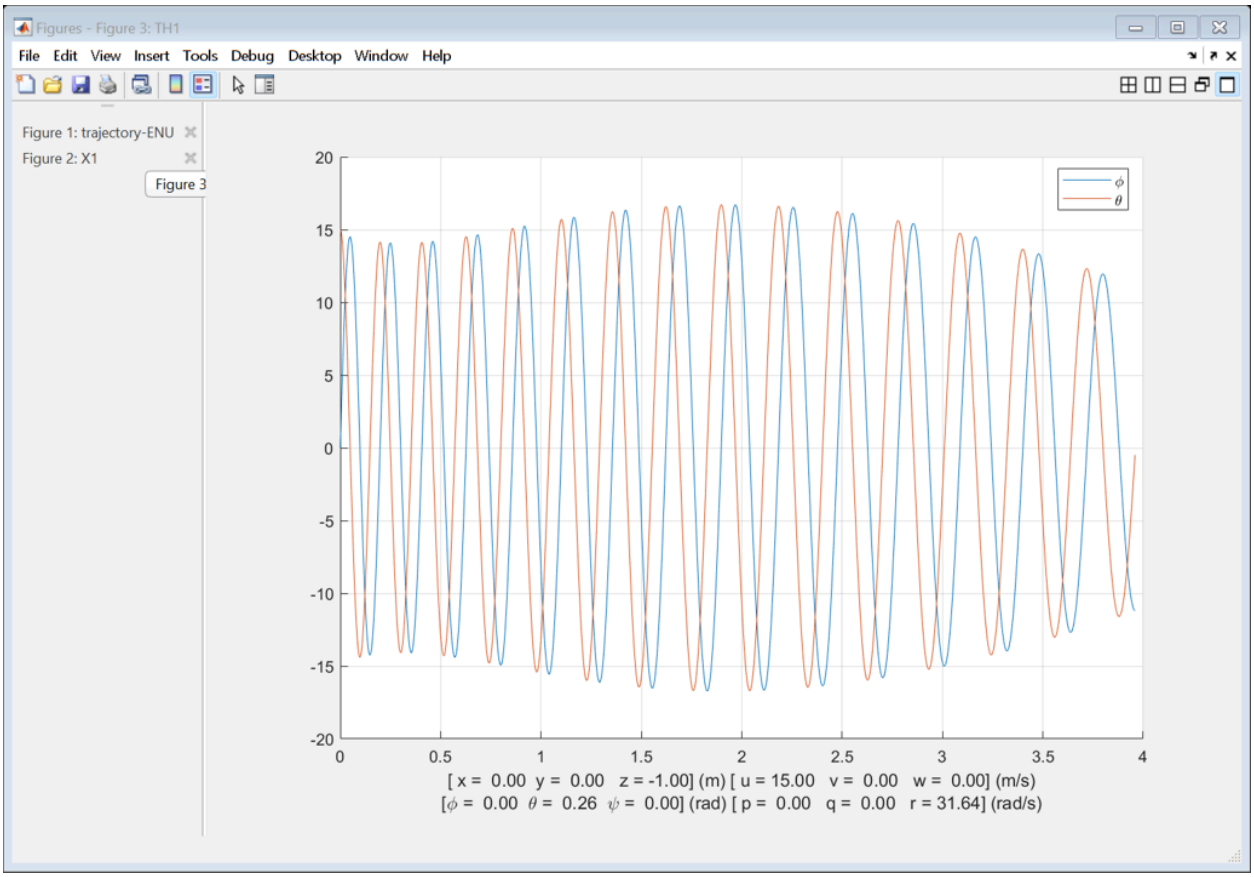
Elapsed time is 10.140464 seconds.

