X-48B Phase 1 Flight Maneuver Database and ICP Airspace Constraint Analysis

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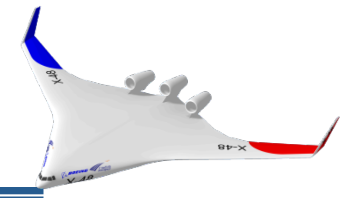
Agenda

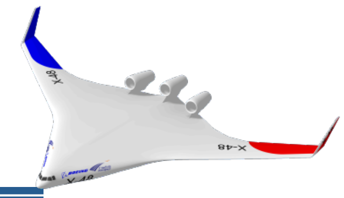


- Flight Maneuver Database
- Airspace Constraint Analysis
  - Ground Circles
  - Air Circles
- V & V and Boeing X-48 Simulator
- Flight Control Theory

Flight Maneuver Database

X-48B Phase 1

Flight Maneuver Database

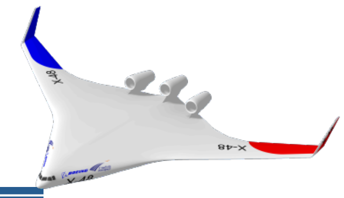


- Purpose:

  To provide a comprehensive database with information covering all flights, maneuvers, time slices, and conversions.

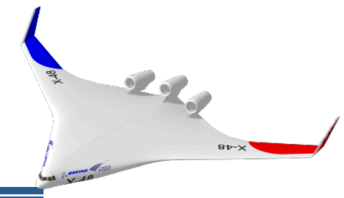
- Initially started by Eric Blood
  - Analyzed data files for maneuver patterns
  - Developed 10 scripts to analyze data files
  - Took nearly 20 hours to understand
  - Was not current

My Contributions



- Streamlined population process
  - 2 scripts used to add new data set
  - Takes less that 30 min to add a flight data file
- Developed text-file to walk-through process
- Now tracking purpose of each flight
- Added Flight Database Tab
- Updated database with Flights 62-80

Flight Maneuver Database



	A	B	C	D	E	F	G	H	I	J	K	
1	Flight Number	Date	Slat Configuration	Weight	CG Location	VMS Version	dat2mat Version	Pilot	Local Time Correction	Chase	Runway	Purpose
2	1											Engine response, Spe
3	2											SHSS
4	3											PID Maneuvers, SHSS
5	4											PIDs, SHSS
6	5											SHSS, B to B turns, PI
7	6											WUT, 1 and 2 Engine
8	7											Auto-trim, Bank hold, A
9	8											PID doublets, Freq sw
10	9											aft CG evaluation
11	10											SHSS, PIDs
12	11											PID Freq sweeps, B to
13	12											First flight Slats Retrac
14	13											mid CG data
15	14											mid CG data / software
16	15											forward CG data / VMS
17	16											fwd CG data
18	17											fwd CG high speed da
19	18											RTSM maneuvers, PID
20	19											PID Freq sweeps
21	20											aft CG data
22	21											Approach to Stall/Hi A
23	22											Approach to Stall/Hi A
24	23											Training flight
25	24											STALL
26	25											STALL
27	26											Block 3 Software Regr

Flight Configuration / Flight Database / FLT80 / FLT79 / FLT78 / FLT77 / FLT76 / FLT75 / FLT74 / FLT73 / FLT72

Ready 100%

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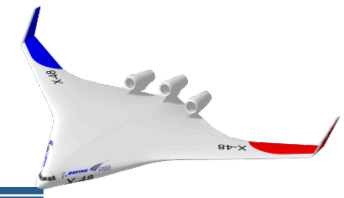
Flight Maneuver Database



	A	B	C	D	E	F	G	H	I
1	Flight Numb	Flight Car	Step	Altitude (f	Airspeed (I	AoA (deg	Level Conditi	Event Type	Notes
2100	65								
2101	65								
2102	65								
2103	65								
2104	65								
2105	65								
2106	65								
2107	65								
2108	65								
2109	65								
2110	65								
2111	65								
2112	65								
2113	65								
2114	65								
2115	66								
2116	66								
2117	66								
2118	66								
2119	66								
2120	66								
2121	66								
2122	66								
2123	66								
2124	66								

