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```
% Astrobee Model
```

System

```
% A Matrix

load Matrices/A_matrix.mat
A = A_matrix

% B Matrix: Stowed

load Matrices/B_stowed.mat
B = B_stowed

% % Full-State Feedback
%
% Cf = eye(12);
%
% Df = [zeros(12, 6)];
%
% sys_full = ss(A, B, Cf, Df);
%
% tf_full = tf(sys_full);
%
% syms s
%
% tf_full_sym = simplify(Cf * inv(s * eye(12) - A) * B + Df);
% pretty(tf_full_sym)

% Coordinate Feedback

Cc = [zeros(6, 12)];
Cc(1:6, 7:12) = eye(6);

Dc = [zeros(6, 6)];

sys_coord = ss(A, B, Cc, Dc);

tf_coord = tf(sys_coord);

syms s
```

```
tf_coord_sym = simplify(Cc * inv(s * eye(12) - A) * B + Dc);
pretty(tf_coord_sym)

% translation_coord_sym = [tf_coord_sym(4:6, 7:9); tf_coord_sym(7:9,
 7:9)];
% pretty(translation_coord_sym)

% attitude_coord_sym = [tf_coord_sym(4:6, 4:6); tf_coord_sym(10:12,
 4:6)];
% pretty(attitude_coord_sym)

A =
     0     0     0     0     0     0     0     0     0     0     0
  0
     0     0     0     0     0     0     0     0     0     0     0
  0
     0     0     0     0     0     0     0     0     0     0     0
  0
     0     0     0     0     0     0     0     0     0     0     0
  0
     0     0     0     0     0     0     0     0     0     0     0
  0
     0     0     0     0     0     0     0     0     0     0     0
  0
     1     0     0     0     0     0     0     0     0     0     0
  0
     0     1     0     0     0     0     0     0     0     0     0
  0
     0     0     1     0     0     0     0     0     0     0     0
  0
     0     0     0     1     0     0     0     0     0     0     0
  0
     0     0     0     0     1     0     0     0     0     0     0
  0
     0     0     0     0     0     1     0     0     0     0     0
  0
B =
    0.0630         0         0         0         0         0
         0    0.0630         0         0         0         0
         0         0    0.0630         0         0         0
         0         0         0    5.4054         0         0
         0         0         0         0    4.9505         0
         0         0         0         0         0    5.3191
         0         0         0         0         0         0
         0         0         0         0         0         0
         0         0         0         0         0         0
         0         0         0         0         0         0
         0         0         0         0         0         0
         0         0         0         0         0         0
/   500                                                   \
| -------,    0,       0,      0,      0,     0   |
|        2                                                 |
| 7939 s                                                   |
|                                                          |
```

```
|          500                                        |
|   0,   -------,   0,      0,      0,      0         |
|              2                                      |
|        7939 s                                       |
|                                                     |
|                   500                               |
|   0,      0,   -------,   0,      0,      0         |
|                      2                              |
|                7939 s                               |
|                                                     |
|                           200                       |
|   0,      0,      0,    -----,    0,      0         |
|                              2                      |
|                         37 s                        |
|                                                     |
|                                   500               |
|   0,      0,      0,      0,   ------,    0         |
|                                     2               |
|                                101 s                |
|                                                     |
|                                           250       |
|   0,      0,      0,      0,      0,    -----       |
|                                              2      |
\                                         47 s      /
```

Section 1: Translation Controller Design -> Unstable Double-Pole at the Origin

```
% Run this section first to calculate 'tz' to ensure that the second
 interpolation condition is satisfied

% d^k(T)/ds^k|(s=0) = 0, where k = 1 (since there is a double unstable
 pole
% (multiplicity ap = 2) in the plant at s = 0; k = ap - 1) -> 2nd
% interpolation condition