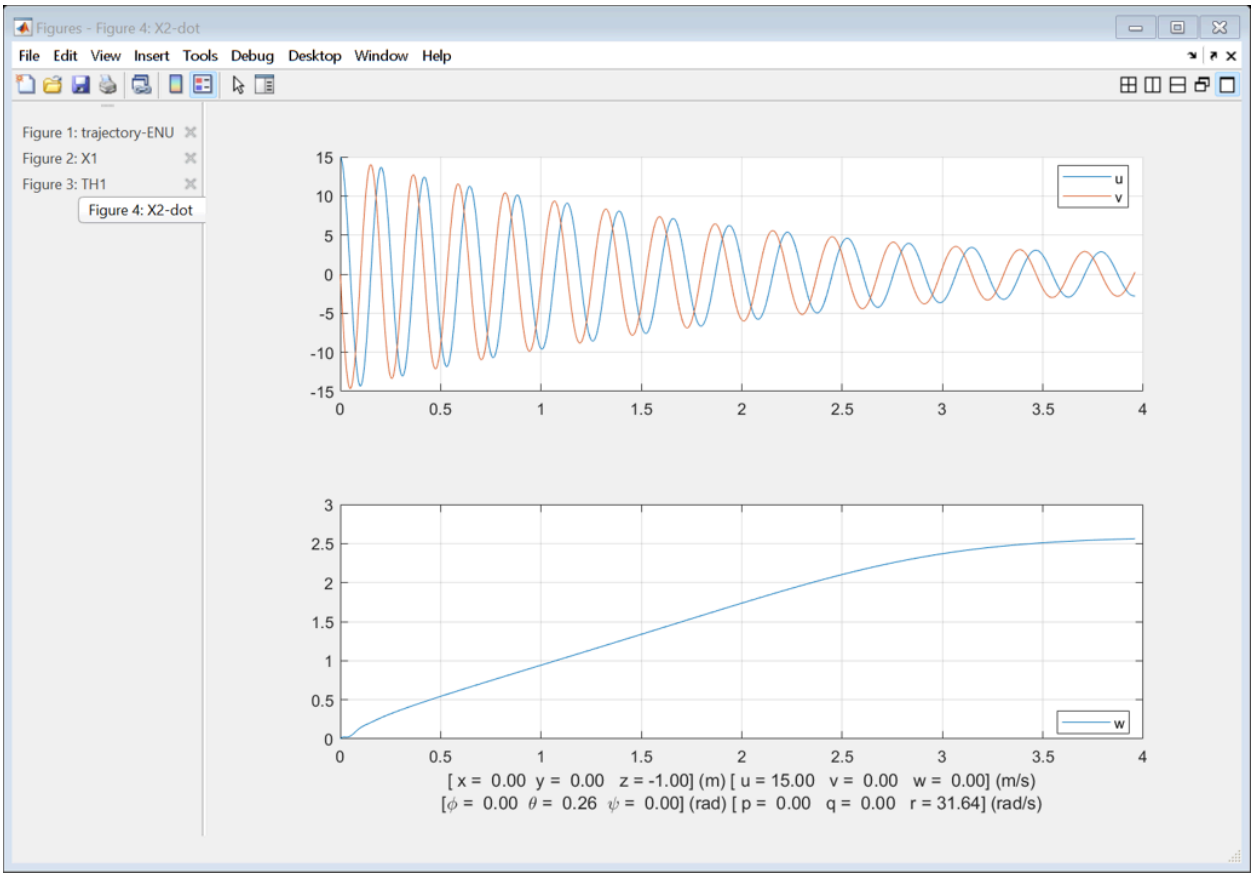
flatball_6dof_eqom.m @ 100Hz - misc

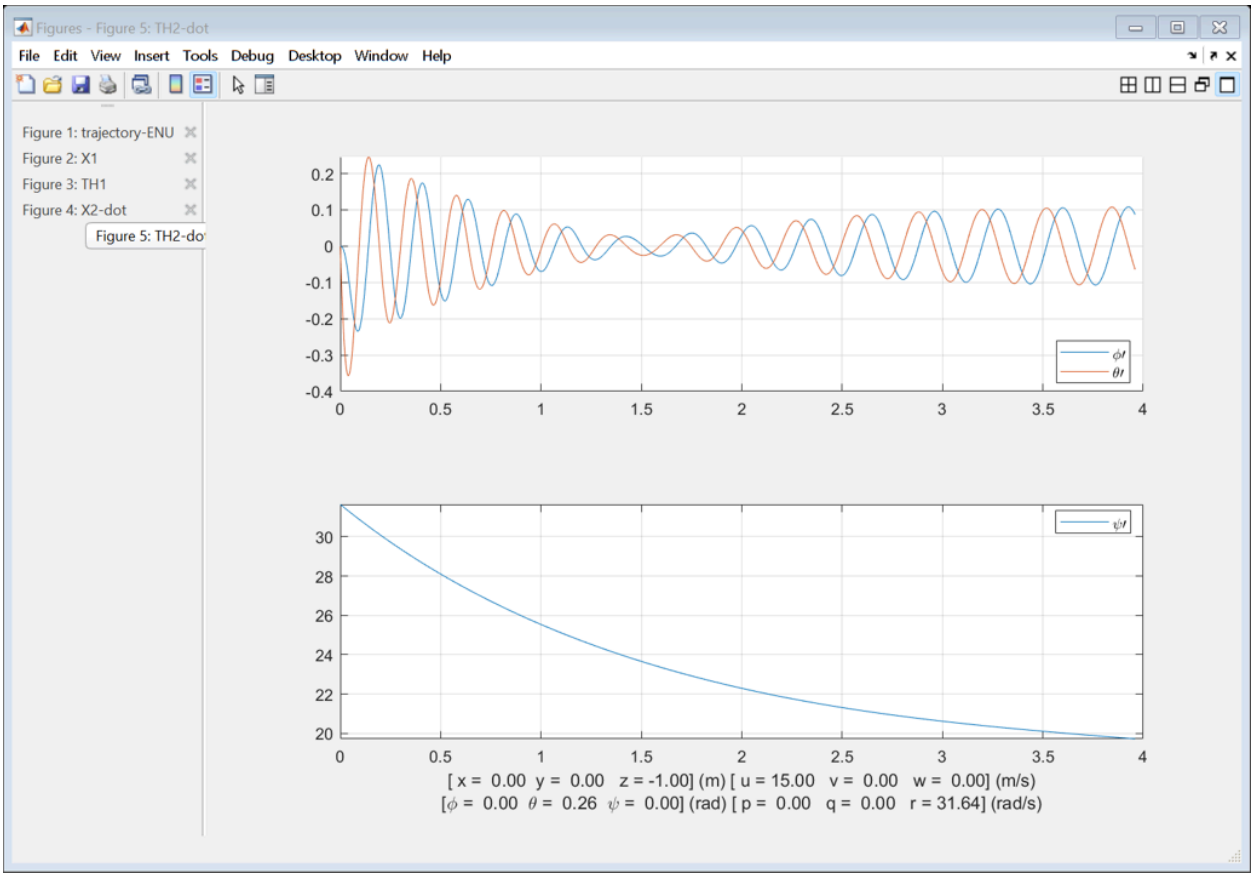
```
flatball_6dof_eqom;
toc( tic0);
close all;
```


Figures - Figure 1: trajectory-ENU
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: trajectory-ENU
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)
U
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-30
-20
-10
0
10
20
30
E
0
10
20
30
N


Figures - Figure 2: X1
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: trajectory-ENU
Figure 2: X1
x
y
z
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)


Figures - Figure 3: TH1
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: trajectory-ENU
Figure 2: X1
Figure 3
20
15
10
5
0
-5
-10
-15
-20
0
0.5
1
1.5
2
2.5
3
3.5
4
ϕ
θ
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)

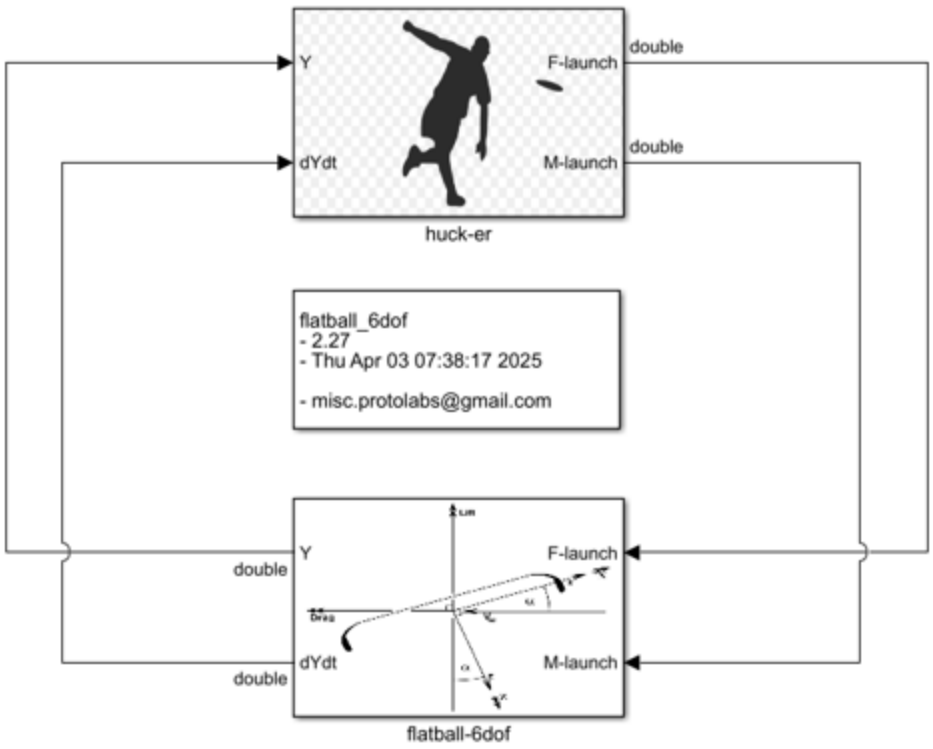

Figures - Figure 4: X2-dot
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: trajectory-ENU
Figure 2: X1
Figure 3: TH1
Figure 4: X2-dot
u
v
w
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)

