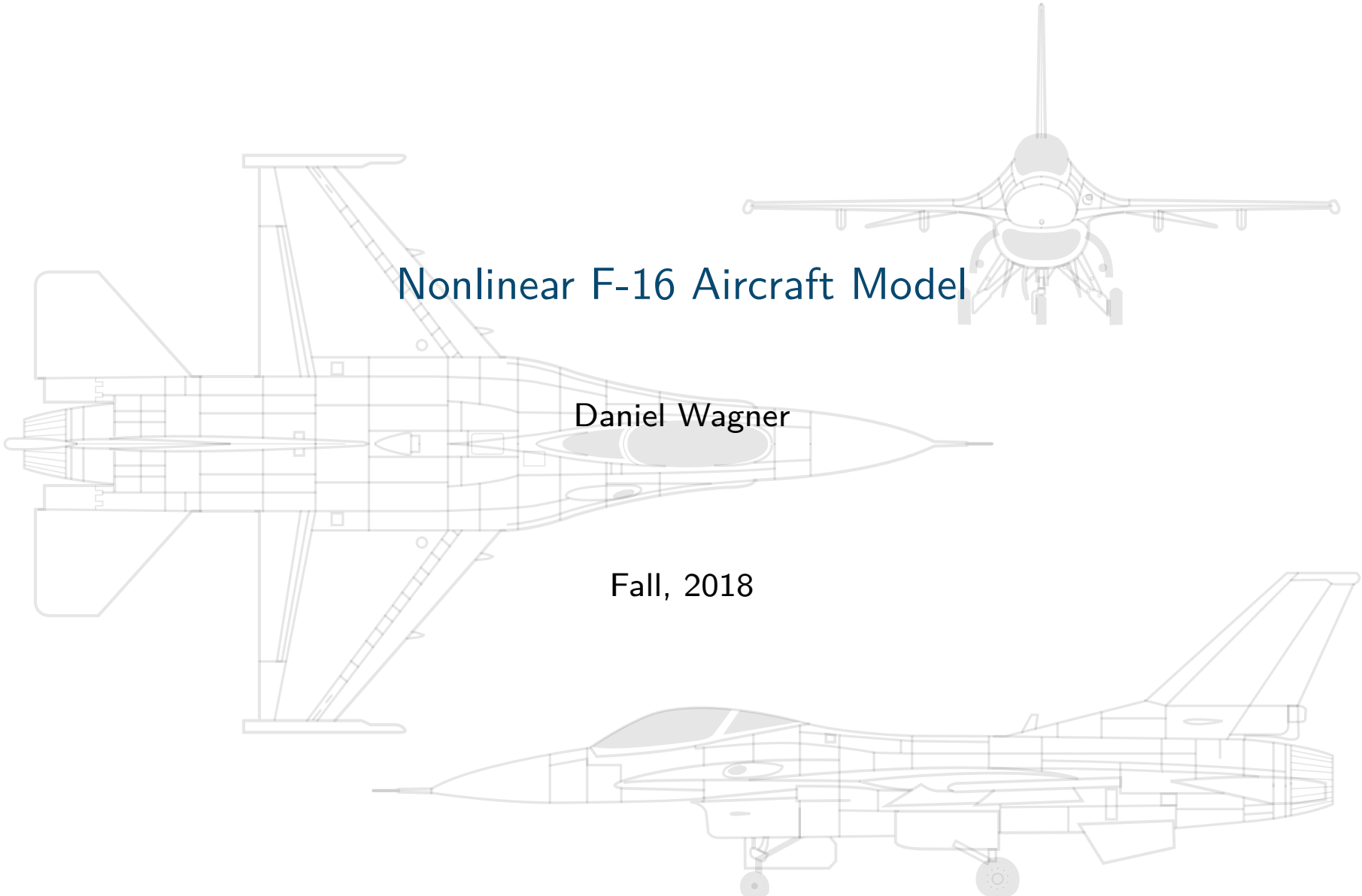

Nonlinear F-16 Aircraft Model

Daniel Wagner

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Why study aircraft control systems?

