Aerospace Applications of SysML: Concept F-35D
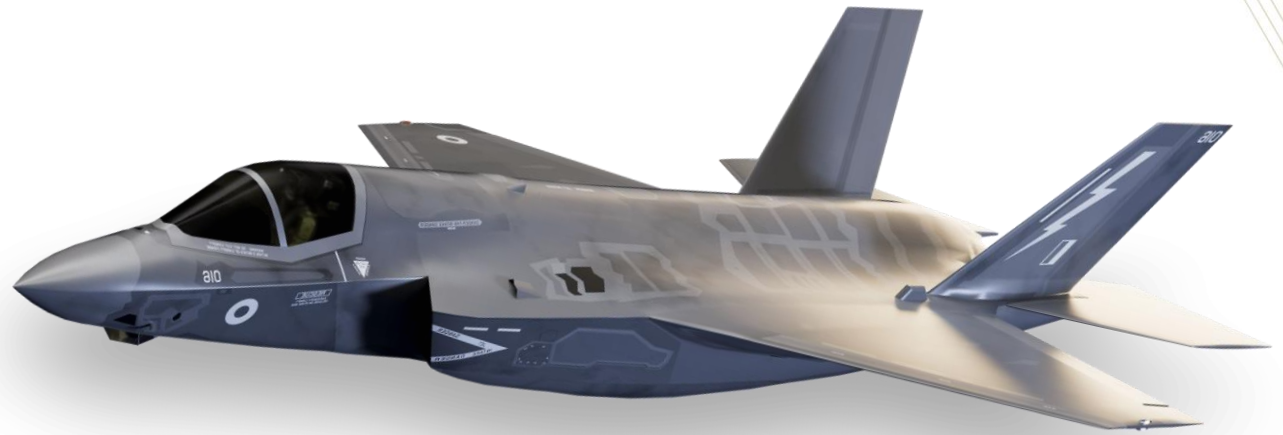
Andrew Greig

Research engineers:

Dr. Selcuk Cimtalay and Dr. Russell Peak
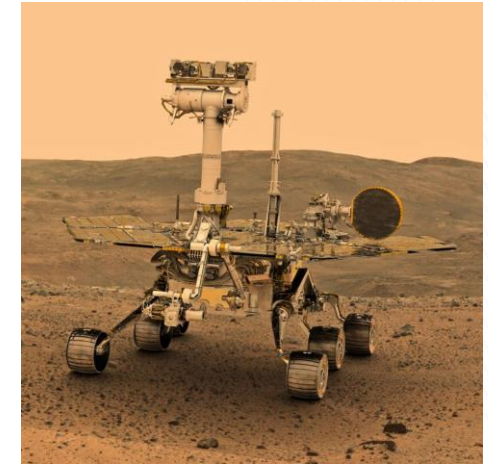
Research advisor:

Dr. Dimitri Mavris

Introduction

Andrew Greig
agreig3@gatech.edu

- Fall 2023
  - Tutorials for familiarization with MBSE and SysML
  - Mars Opportunity Rover Team Project (Instruments Subsystem)