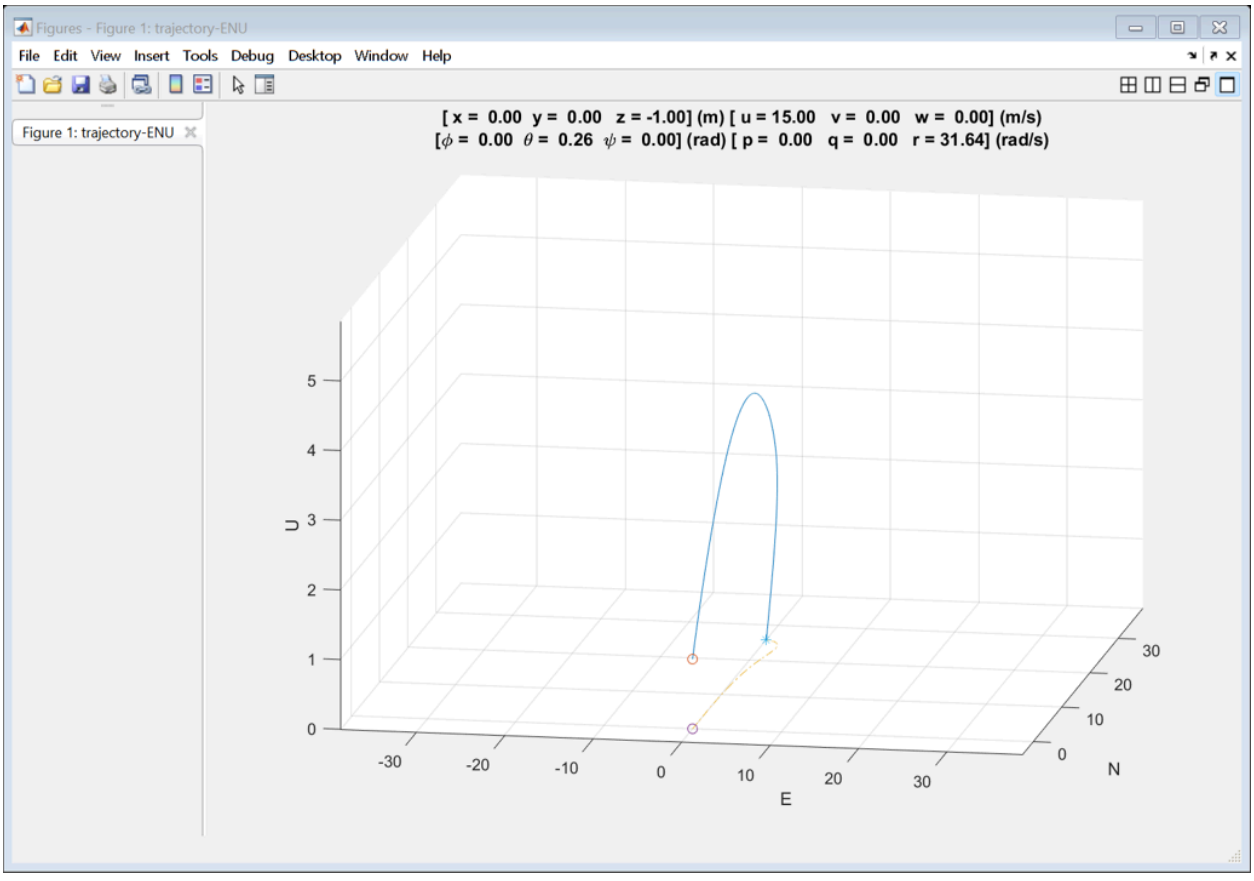


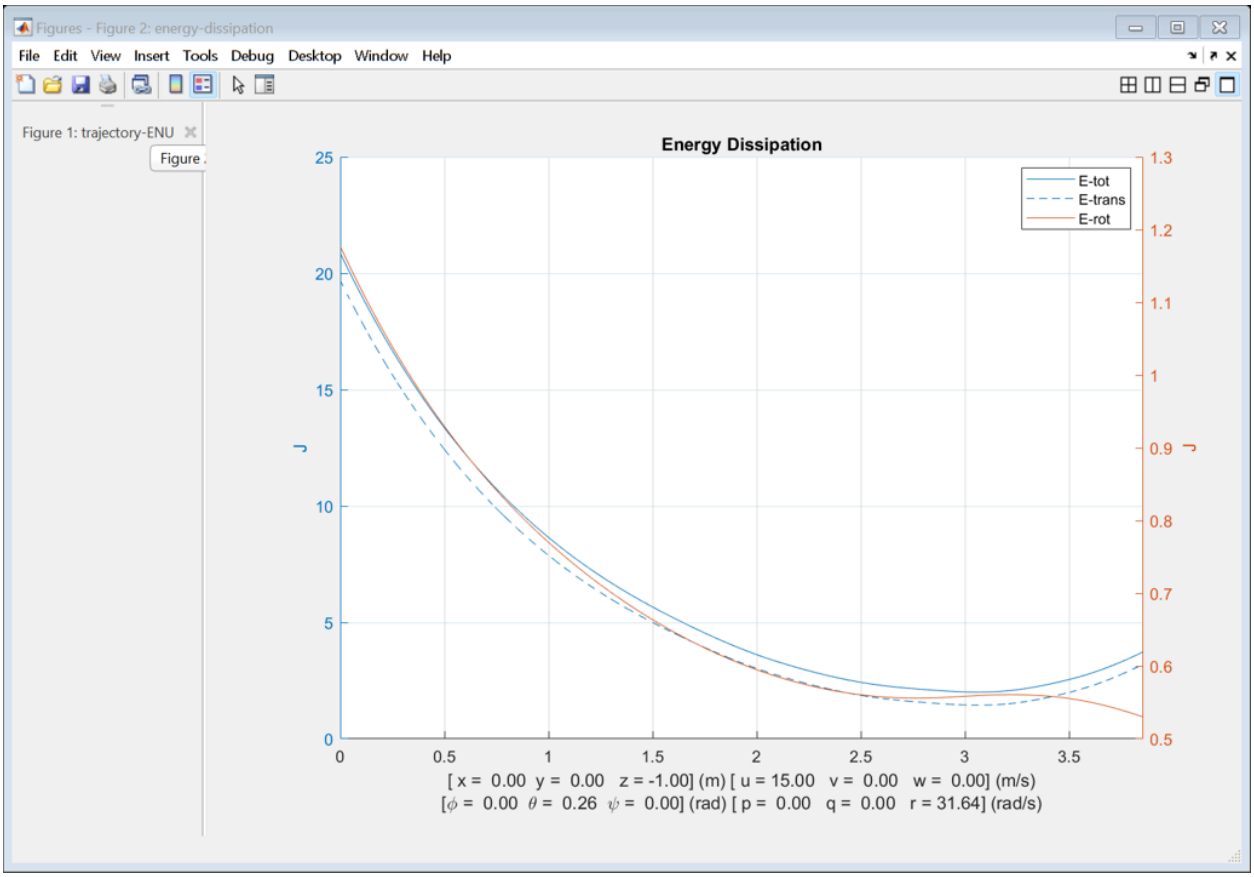
Elapsed time is 13.188313 seconds.