Brief history

X-15 in flight
NASA Langley Research Center 8/31/1989 Image # EL-2001-00429

1. Frequency domain methods
2. Sputnik and IFAC Moscow 1960
3. Kalman and state space methods
4. Digital control systems
5. Nonlinear control, adaptive control, and the X-15

F-16 “Fighting Falcon”

1. Dynamics of this aircraft are well documented and understood
2. Popular aircraft within the controls research community
3. First use of a relaxed static stability/fly-by-wire flight control system

Design challenge:

Design a flight control system that achieves and maintains longitudinal/lateral performance goals

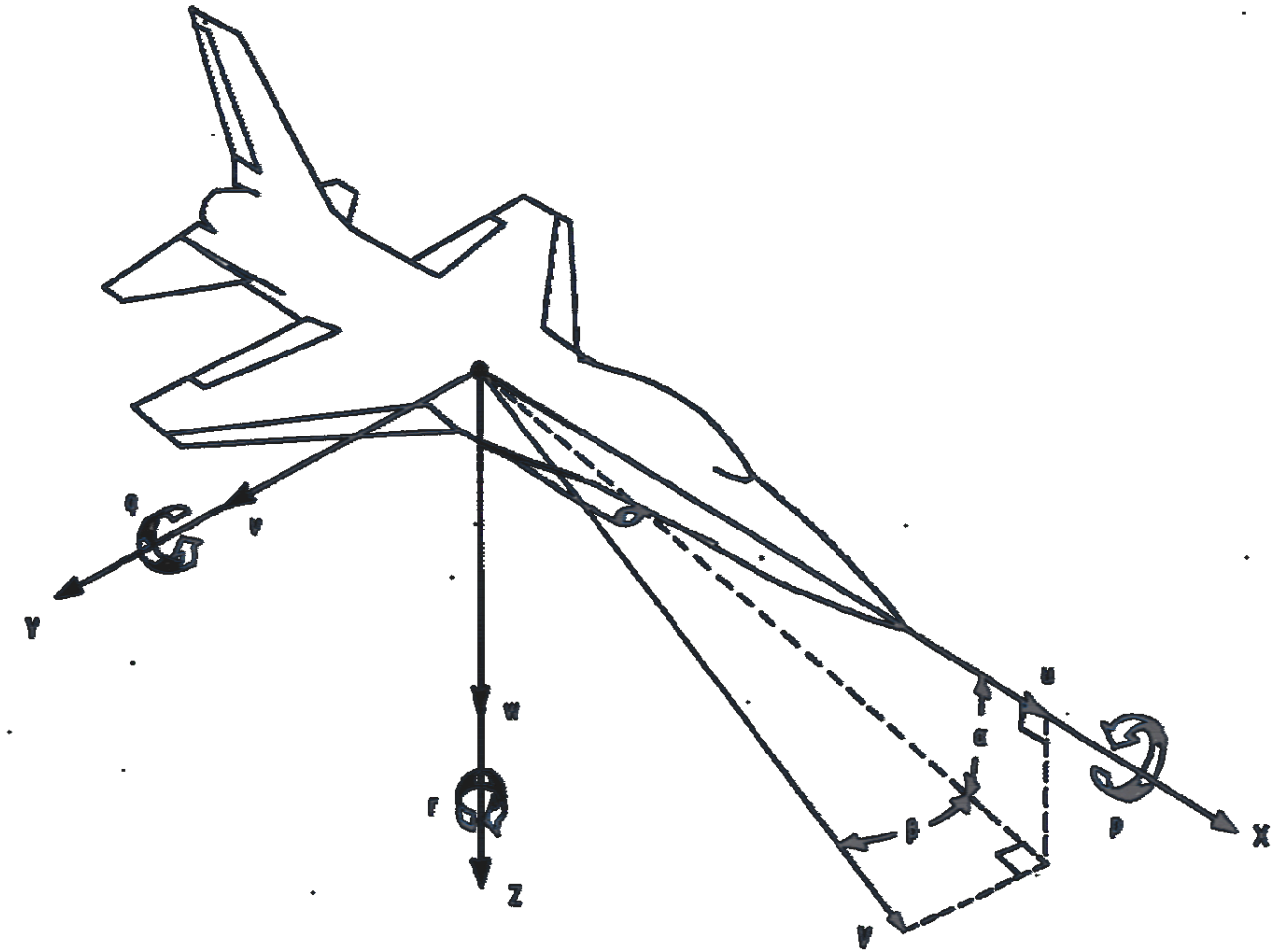
Nonlinear F-16 Aircraft Model

Developed by Dr. Gary Balas et al.

What is included:

- `runF16Sim.m`
- `FindF16Dynamics.m`
- `trim_F16.m`
