Weapon Engagement Zone Maximum Launch Range Estimation Using a Deep Neural Network

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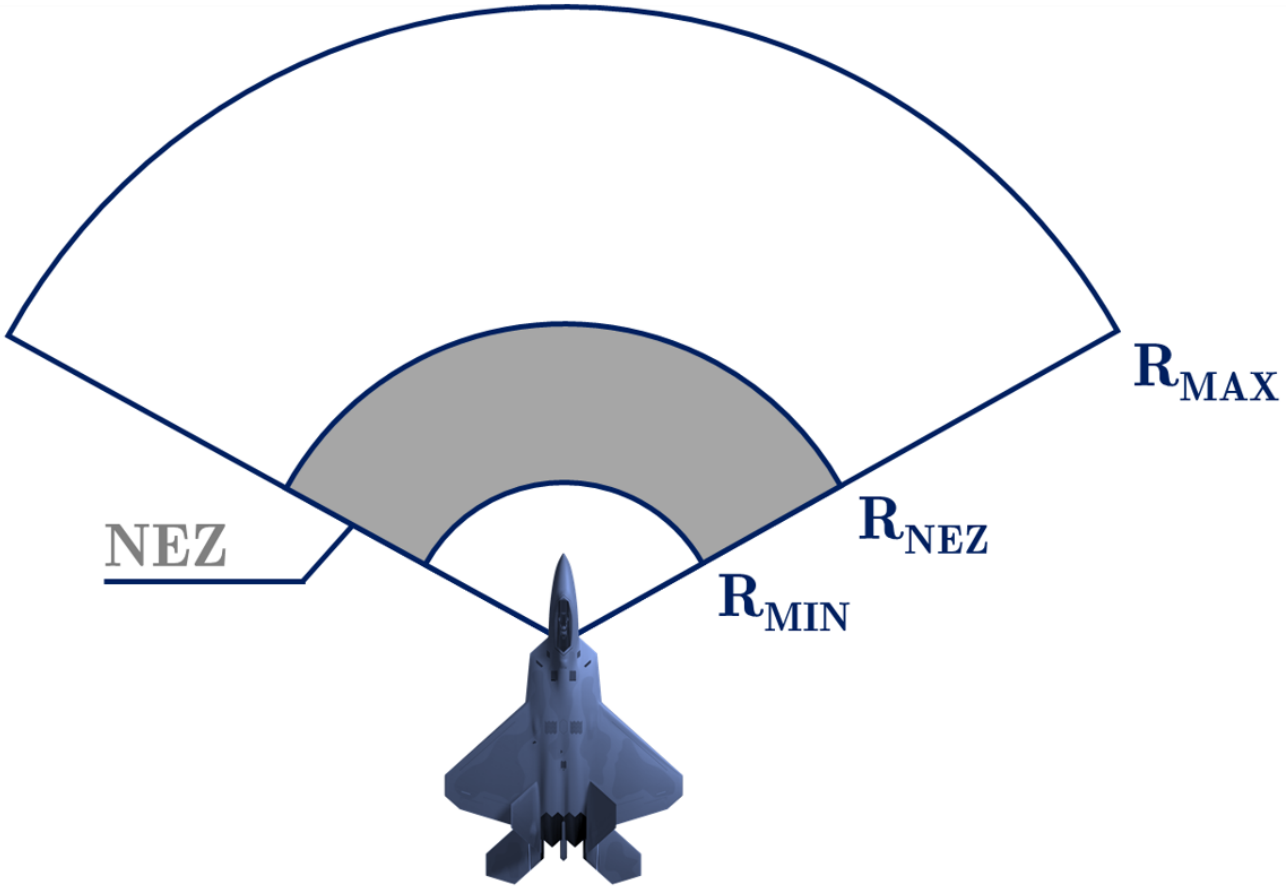
INTRODUCTION

- Simulation environment: level of fidelity
- Critical part: modeling missiles
- Deciding launching a missile
- Weapon Engagement Zone (WEZ)