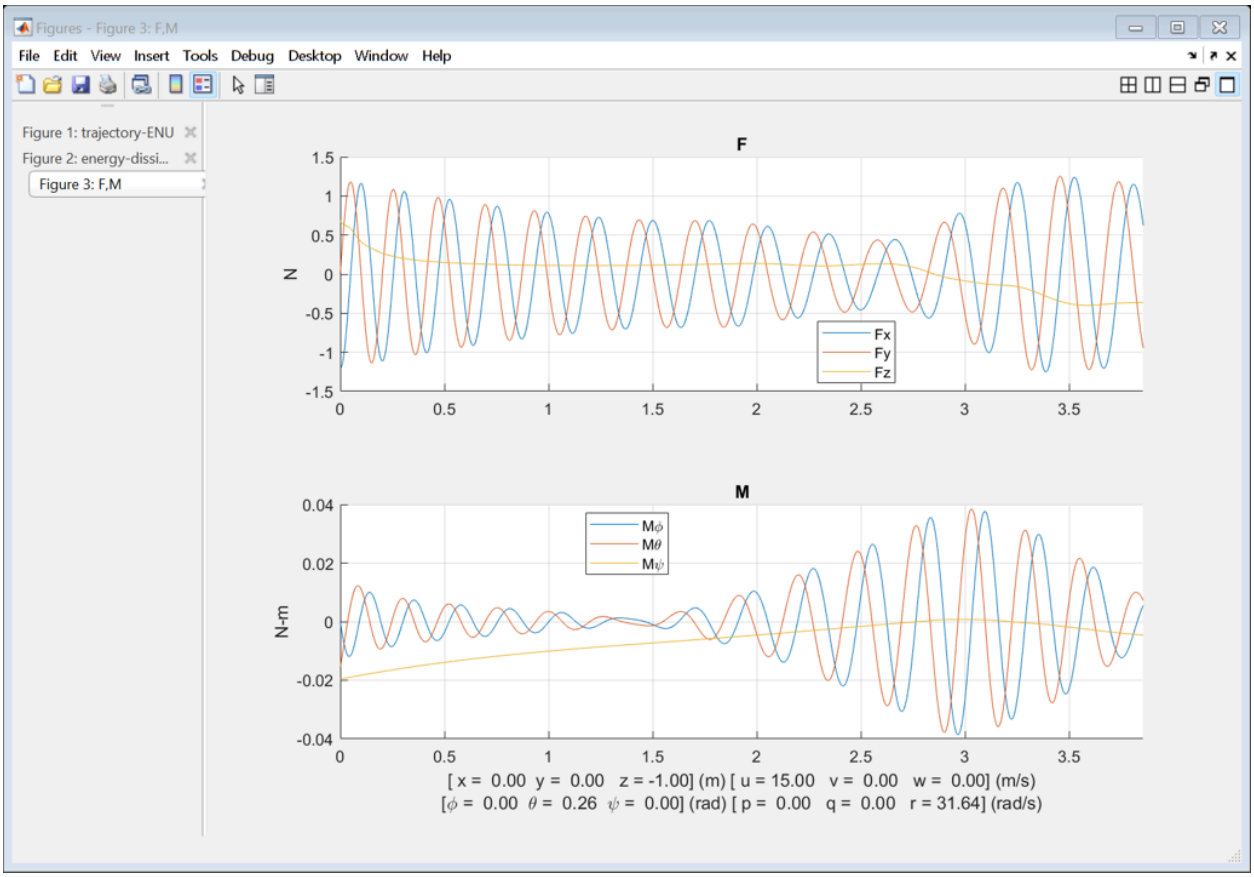
flatball_6dof @ 1kHz - misc

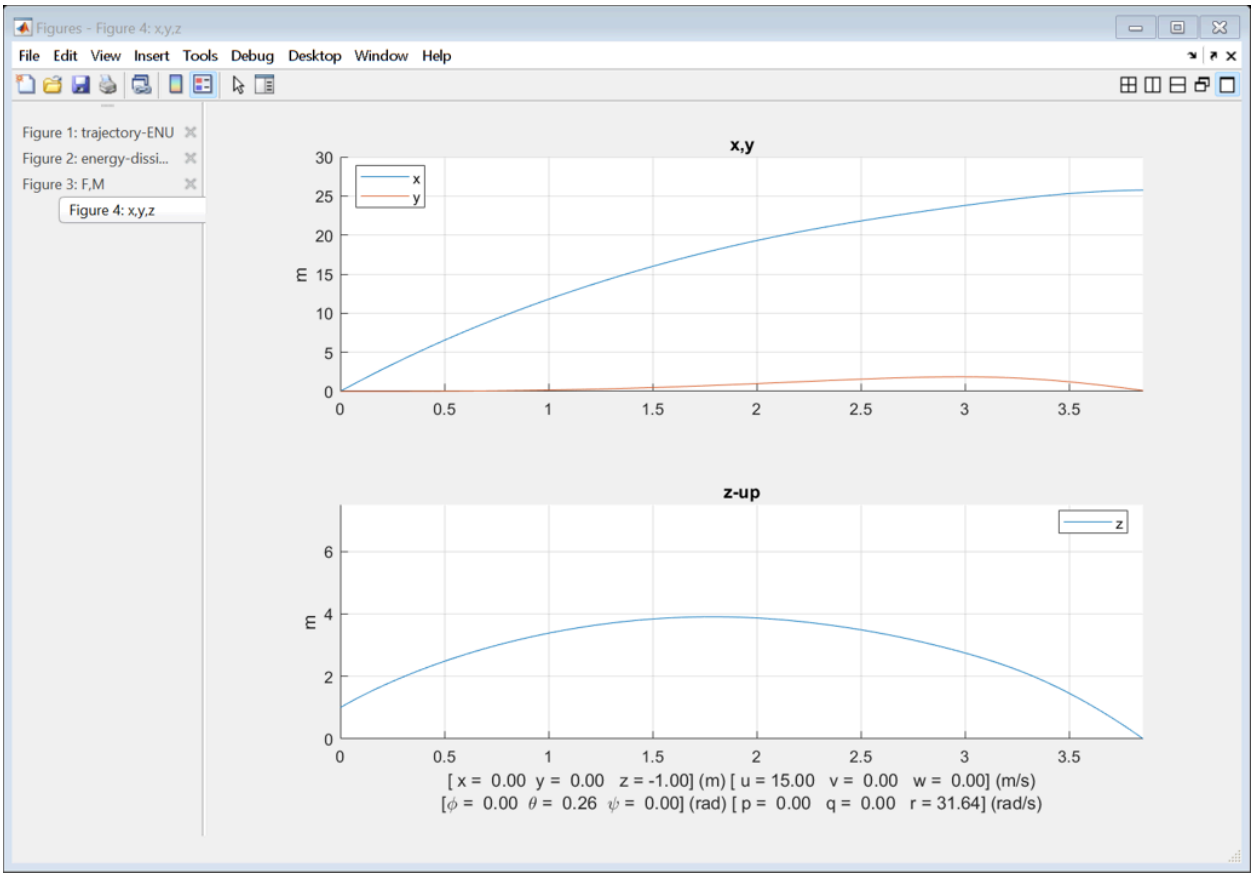
```
% open model and run simulation
sys = 'flatball_6dof';
open_system( sys);

simout = sim( sys);

% post process and generate plots
tsc = flatball_6dof_post( simout.logsout, disc, amb);
flatball_6dof_plots;
toc( tic0);
```