- `nlplant.c`
- `F16Block.slx`

Equations of Motion

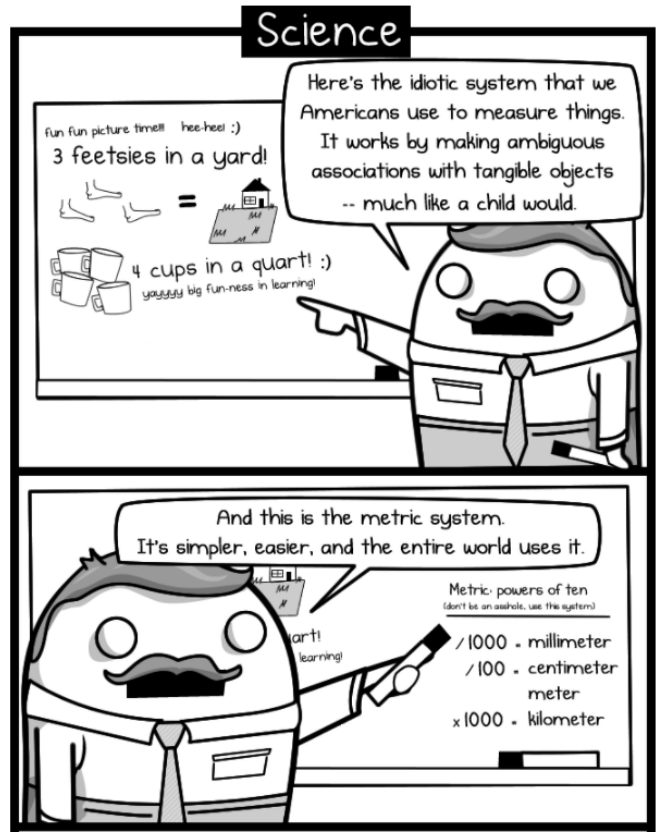


States

Units

State	Passed to **nlplant**	Used by **nlplant**	Passed from **nlplant**
npos	*ft*	*ft*	*ft*
epos	*ft*	*ft*	*ft*
h	*ft*	*ft*	*ft*
ϕ	*rad*	*rad*	*rad*
V_t	ft/s	ft/s	ft/s
α	*rad*	*deg*	*rad*
β	*rad*	*deg*	*rad*
p	rad/s	deg/s	rad/s
q	rad/s	deg/s	rad/s
r	rad/s	deg/s	rad/s
a_{nx}	N/A	*g*	*g*
a_{ny}	N/A	*g*	*g*
a_{nz}	N/A	*g*	*g*
M	N/A	-	-
$\bar{q}$	N/A	lb/ft^2	lb/ft^2
P_s	N/A	lb/ft^2	lb/ft^2

The units of states used in the F-16 model



Controls

Control	Units Inputs	Units Used by **nlplant**	Min	Max
Thrust	*lbs*	*lbs*	1000	19000 *lbs*
Elevator	*deg*	*deg*	-25	25 *deg*
Aileron	*deg*	*deg*	-21.5	21.5 *deg*
Rudder	*deg*	*deg*	-30	30 *deg*
Leading Edge Flap	*deg*	*ft*/s	0	25 *deg*

