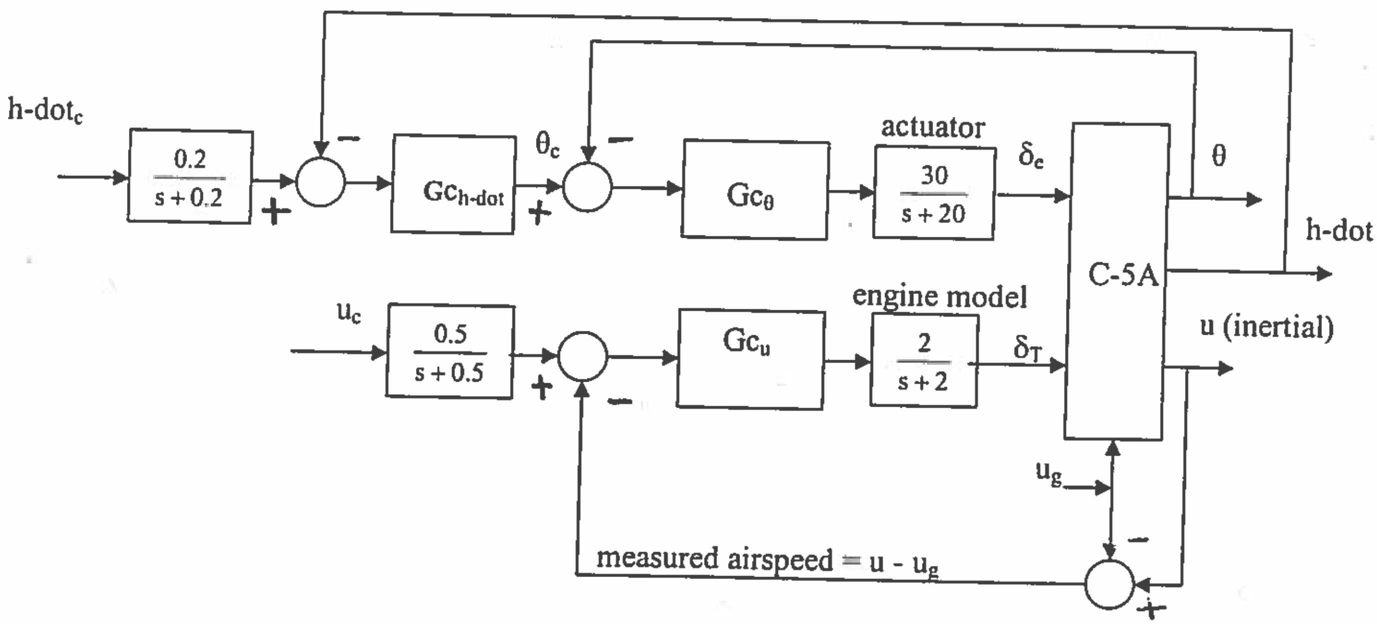
University of California, Davis
Dept. of Mechanical and Aerospace Engineering

MAE-275

Mid-Term Project

Friday, May 22

This problem will involve designing an altitude-rate and airspeed autopilot system for the C-5A aircraft shown on the next page. The flight condition is level flight at sea level at a trim airspeed of 246 ft/sec. The pertinent stability derivatives are also enclosed. This means determining the transfer functions Gc_θ, $Gc_{h\text{-dot}}$ and Gc_u in the diagram below. Use loop shaping and sequential loop closure in the problem. All variables in the figure represent deviations from trim values.



The design requirements are:

1.) Pitch-attitude loop bandwidth approximately 2 rad/sec. Airspeed loop bandwidth approx. 0.5 rad/sec Altitude loop bandwidth approx. 0.2 rad/sec.

2.) Gain and phase margins of at least 12 dB and 45 deg in each loop.

3.) Strictly proper compensators, i.e., each with more poles than zeros.

4.) Zero steady state errors to filtered step h_c and u_c.

Simulation: Place limiters immediately after the actuator and engine model to limit elevator angles to ± 20/57.3 rad from the trim position and thrust input to ± 70,000 lbf from trim value.

Simulate the response of your system to
(1) a filtered step altitude-rate command of 20 ft/sec and a filtered step airspeed command of 20 ft/sec, applied simultaneously.