C = 250/47; % Constant
Wn = 1; % Natural Frequency of the Control System
K = Wn^2/C; % Controller Gain
Z = 2^-0.5; % Damping Ratio
tp = 1/(10*Wn); % Time constant (of the included pole)
tpx = 0.5; % Time constant (of the pole included to drop Youla at high
 frequencies)

syms s tz

T_eqn = ((K*C)*(tz*s + 1)/((s^2 + 2*Z*Wn*s + Wn^2)*(tp*s + 1)*(tpx*s +
 1)^2));
dT_eqn = diff(T_eqn,s);
eqn = subs(dT_eqn,s,0) == 0;
tz = double(solve(eqn,tz))
```

```
tz =
    2.5142
```

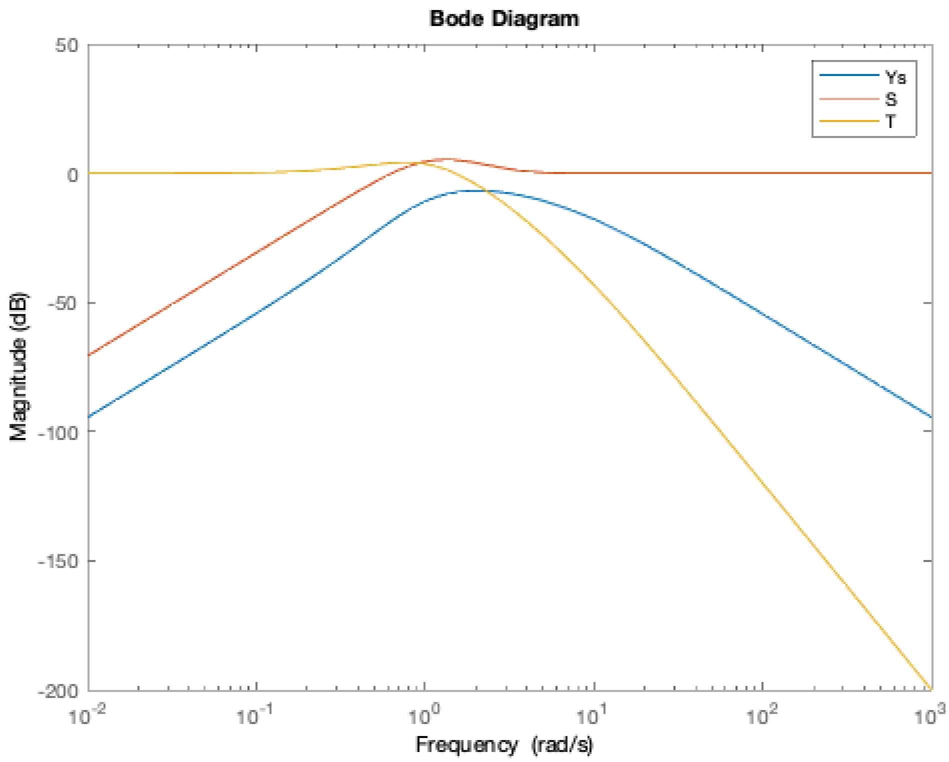
Section 3: Translation Controller Design -> Unstable Double-Pole at the Origin

```
% Youla Control Design

s = tf('s');

% % Constants & Design Parameters
% C = 500/7939; % Constant
% Wn = 3.25; % Natural Frequency of the Control System
% K = Wn^2/C; % Controller Gain
% Z = 2^-0.5; % Damping Ratio
% tp = 1/(10*Wn); % Time Constant of the added pole
% tz = (4*2^(1/2))/13 + 2/65; % 100*2^(1/2) + 10;

% Plant TF, 'Gp'
Gp = minreal(C/s^2)

% Chosen Youla Parameter, 'Y' -> Y(0) = 0
Ys = minreal(((K*s^2)*(tz*s + 1)/((s^2 + 2*Z*Wn*s + Wn^2)*(tp*s +
 1)*(tpx*s + 1)^2)),1e-04)

% Complementary Sensitivity TF, 'T' -> T(0) = 1 (1st interpolation
% condition)
T = minreal((Ys*Gp),1e-04)