Flight Configuration | Flight Database | FLT80 | FLT79 | FLT78 | FLT77 | FLT76 | FLT75 | FLT74 | FLT73 | FLT72

Ready 100%

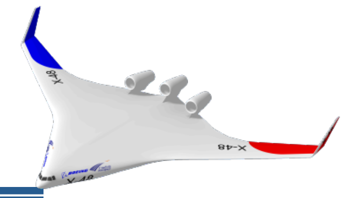
Integrated Control for Performance

Airspace Constraint Analysis

Airspace Constraint Analysis

- Desired Goal
  - Fly as long as possible in the EAFB ROA Area at constant flight condition
- Design Trajectories
  - Maintain boundaries and current wind tolerances
  - Flight Conditions: TBD
- Parameters to use to optimize flight time
  - Indicated Airspeed, Wind Speed, Wind Direction, Bank Angle, Starting Position

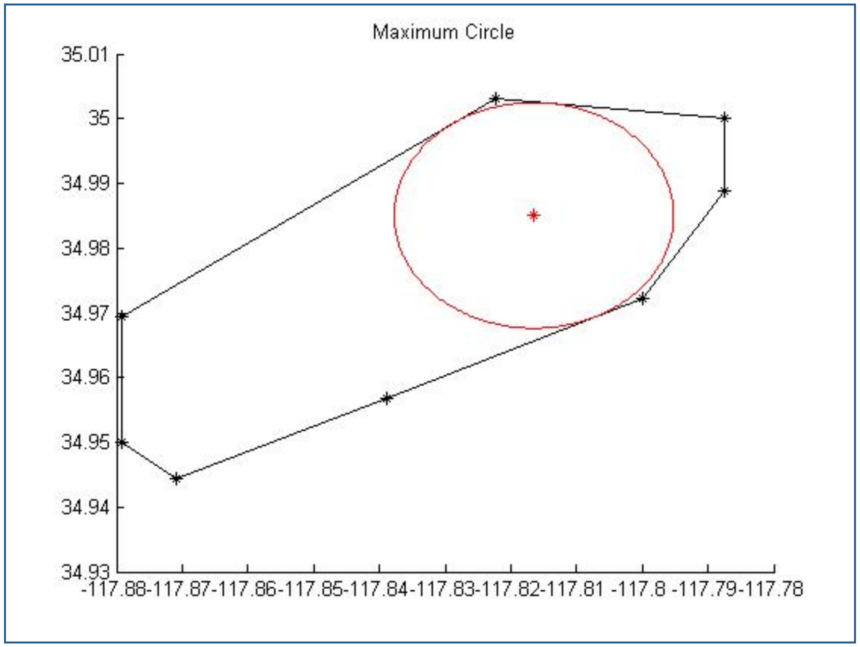
Airspace Constraint Analysis



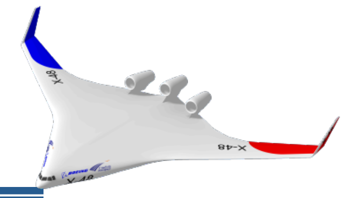
- Ground Circles
  - Constant ground track (unlimited time)
  - Requires various bank angles in wind
  - Risk: Bank angle influences performance
- Air Circles
  - Constant flight condition
  - Ground track pushed by wind (limited time)
  - Risk: Force convergence in short time

Airspace Constraint Analysis

- Ground Circles
  - Maximum circle found for ROA area
  - Bank angle variance caused by wind
  - FTS safety zone subtracted from radius

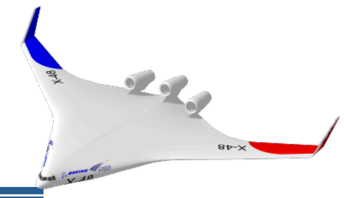


Airspace Constraint Analysis



- Air Circles - Which Approach?
  - Boeing batch simulator
    - Full airplane dynamics
    - Time consuming to use
    - Steep learning curve
  - Develop simple MATLAB numeric solution
    - Quick to run
    - Requires debug and verification
    - Requires assumptions