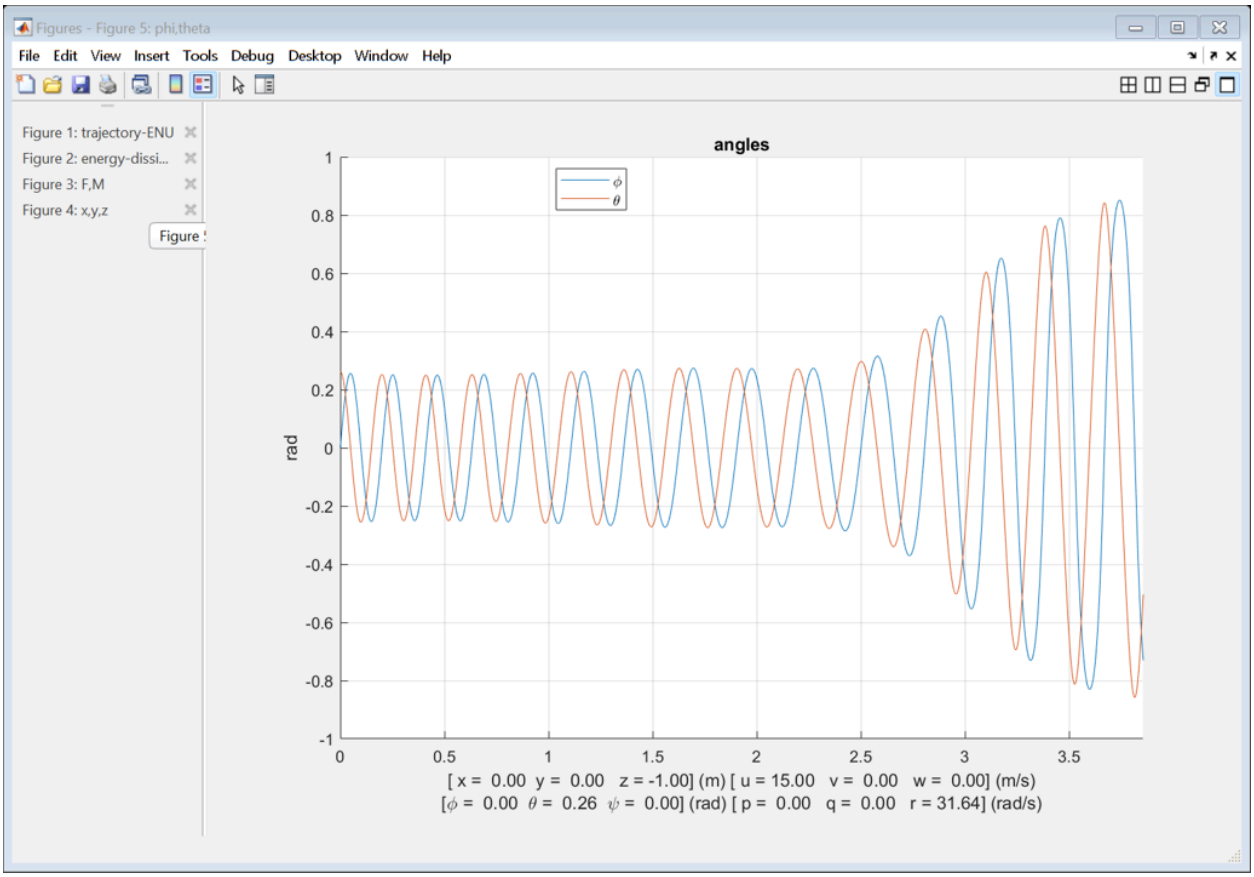

Y
dYdt
F-launch
M-launch
double
double
huck-er
flatball_6dof
- 2.27
- Thu Apr 03 07:38:17 2025
- misc.protolabs@gmail.com
Y
dYdt
F-launch
M-launch
double
double
flatball-6dof