- Spring 2024
  - Completed tutorials in modeling Breckenridge Ski Resort
  - Modeled potential 'D' revision for F-35
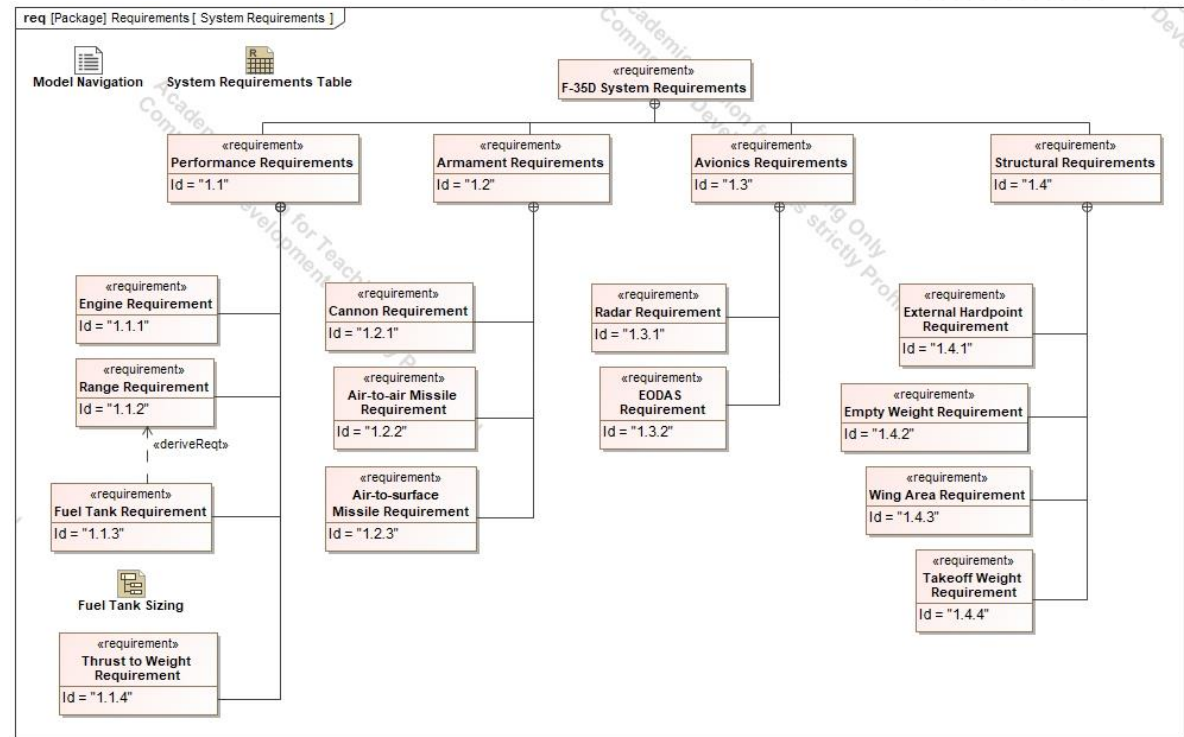
- Fall 2024
  - Continuing MBSE research

Opportunity Rover rendering

F-35A Lightning II

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Requirements

- Help develop model structure
- Many adapted from F-35A (ex. structural requirements)
- Define areas of improvement over previous vehicle revisions

#	Name	Text	Satisfied By	Derived From
1	☐ R 1 F-35D System Requirements			
2	☐ R 1.1 Performance Requirements			
3	R 1.1.1 Engine Requirement	The aircraft shall have one engine capable of at least 28,000 lb thrust.	Engine	
4	R 1.1.2 Range Requirement	The aircraft shall have a range of 1900 miles.	F-35D	
5	R 1.1.3 Fuel Tank Requirement	The aircraft shall have an internal fuel capacity of 20,500 lb.	Fuel Tank	R 1.1.2 Range Requirement
6	R 1.1.4 Thrust to Weight Requirement	The aircraft's thrust to weight ratio shall not be less than 0.5.	F-35D	
7	☐ R 1.2 Armament Requirements			
8	R 1.2.1 Cannon Requirement	The aircraft shall have one rotary cannon.	Cannon	
9	R 1.2.2 Air-to-air Missile Requirement	The aircraft shall carry any combination of AIM-9s, AIM-132s, or AIM-260s.	Air-to-air Missiles	
10	R 1.2.3 Air-to-surface Missile Requiren	The aircraft shall carry any combination of AGM-88s, AGM-158s, or SPEAR-3s.	Air-to-surface Missiles	
11	☐ R 1.3 Avionics Requirements			
12	R 1.3.1 Radar Requirement	The aircraft shall have a fire-control radar system.	Radar	
13	R 1.3.2 EODAS Requirement	The aircraft shall have an electro-optical distributed aperture system.	EODAS	
14	☐ R 1.4 Structural Requirements			
15	R 1.4.1 External Hardpoint Requiremer	The aircraft shall have six external wing-mounted hardpoints.	Weapons Systems	
16	R 1.4.2 Empty Weight Requirement	The aircraft shall have an empty weight of 29,000 lb.	F-35D	
17	R 1.4.3 Wing Area Requirement	The aircraft shall have a wing area of 460 square feet.	F-35D	
18	R 1.4.4 Takeoff Weight Requirement	The aircraft shall have a maximum takeoff weight of 70,000 lb.	F-35D	