The control input units and maximum values

Leading Edge Flaps

High fidelity model

- Without leading edge

$$\dot{v} = 0.0001h - 3.17\theta - 0.0131v - 10.2070\alpha - 0.1337\beta - 1.5837q$$

- With leading edge

$$\dot{v} = 0.0001h - 3.17\theta - 0.0133v + 4.837\alpha - 0.4401\beta - 0.707q$$

Installation

A3M35SRL - Systémy řízení letu, Control systems for aircraft and spacecraft

The course is devoted to classical and modern control design techniques for autopilots and flight control systems Particular levels are discussed, starting with the dampers attitude angle stabilizers, to guidance and navigation systems. Next to the design itself, important aspects of aircraft modelling, both as a rigid body and considering flexibility of the structure, are discussed.

Výsledek studentské ankety předmětu je zde: A3M35SRL

- Novinky
- Anotace předmětu
- Staré stránky předmětu SRL1
- Staré stránky předmětu SRL2
- Zadání semestrální práce
- Diskusní fórum k systémům řízení letu
- Hodnocení předmětu
- Semestral work - flight guidance
- Semestral work - flexible aircraft
- Nonlinear F-16 Model

  Nonlinear F-16 model for the semester project. Includes all necessary files. MATLAB requires a mex computer to run nlplant.c.

  Test your mex compiler by typing the following into the MATLAB command window:

  mex -setup

mex setup

```
>> mex -setup MEX configured to use 'Xcode with Clang' for C language
compilation.
Warning: The MATLAB C and Fortran API has changed to support MATLAB
variables with more than 2^32-1 elements. You will be required
to update your code to utilize the new API.
You can find more information about this at:
http://www.mathworks.com/help/matlab/matlab_external/
upgrading-mex-files-to-use-64-bit-api.html

To choose a different language, select one from the following:
mex -setup C++
mex -setup FORTRAN
```