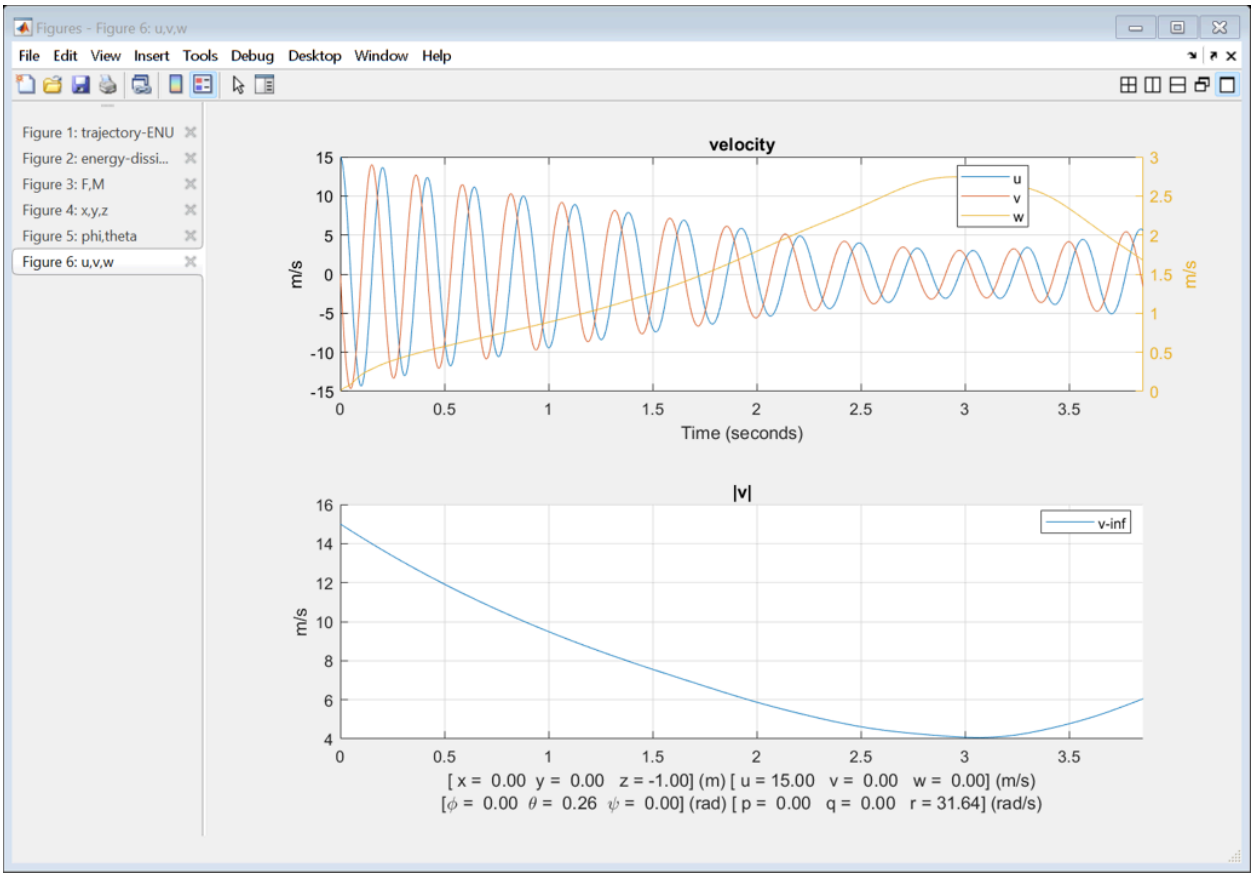

Figures - Figure 1: trajectory-ENU
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: trajectory-ENU
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)
U
E
N

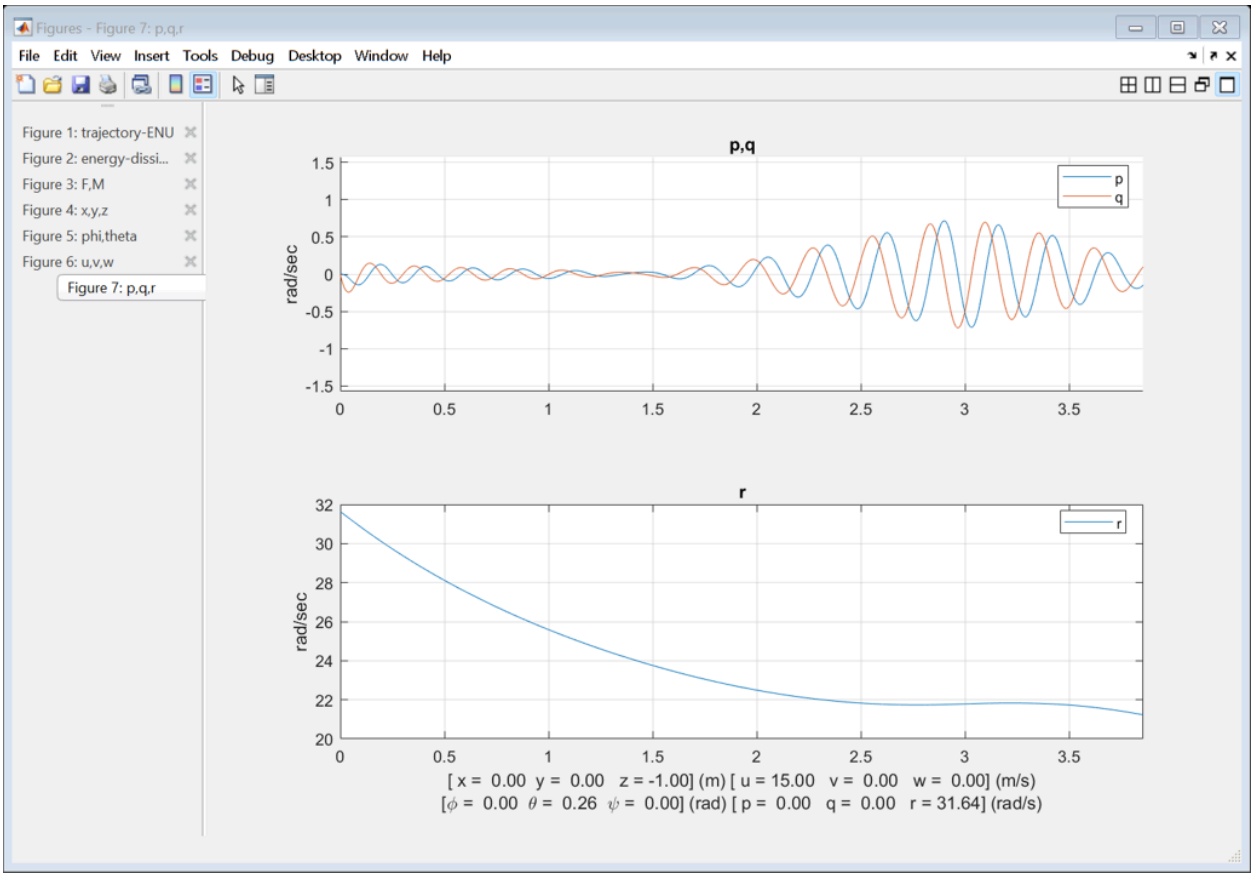

Figures - Figure 2: energy-dissipation
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: trajectory-ENU
Figure
Energy Dissipation
E-tot
E-trans
E-rot
J
T
25
20
15
10
5
0
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0
0.5
1
1.5
2
2.5
3
3.5
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)