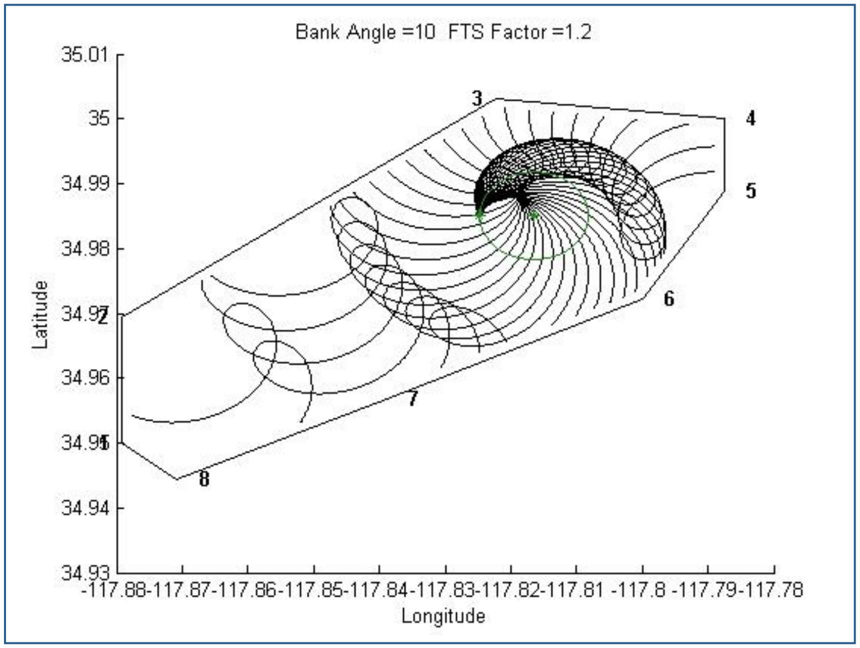
Airspace Constraint Analysis

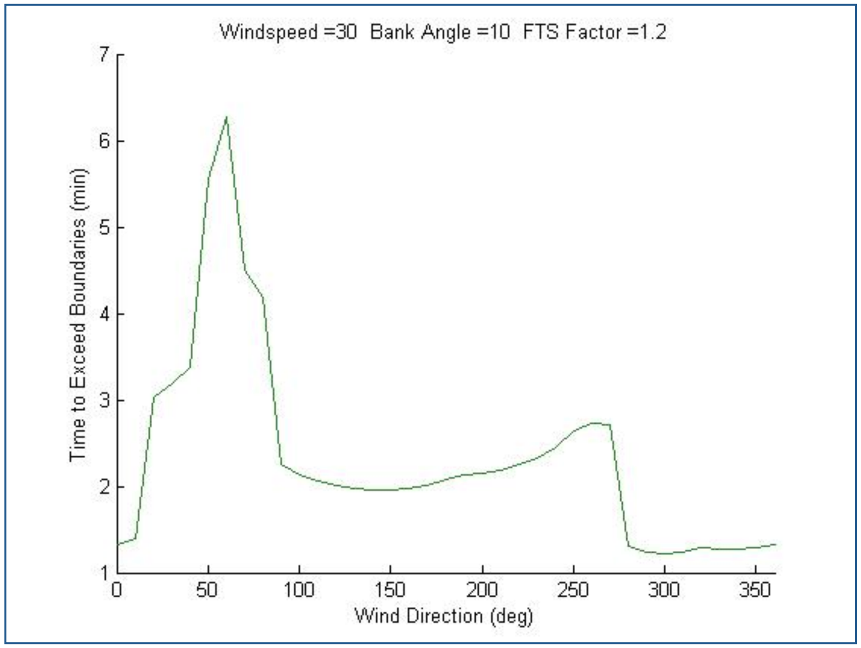


- Assumptions for Numeric Analysis
  - Constant radius circle
    - Constant bank angle
    - Constant altitude
    - Constant airspeed
  - Constant wind (direction and magnitude)
  - Spherical Earth
  - FTS safety buffer is proportional to the radius of the circle flown