WEAPON ENGAGEMENT ZONE



LITERATURE REVIEW

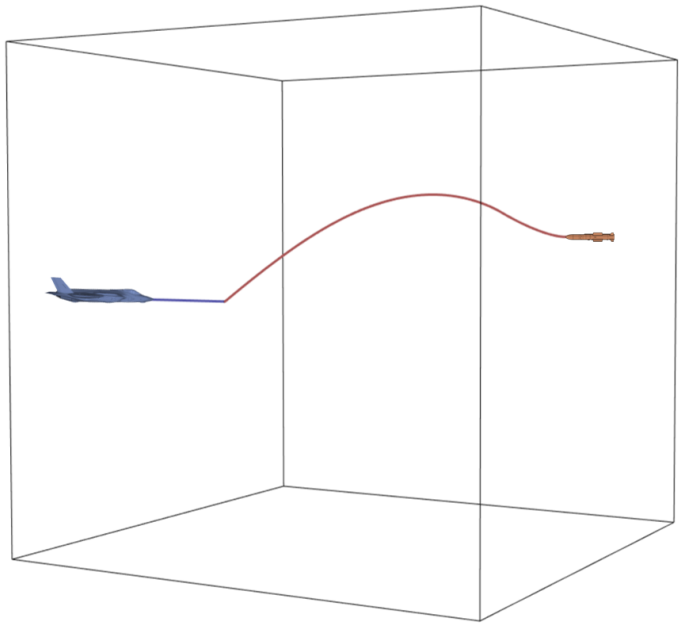
- Yoon et al, 2010: Lauch Acceptability Region
- Alkaher and Moshaiov, 2015: Dynamic Lauch Zone
- Portrey et al, 2005: factors regarding shooter and target
- Birkmire, 2011: WEZ determination
- Farlik et al, 2017 and Li et al, 2020: mathematical approaches

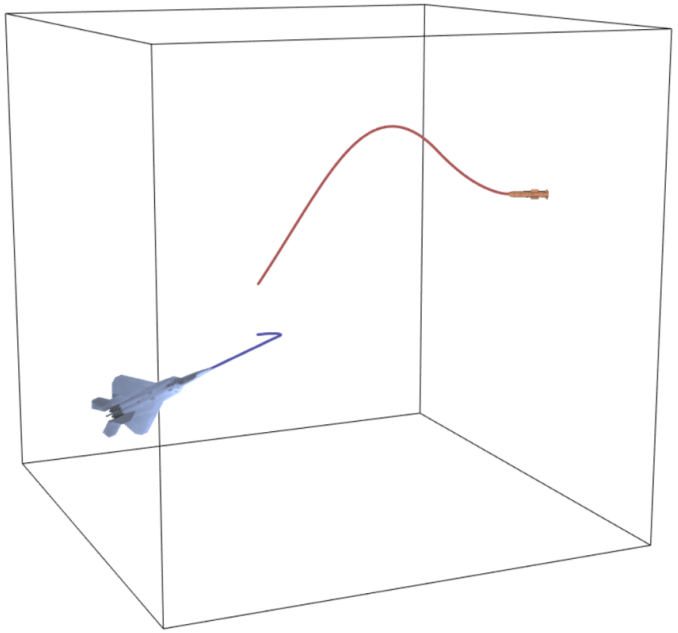
OBJECTIVES

- Autonomous agents
- Construtive Simulations
- Simulated launches in variate conditions
- Machine Learning Algorithm
- Deep Neural Network