3

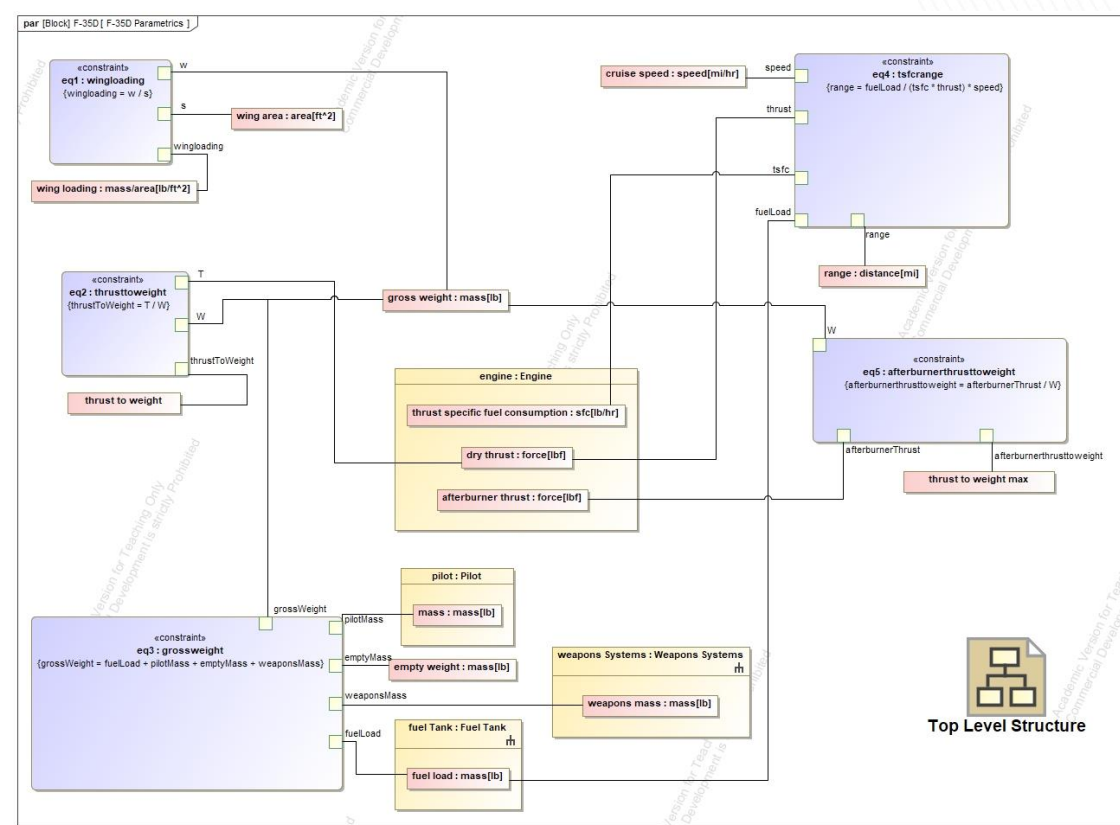Georgia Tech

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Model structure and objective