% Sensitivity TF, 'S'
S = minreal((1-T),1e-04)

% Controller TF, 'Gc'
Gc = minreal((Ys/S),1e-04)

% Return Ratio, 'L'
L = minreal((Gc*Gp),1e-04)

GpS = minreal((Gp*S),1e-04)

% Internal stability check
Ys_stability = isstable(Ys)
T_stability = isstable(T)
S_stability = isstable(S)
GpS_stability = isstable(GpS)

M2 = 1/getPeakGain(S) % M2-margin
BW = bandwidth(T) % Bandwidth of the closed-loop
AE = getPeakGain(Ys) % Maximum actuator effort

figure(1)
bodemag(Ys, S, T);
```

```
legend('Ys','S','T');
```

```
Gp =

  5.319
  -----
   s^2

Continuous-time transfer function.


Ys =

                 18.91 s^3 + 7.52 s^2
  -----------------------------------------------------
  s^5 + 15.41 s^4 + 64.8 s^3 + 116.2 s^2 + 100.6 s + 40

Continuous-time transfer function.


T =

                     100.6 s + 40
  -----------------------------------------------------
  s^5 + 15.41 s^4 + 64.8 s^3 + 116.2 s^2 + 100.6 s + 40

Continuous-time transfer function.


S =

  s^5 + 15.41 s^4 + 64.8 s^3 + 116.2 s^2 - 2.274e-13 s - 1.847e-13
  ----------------------------------------------------------------
       s^5 + 15.41 s^4 + 64.8 s^3 + 116.2 s^2 + 100.6 s + 40

Continuous-time transfer function.


Gc =

          18.91 s + 7.52
  --------------------------------
  s^3 + 15.41 s^2 + 64.8 s + 116.2

Continuous-time transfer function.


L =

               100.6 s + 40
  --------------------------------------
  s^5 + 15.41 s^4 + 64.8 s^3 + 116.2 s^2
```

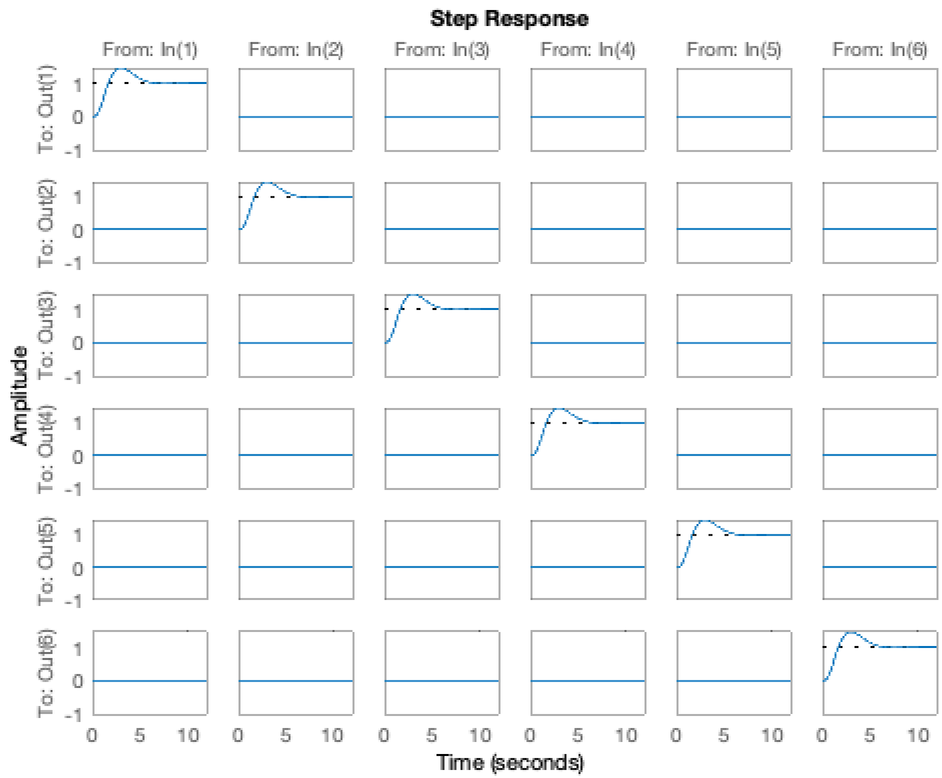
```
Continuous-time transfer function.