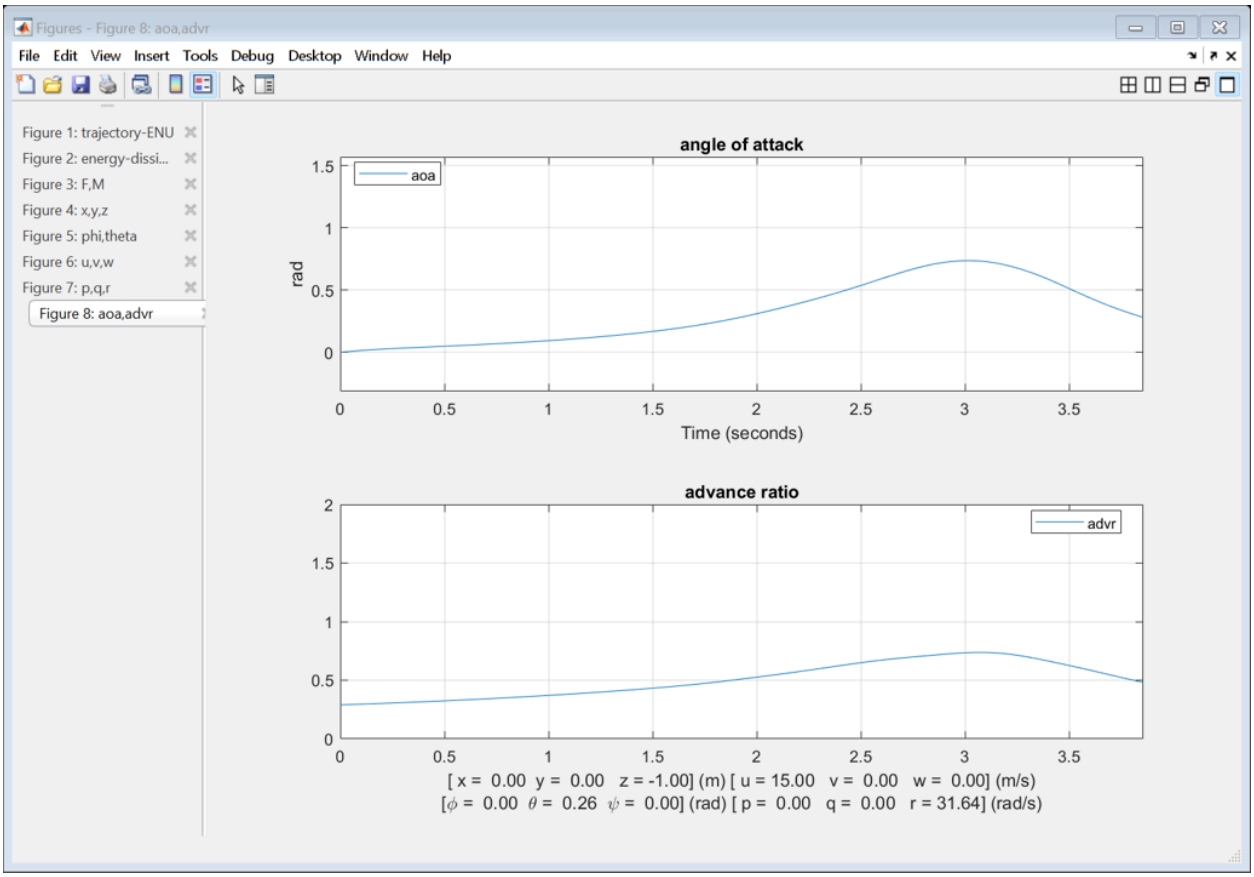

Figures - Figure 3: F,M
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: trajectory-ENU
Figure 2: energy-dissi...
Figure 3: F,M
F
N
Fx
Fy
Fz
M
N-m
Mϕ
Mθ
Mψ
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)

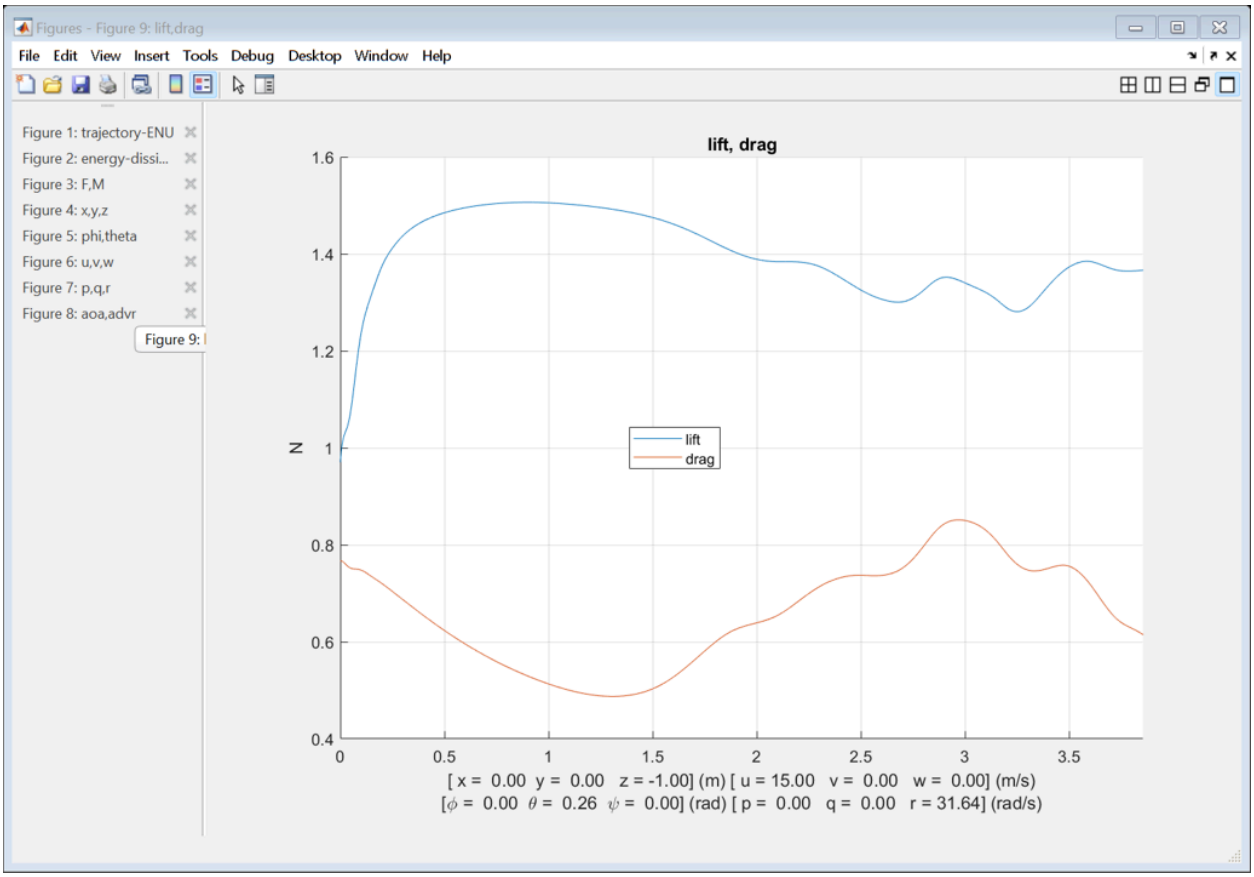

Figures - Figure 4: x,y,z
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: trajectory-ENU
Figure 2: energy-dissi...
Figure 3: F,M
Figure 4: x,y,z
x,y
x
y
m
z-up
z
m
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)