- New updates in weaponry
  - Improved missiles since F-35 inception
- Increased combat range
  - Larger fuel capacity
  - Improved engine efficiency?
- Focus on vehicle performance
  - Thrust to weight, wing loading, etc.
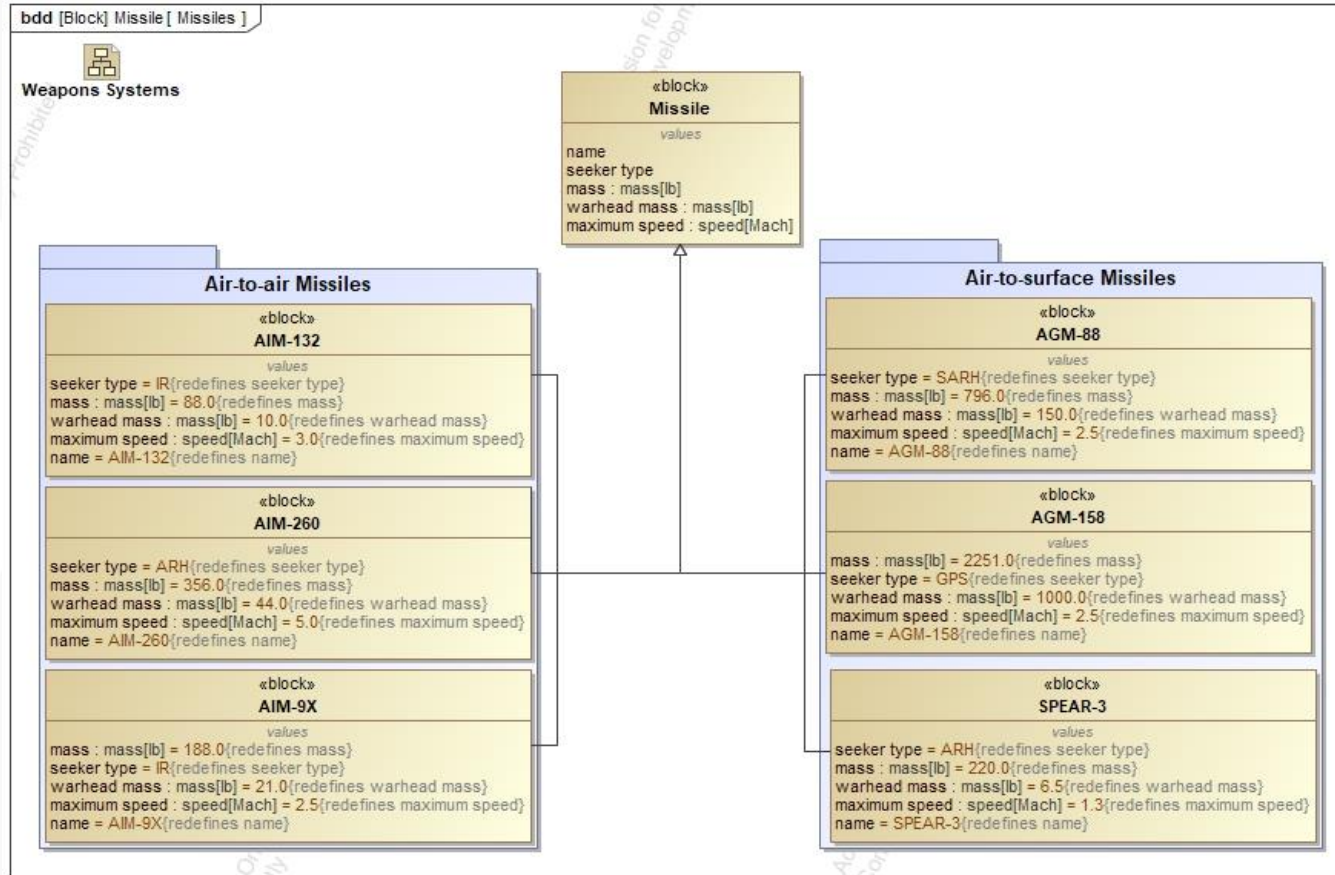- Hierarchy: System level – Subsystems
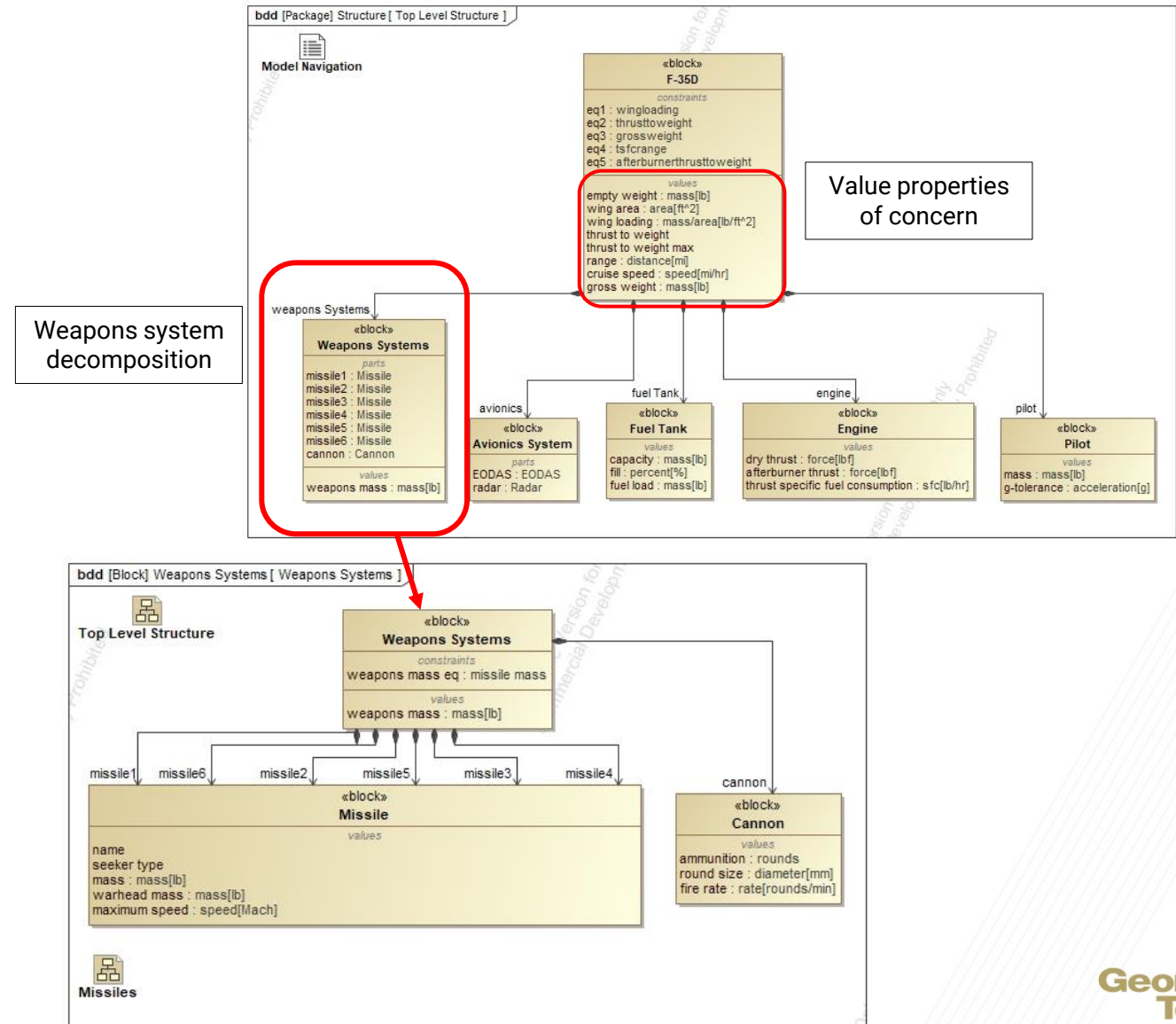
Parametrics