GpS =

         5.319 s^3 + 81.99 s^2 + 344.7 s + 618.2
  -----------------------------------------------------
  s^5 + 15.41 s^4 + 64.8 s^3 + 116.2 s^2 + 100.6 s + 40

Continuous-time transfer function.

Ys_stability =
  logical
   1
T_stability =
  logical
   1
S_stability =
  logical
   1
GpS_stability =
  logical
   1
M2 =
    0.5469
BW =
    1.8487
AE =
    0.4587
```

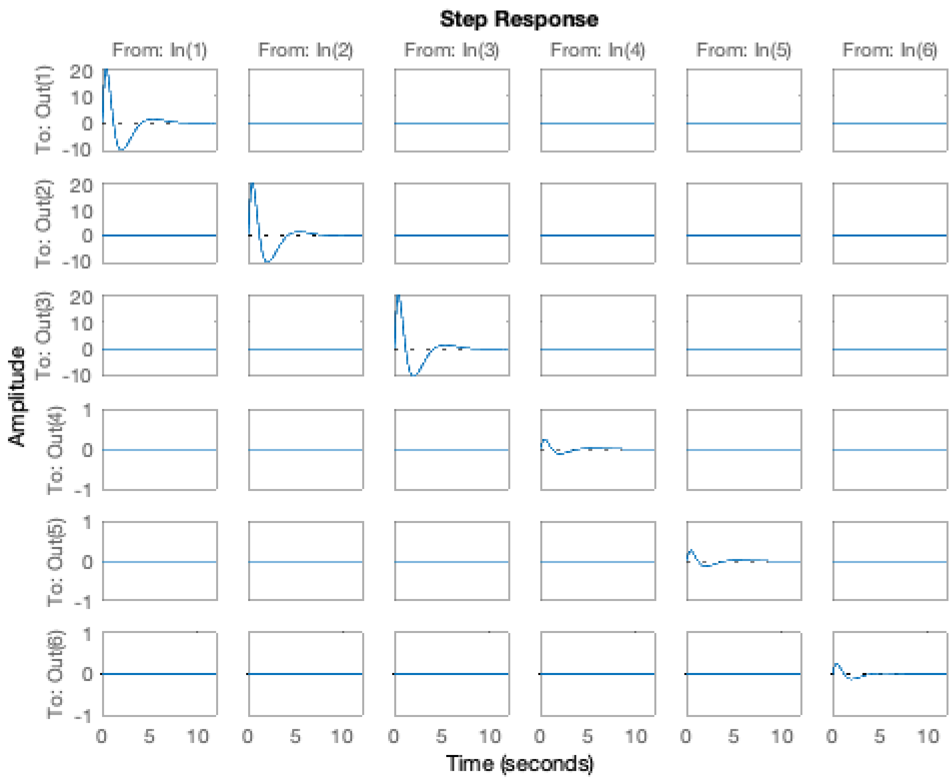


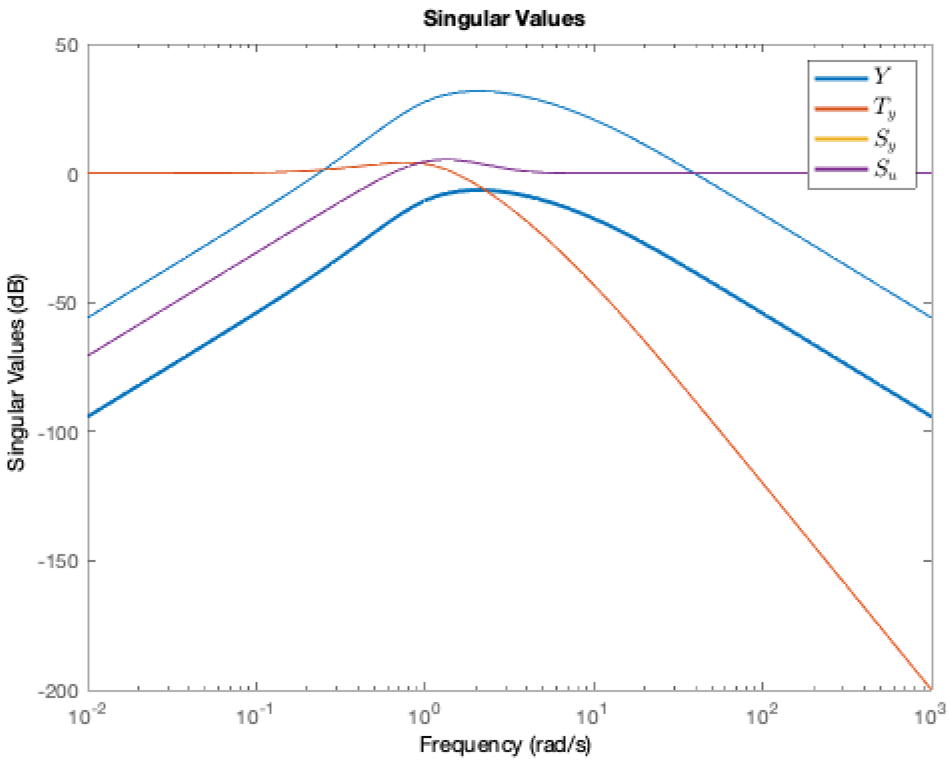
Simulation