Airspace Constraint Analysis

Ground Track Mode





Constant wind magnitude, varying wind direction

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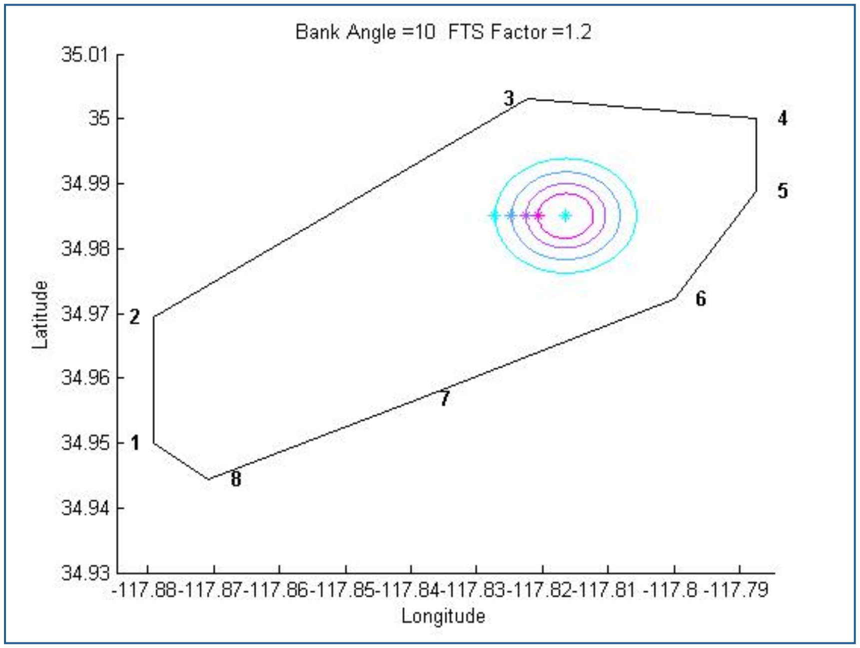
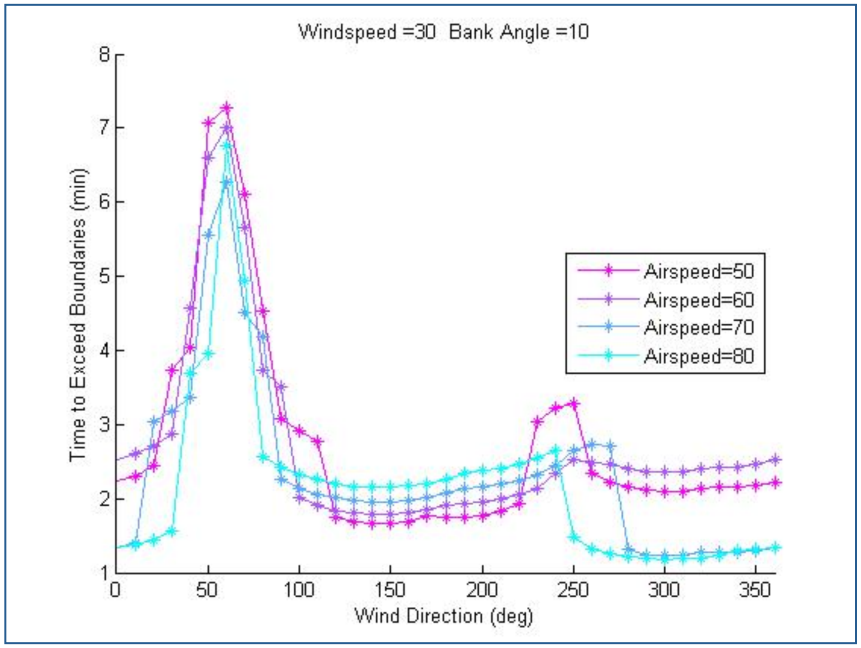
Airspace Constraint Analysis