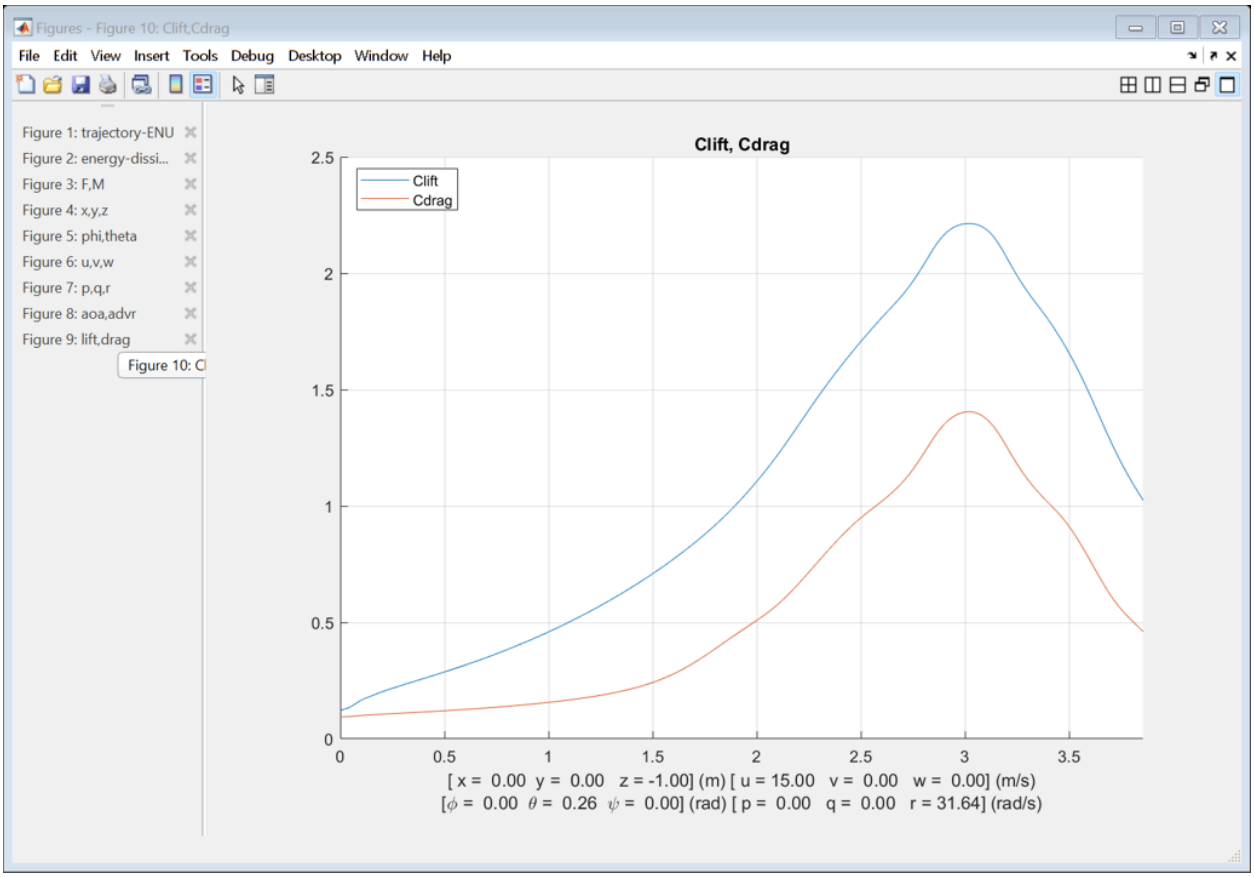

Figures - Figure 5: phi,theta
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: trajectory-ENU
Figure 2: energy-dissi...
Figure 3: F,M
Figure 4: x,y,z
angles
rad
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
0.5
1
1.5
2
2.5
3
3.5
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)


Figures - Figure 6: u,v,w
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: trajectory-ENU
Figure 2: energy-dissi...
Figure 3: F,M
Figure 4: x,y,z
Figure 5: phi,theta
Figure 6: u,v,w
velocity
u
v
w
m/s
m/s
Time (seconds)
|v|
v-inf
m/s
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)


Figures - Figure 7: p,q,r
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: trajectory-ENU
Figure 2: energy-dissi...
Figure 3: F,M
Figure 4: x,y,z
Figure 5: phi,theta
Figure 6: u,v,w
Figure 7: p,q,r
p,q
rad/sec
p
q
r
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)


Figures - Figure 8: aoa,advr
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: trajectory-ENU
Figure 2: energy-dissi...
Figure 3: F,M
Figure 4: x,y,z
Figure 5: phi,theta
Figure 6: u,v,w
Figure 7: p,q,r
Figure 8: aoa,advr
angle of attack
aoa
rad
Time (seconds)
advance ratio
advr
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)


Figures - Figure 9: lift,drag
File Edit View Insert Tools Debug Desktop Window Help
Figure 1: trajectory-ENU
Figure 2: energy-dissi...
Figure 3: F,M
Figure 4: x,y,z
Figure 5: phi,theta
Figure 6: u,v,w
Figure 7: p,q,r
Figure 8: aoa,advr
Figure 9:
lift, drag
N
lift
drag
1.6
1.4
1.2
1
0.8
0.6
0.4
0
0.5
1
1.5
2
2.5
3
3.5
[x = 0.00 y = 0.00 z = -1.00] (m) [u = 15.00 v = 0.00 w = 0.00] (m/s)
[ϕ = 0.00 θ = 0.26 ψ = 0.00] (rad) [p = 0.00 q = 0.00 r = 31.64] (rad/s)




```
Elapsed time is 24.613998 seconds.
```

work-in-progress

```
% pitch_sweep;
% toc( tic0);

% roll_sweep;
% toc( tic0);
```

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