```
load Gcs.mat

Gp = minreal(tf_coord, 1e-04);
Gc = minreal([Gc1 0 0 0 0 0; 0 Gc2 0 0 0 0; 0 0 Gc3 0 0 0; 0 0 0 Gc4 0
 0; 0 0 0 0 Gc5 0; 0 0 0 0 0 Gc6], 1e-04);
Lu = minreal(Gc * Gp, 1e-04);
Ly = minreal(Gp * Gc, 1e-04);
Y = minreal(inv(eye(6) + Lu) * Gc);
Ty = minreal(inv(eye(6) + Ly) * Ly);
Sy = minreal(inv(eye(6) + Ly), 1e-04);
Su = minreal(inv(eye(6) + Lu), 1e-04);

figure
step(Ty);

figure
step(Y);

figure
sigma(Y, Ty, Sy, Su)
[l, hObj] = legend('$Y
$', '$T_{y}$', '$S_{y}$', '$S_{u}$','Interpreter','latex','FontSize',
 12);
```

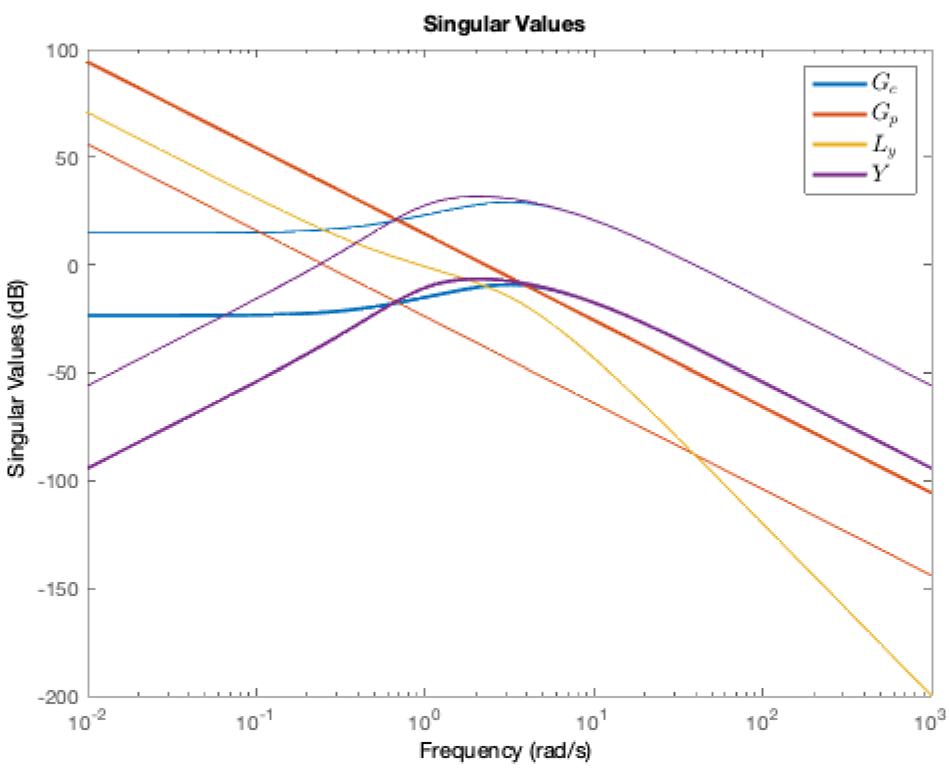
```
set(l,'string',{'$Y$', '$T_{y}$', '$S_{y}$', '$S_{u}$'});
hL = findobj(hObj,'type','line');
set(hL,'linewidth', 2);