Airspeed Sensitivity Mode

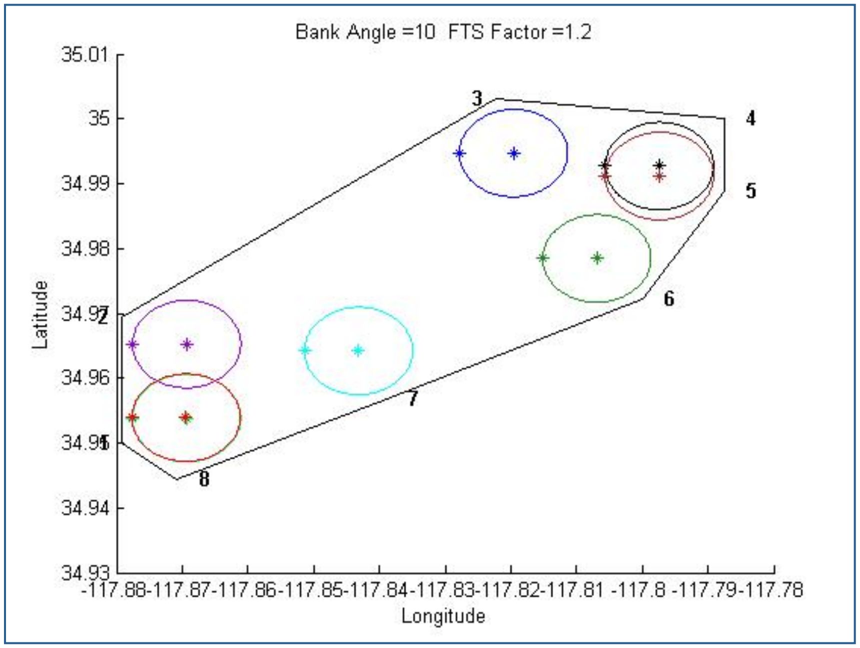


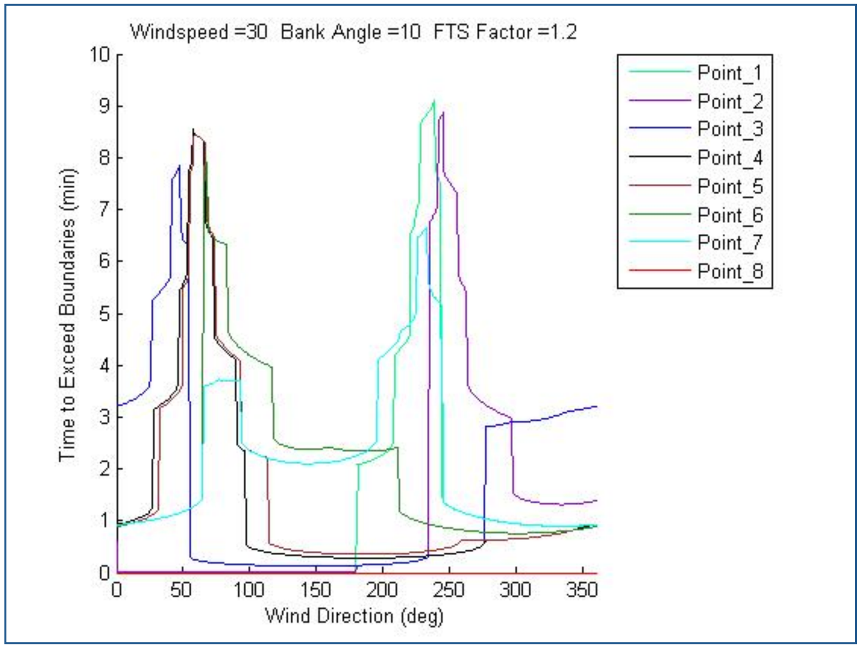


Constant wind magnitude, varying wind direction

Airspace Constraint Analysis

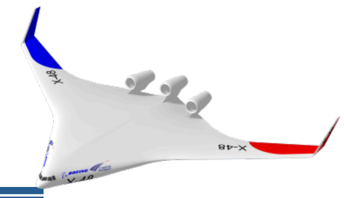
Starting Point Comparison Mode





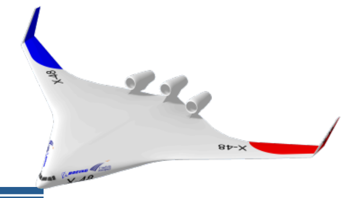
Constant wind magnitude, varying wind direction