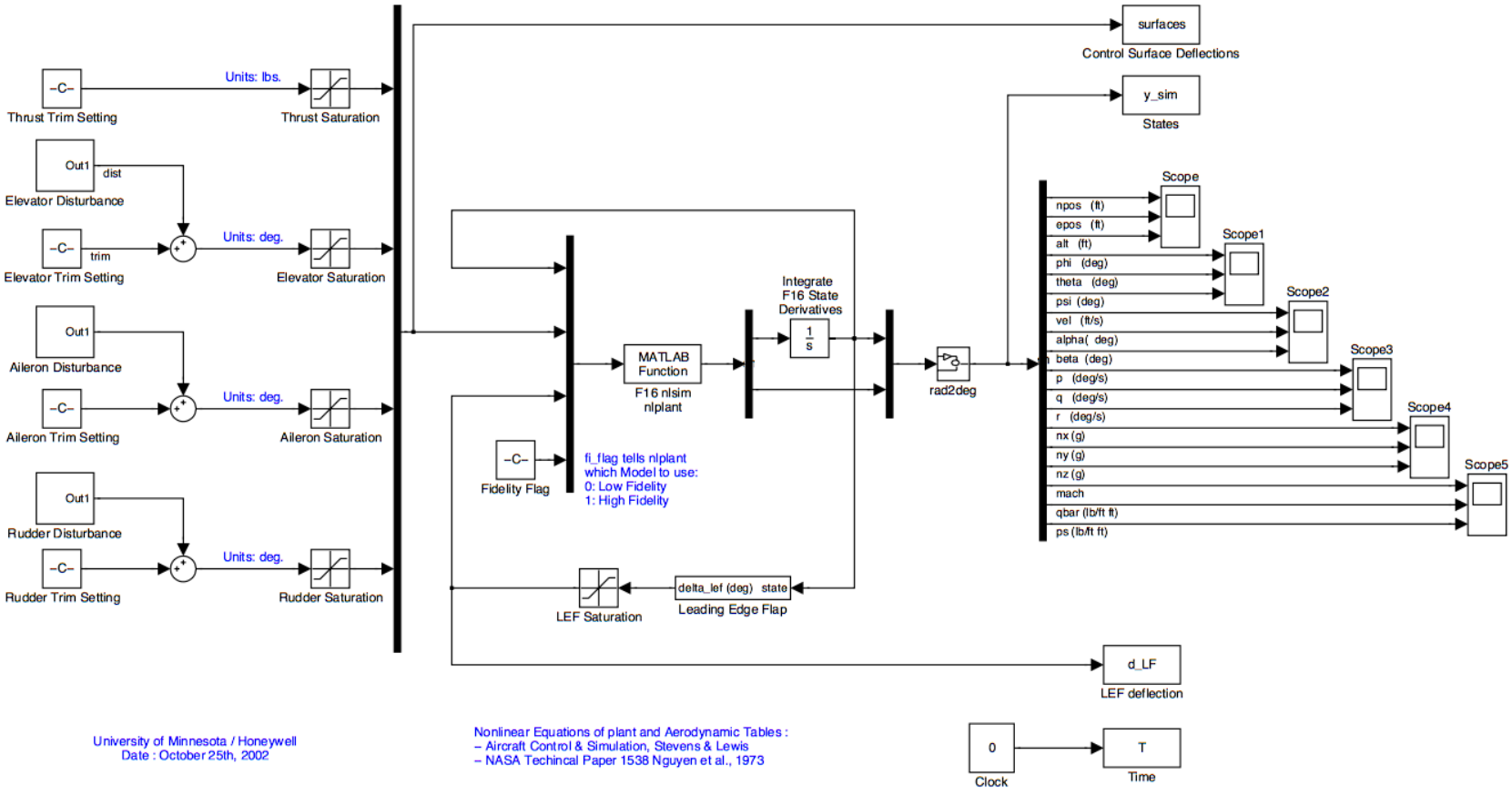
runF16Sim.m

```
>> cd F16sim.m
>> runF16Sim

Which model would you like to use to trim the aircraft:
  1. Low Fidelity F-16 Trim
  2. High Fidelity F-16 Trim
Your Selection: 1

Enter the altitude for the simulation (ft) : 15000
Enter the velocity for the simulation (ft/s): 500
Would you like to create a disturbance on a surface (y/n): y
Enter the elevator distrubance deflection (deg) : 5
Enter the aileron distrubance deflection (deg) : 1
Enter the rudder distrubance deflection (deg) : 1
```

runF16Sim.m

```
At what flight condition would you like to trim the F-16?
1.  Steady Wings-Level Flight.
2.  Steady Turning Flight.
3.  Steady Pull-Up Flight.
4.  Steady Roll Flight.
Your Selection:  1
Trim Values and Cost:  cost = 2.2909e-29
thrust = 2120.6214 lb
elev = -2.4607 deg
ail = 2.9129e-16 deg
rud = 2.7966e-15 deg
alpha = 4.4655 deg
dLEF = 0 deg
Vel.  = 500ft/s
Continue trim rountine iterations?  (y/n):  n
```