figure
sigma(Gc, Gp, Ly, Y)
[l, hObj] = legend('$G_{c}$', '$G_{p}$', '$L_{y}$', '$Y
$','Interpreter','latex','FontSize', 12);
set(l,'string',{'$G_{c}$', '$G_{p}$', '$L_{y}$', '$Y$'});
hL = findobj(hObj,'type','line');
set(hL,'linewidth', 2);

figure
sigma(Gc, Gp, Y)
[l, hObj] = legend('$G_{c}$', '$G_{p}$', '$Y
$','Interpreter','latex','FontSize', 12);
set(l,'string',{'$G_{c}$', '$G_{p}$', '$Y$'});
hL = findobj(hObj,'type','line');
set(hL,'linewidth', 2);

figure
sigma(Ly, Sy, Ty)
[l, hObj] =
 legend('$L_{y}$', '$S_{y}$', '$T_{y}$','Interpreter','latex','FontSize',
 12);
set(l,'string',{'$L_{y}$', '$S_{y}$', '$T_{y}$'});
hL = findobj(hObj,'type','line');
set(hL,'linewidth', 2);

figure
sigma(Sy, Su)
[l, hObj] =
 legend('$S_{y}$', '$S_{u}$','Interpreter','latex','FontSize', 12);
set(l,'string',{'$S_{y}$', '$S_{u}$'});
hL = findobj(hObj,'type','line');
set(hL,'linewidth', 2);
```


Step Response
From: In(1)
From: In(2)
From: In(3)
From: In(4)
From: In(5)
From: In(6)
To: Out(1)
To: Out(2)
To: Out(3)
To: Out(4)
To: Out(5)
To: Out(6)
Amplitude
Time (seconds)

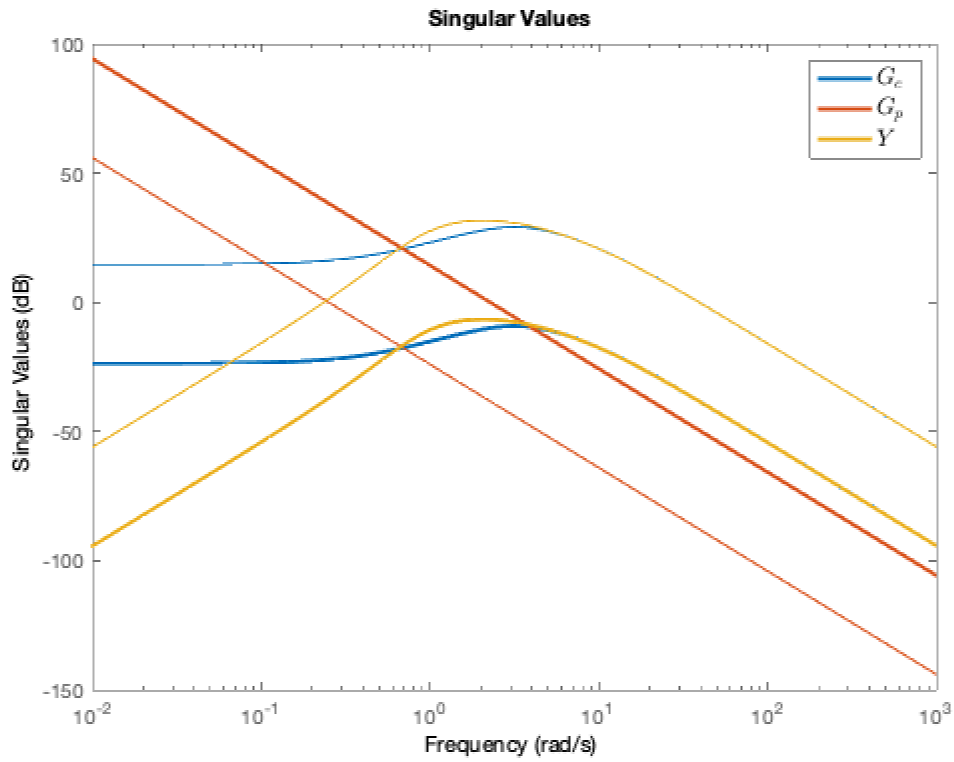

Step Response
From: In(1)
From: In(2)
From: In(3)
From: In(4)
From: In(5)
From: In(6)
To: Out(1)
To: Out(2)
To: Out(3)
To: Out(4)
To: Out(5)
To: Out(6)
Amplitude
Time (seconds)

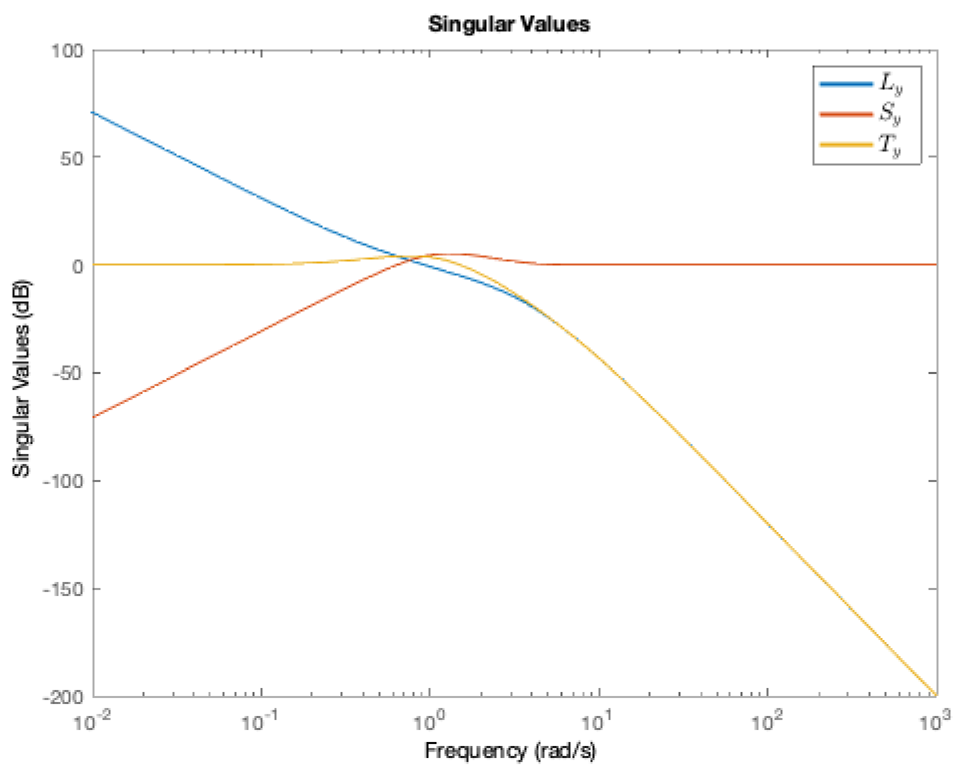


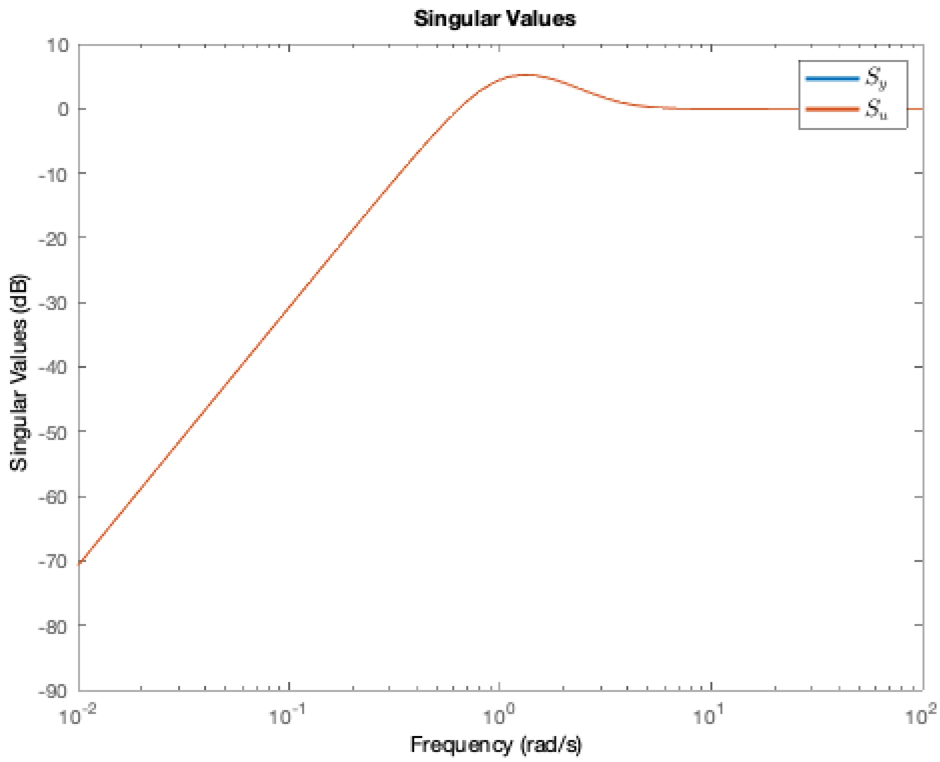
Singular Values
Singular Values (dB)
Frequency (rad/s)
Y
T_y
S_y
S_u



Singular Values
Singular Values (dB)
Frequency (rad/s)
G_c
G_p
L_y
Y


Singular Values
G_c
G_p
Y
Singular Values (dB)
Frequency (rad/s)
100
50
0
-50
-100
-150
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}


Singular Values
L_y
S_y
T_y
Singular Values (dB)
Frequency (rad/s)
100
50
0
-50
-100
-150
-200
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}



Coordinate Feedback

```
% Cc = [zeros(6, 12)];
% Cc(1:6, 1:6) = eye(6);
%
% Dc = [zeros(6, 6)];
%
% sys_coord = ss(A, B, Cc, Dc);
%
% tf_coord = tf(sys_coord);
%
% syms s
%
% tf_coord_sym = simplify(Cc * inv(s * eye(12) - A) * B + Dc);
% pretty(tf_coord_sym)
%
% translation_coord = [tf_coord_sym(1:3, 1:3); tf_coord_sym(7:9,
 1:3)];
% pretty(translation_coord)
%
% attitude_coord = [tf_coord_sym(4:6, 4:6); tf_coord_sym(10:12, 4:6)];
% pretty(attitude_coord)
```

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