V & V and Boeing Sim



- V & V
  - Monitor procedure
  - Connect/disconnect components
  - Toggle bit check
  - Rotate/translate IMU
- Boeing simulator scripts
  - Constant bank (Air Circle)
  - Autopilot on/off
  - Maintain altitude
  - Adjust max/min bank angles
  - Set initial position
  - Set wind components

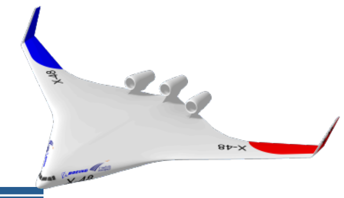
SWOT for X-48



Airspace Constraint Analysis

- Strengths
  - User-friendly
  - Versatile
- Weaknesses
  - Incomplete requirements
  - Still requires validation
- Opportunities
  - Applicable to any aircraft in ROA
- Threats
  - Unknown winds
  - System constraints

X-48B Connection to DFRC



Sub Goal 3E:

Advance knowledge in the fundamental disciplines of aeronautics, and develop technologies for safer aircraft and **higher capacity airplane systems**

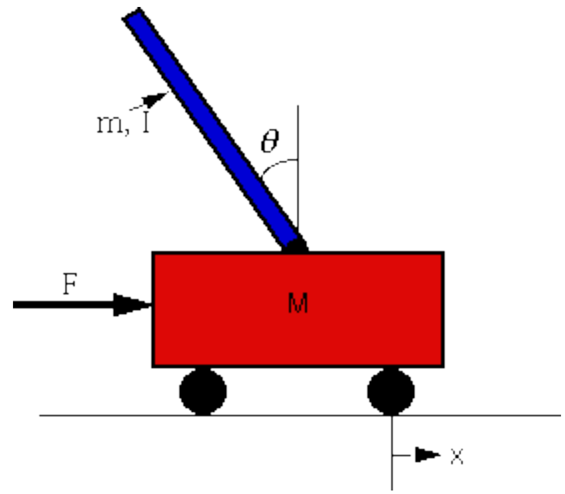
Agency Strategic Goal:

Develop a **balanced** overall program of science, exploration, and **aeronautics** consistent with the redirection of human spaceflight program to focus on exploration.

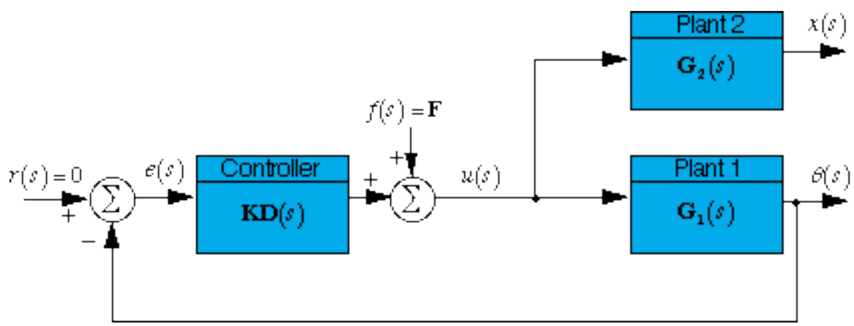
Flight Control Theory

Inverted Pendulum

- System modeling
- Root Locus Design
- PID response
- Frequency response
- LQR Design
- Observer Design