- Parametric modeling for vehicle parameters.
  - Wing loading, thrust to weight ratio (with and without afterburner), gross weight, range, fuel load
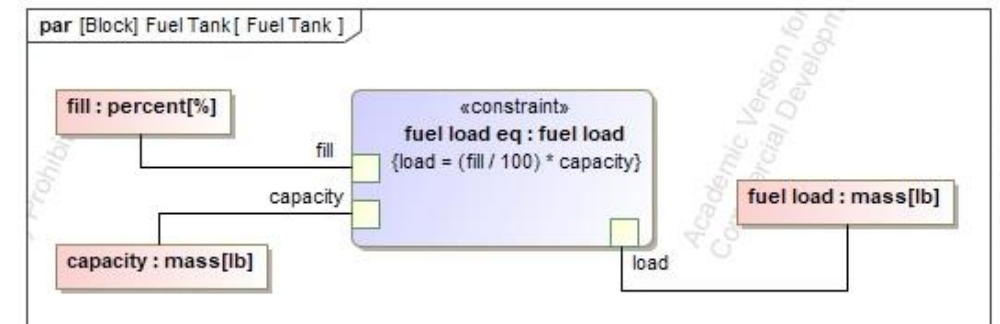- Use of Cameo Simulation Toolkit for calculation and validation of results against F-35A data