MISSILE MODEL

- 5 DOF
- FOX 3
- Perfect proportional navigation
- Loft maneuver





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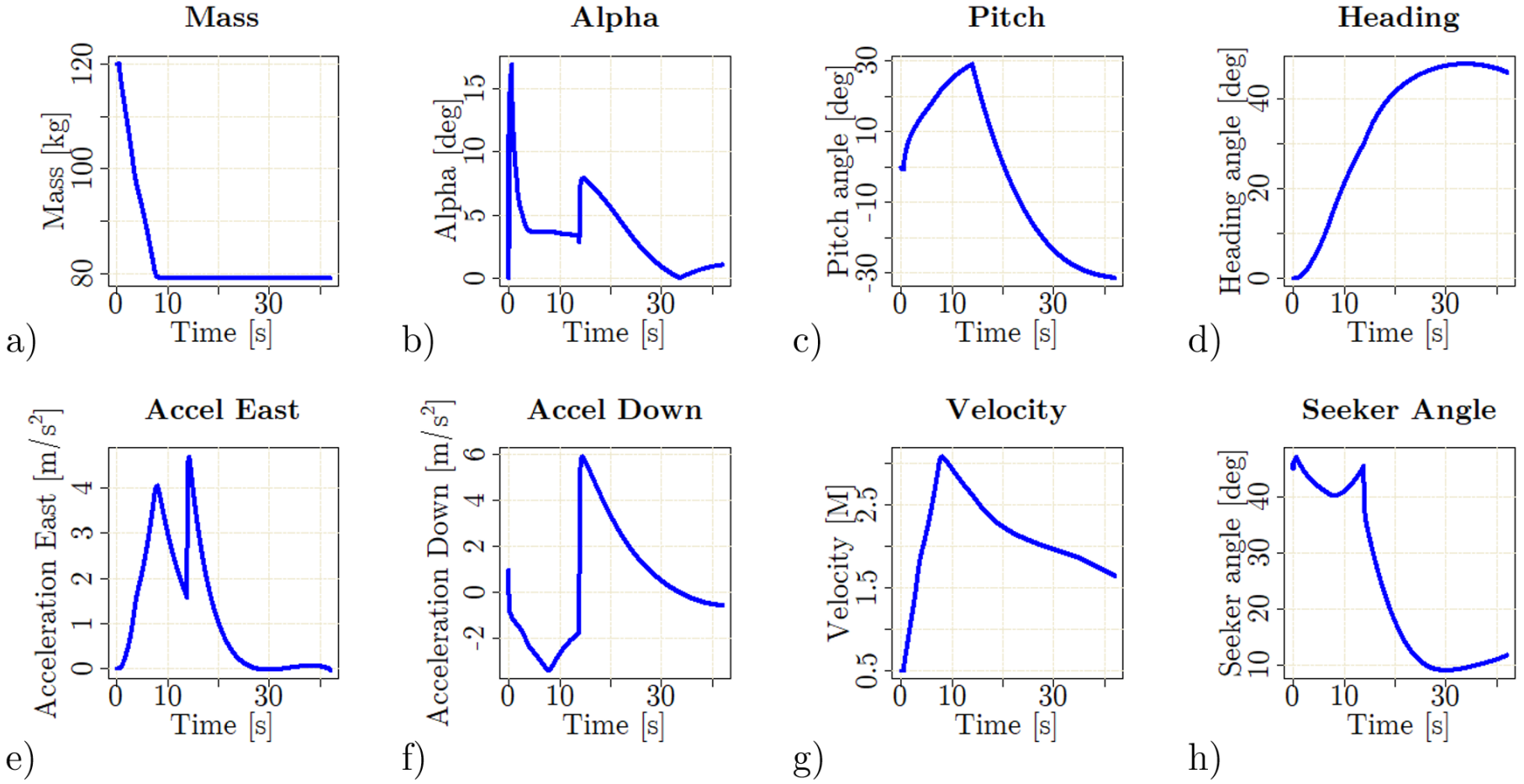
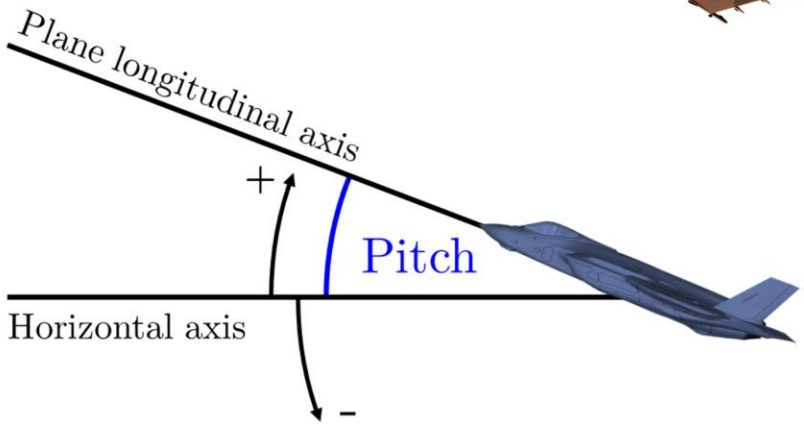
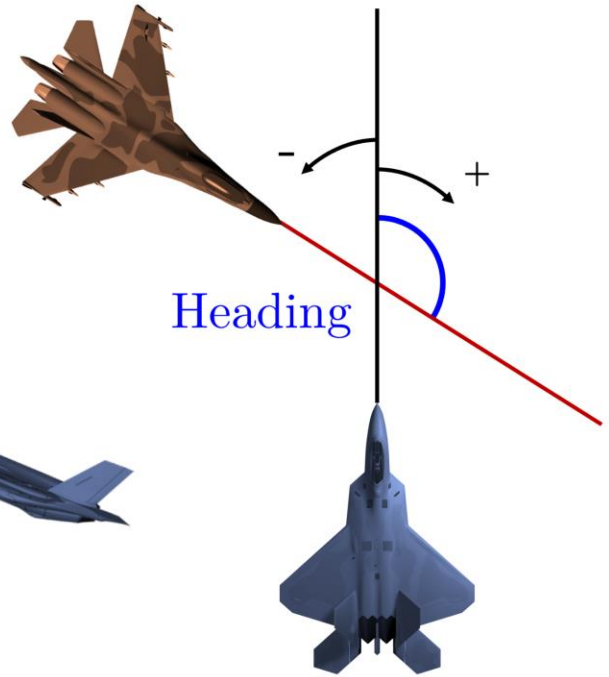
MISSILE MODEL