http://www.engin.umich.edu/group/ctm/examples/pend/invpen.html



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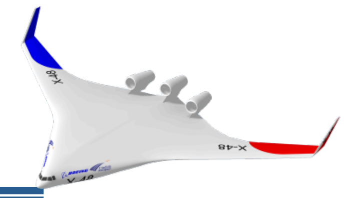
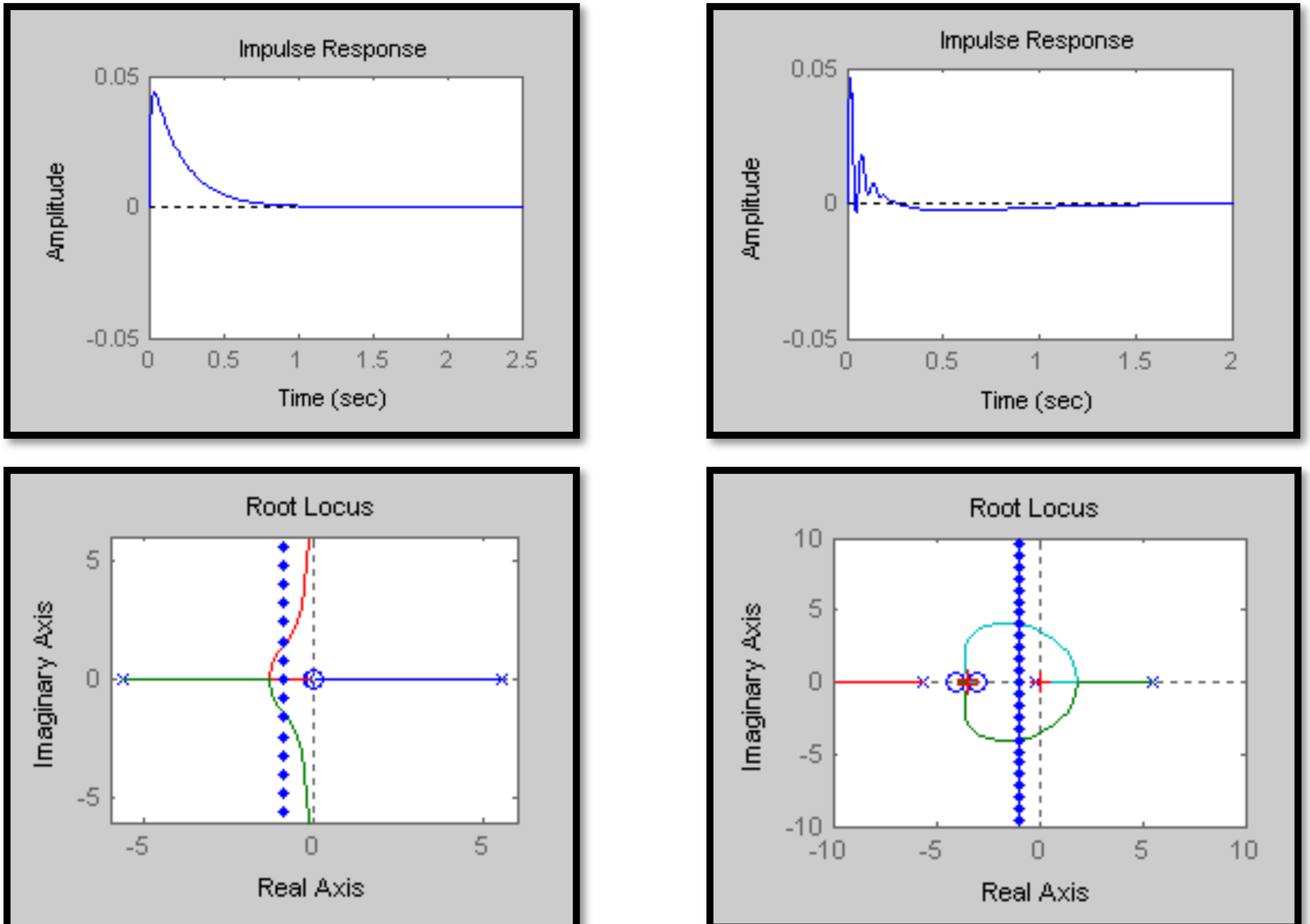
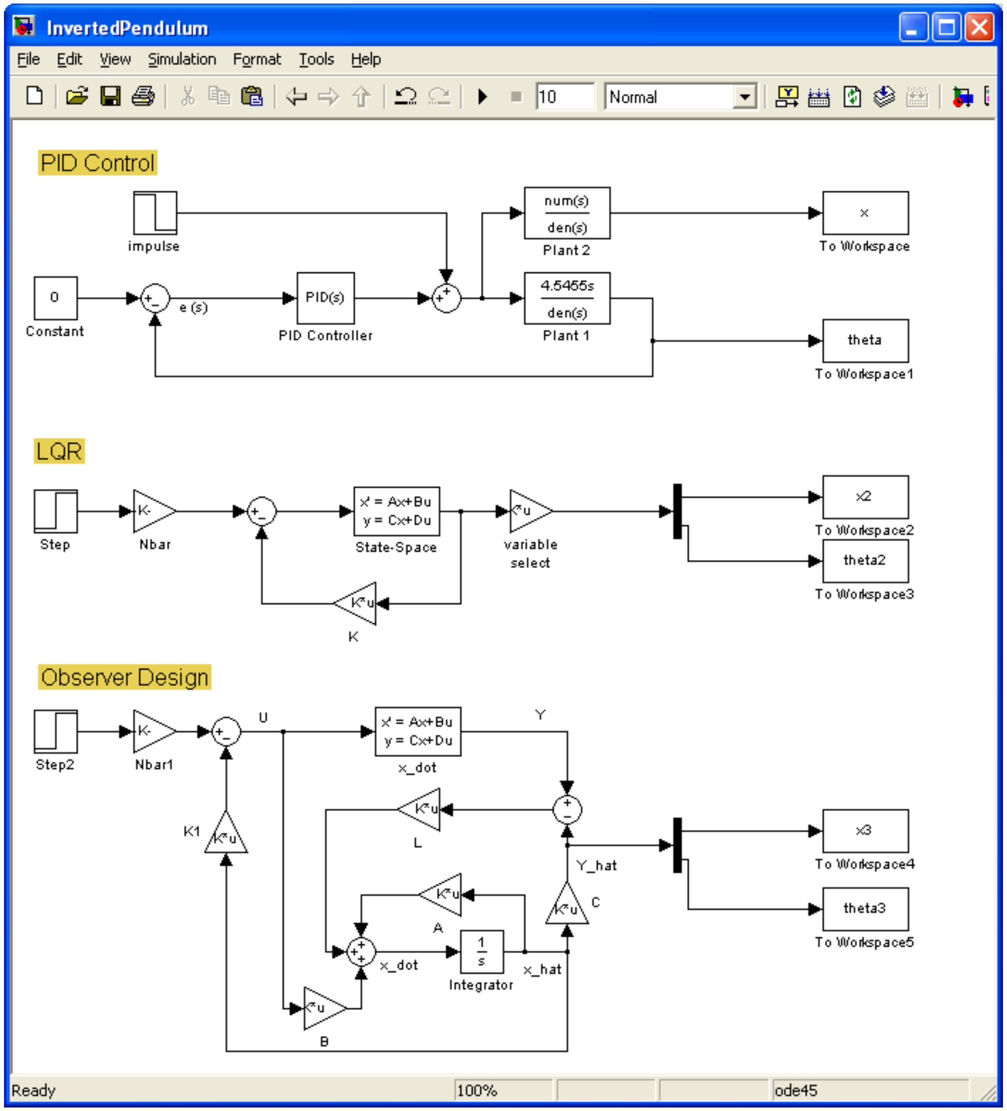
Flight Control Theory



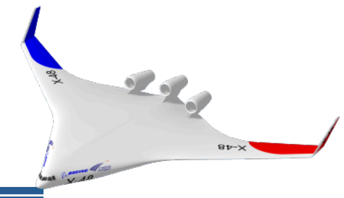


Effect of adding roots and poles

Flight Control Theory



Special Thanks



- Cheng Moua
- Nelson Brown
- Steve Goldthorpe
- Tony Kawano
- Chris Miller and Donna Vasseur

Questions?