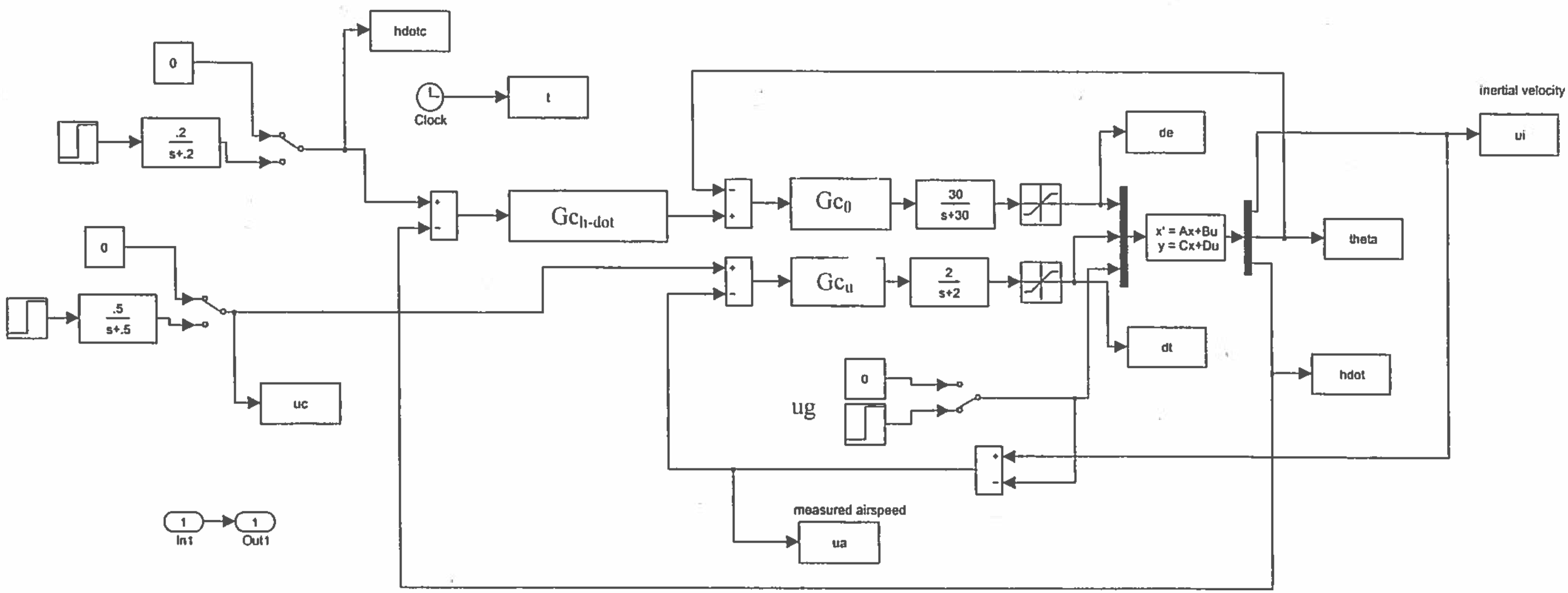
(2) A step u_g of 20 ft/sec (a tail wind), without the altitude and airspeed commands. Only u_g is needed in your model, not w_g or q_g.

Show plots of control inputs δ_e and δ_T and the response variables θ, h, and u in the maneuver and gust response simulations. Plot angles in units of deg, and deg/sec. Your results should include:

a.) Compensator transfer functions Gc_θ, $Gc_{h\text{-dot}}$ and Gc_u
b.) Nyquist sketches (3) for the θ, u and h-dot loops as you move through the design.
c.) Gain and phase margins for each loop
d.) Bode diagrams (3) for open-loop transfer functions as you move through the design
e.) Closed loop Bode diagrams (2) for transfer functions u/u_c and h-dot/h-dot$_c$
f.) Simulink diagram

Stability derivatives in <u>stability axis</u> system given below. These derivatives assume angles in rad and thrust in lbf. Any derivatives not shown can be assumed to be zero

$X_u = -0.0214$	$X_{\delta T} = 0.554e\text{-}4$	$U_0 = 246$ ft/sec
$X_w = 0.0957$	$X_{\delta e} = 0.45$	
$Z_u = -0.231$	$Z_{\delta T} = -0.193e\text{-}5$	
$Z_w = -0.634$	$Z_{\delta e} = -9.53$	
$Z_{\dot{w}} = 0$	$Z_q = 0$	
$M_u = -0.778e\text{-}5$	$M_{\delta T} = 0.144e\text{-}6$	$M_{\dot{w}} = -0.000884$
$M_w = -0.00145$	$M_{\delta e} = -0.688$	$M_q = -0.610$



hdotc
0
.2
s+.2
Clock
t
Gch-dot
0
.5
s+.5
uc
In1
Out1
Gc0
30
s+30
Gcu
2
s+2
de
dt
x' = Ax+Bu
y = Cx+Du
theta
hdot
inertial velocity
ui
ug
0
measured airspeed
ua