Parametric modeling of top-level parameters

Instances

- Generalizations and parametric equations allow for easy creation of new instances

Instances

• Varying fuel load and weapon outfit for different mission types

#	Name	wing loading △ : mass/area [lb/ft^2]	thrust to weight	thrust to weight max	range : distance[mi]	cruise speed : speed[mi/hr]	gross weight : mass[lb]	fuel Tank.fill : percent[%]
1	Close Range Intercept	88.8783	0.6849	1.0518	325.3968	800	40884	50
2	Long Range Patrol	111.8913	0.544	0.8354	650.7937	800	51470	100
3	Air Interdiction	115.8565	0.5254	0.8068	650.7937	800	53294	100
4	Heavy Air Interdiction	117.2283	0.5192	0.7974	488.0952	800	53925	75

#	Name	weapons mass : mass[lb]	name	seeker type	mass : mass[lb]	warhead mass : mass[lb]	maximum speed : speed [Mach]
1	Close Range Intercept						
2	f-35D.weapons Systems	1464					
3	f-35D.weapons Systems.missile1		AIM-9X	IR	188	21	2.5
4	f-35D.weapons Systems.missile2		AIM-9X	IR	188	21	2.5
5	f-35D.weapons Systems.missile3		AIM-9X	IR	188	21	2.5
6	f-35D.weapons Systems.missile4		AIM-9X	IR	188	21	2.5
7	f-35D.weapons Systems.missile5		AIM-260	ARH	356	44	5
8	f-35D.weapons Systems.missile6		AIM-260	ARH	356	44	5
9	Long Range Patrol						
10	f-35D1.weapons Systems	1800					
11	f-35D1.weapons Systems.missile1		AIM-9X	IR	188	21	2.5
12	f-35D1.weapons Systems.missile2		AIM-9X	IR	188	21	2.5
13	f-35D1.weapons Systems.missile3		AIM-260	ARH	356	44	5
14	f-35D1.weapons Systems.missile4		AIM-260	ARH	356	44	5
15	f-35D1.weapons Systems.missile5		AIM-260	ARH	356	44	5
16	f-35D1.weapons Systems.missile6		AIM-260	ARH	356	44	5
17	Heavy Air Interdiction						
18	f-35D11.weapons Systems	9380					
19	f-35D11.weapons Systems.missile		AIM-9X	IR	188	21	2.5
20	f-35D11.weapons Systems.missile		AIM-9X	IR	188	21	2.5
21	f-35D11.weapons Systems.missile		AGM-158	GPS	2251	1000	2.5
22	f-35D11.weapons Systems.missile		AGM-158	GPS	2251	1000	2.5
23	f-35D11.weapons Systems.missile		AGM-158	GPS	2251	1000	2.5
24	f-35D11.weapons Systems.missile		AGM-158	GPS	2251	1000	2.5
25	Air Interdiction						
26	f-35D1111.weapons Systems	3624					
27	f-35D1111.weapons Systems.miss		SPEAR-3	ARH	220	6.5	1.3
28	f-35D1111.weapons Systems.miss		SPEAR-3	ARH	220	6.5	1.3
29	f-35D1111.weapons Systems.miss		AGM-88	SARH	796	150	2.5
30	f-35D1111.weapons Systems.miss		AGM-88	SARH	796	150	2.5
31	f-35D1111.weapons Systems.miss		AGM-88	SARH	796	150	2.5
32	f-35D1111.weapons Systems.miss		AGM-88	SARH	796	150	2.5

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Future Goals

- MATLAB to solve for aircraft speed
- State machine functionality for avionics system
- Maneuver performance
  - Turns, climb, descent (pilot g-tolerance?)
- Variable thrust settings and calculating range given changing weight due to fuel (MATLAB)

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