F16Block.slx



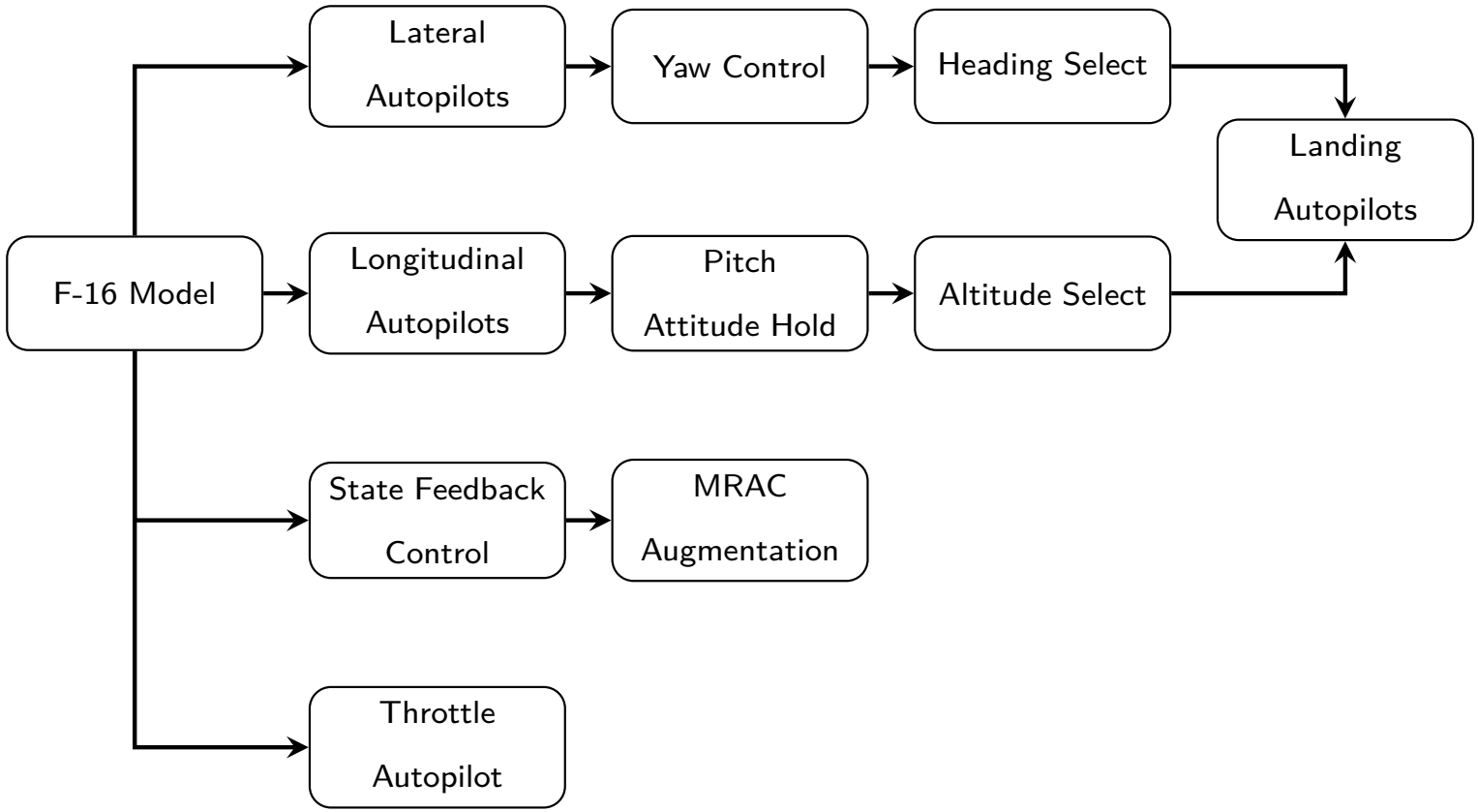
Common issues

```
Error using runF16Sim (line 128)
Error due to multiple causes.
Caused by:
Error using runF16Sim (line 128)
Point lies out data grid (in getHyperCube) Error using runF16Sim (line
128)
Error evaluating MATLAB function in 'F16Block/F-16 Non-linear Plant/F16
nlsim nlplant'
```

```
Error using mex
No supported compiler or SDK was found. You can install the freely
available MinGW-w64 C/C++ compiler; see
Install MinGW-w64 Compiler. For more options, visit
http://www.mathworks.com/support/compilers/R2016b/win64.html.
```

```
Error using feval
Undefined function 'nlplant' for input arguments of type 'double'.
```

Semester Project



Summary

1. Why controls systems?
2. Nonlinear F-16 model description
3. Installation instructions
4. Semester Project

Useful Links:

- Course Moodle Page
- MATLAB Supported and Compatible Compilers
- F-16 Stall/Post Stall Characteristics
- F-16 Flight Testing Videos

Questions?

Thank You!