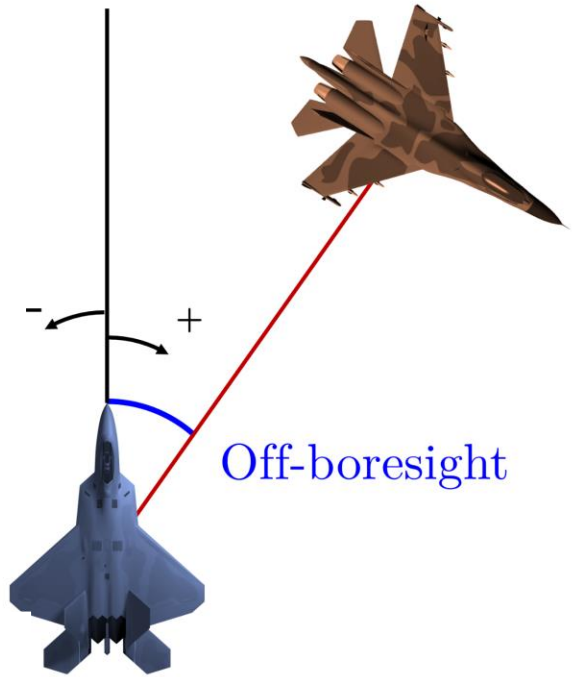


EXPERIMENTAL DESIGN

Parameter	Variable	Min	Max	Unit
Shooter altitude	alt_sht	1,000	45,000	feet
Shooter velocity	vel_sht	400	600	knots
Shooter pitch	pit_sht	-45	45	degrees
Target altitude	alt_tgt	1,000	45,000	feet
Target velocity	vel_tgt	400	600	knots
Target heading	hdg_tgt	-180	180	degrees
Target off-boresight	rgt_tgt	-60	60	degrees







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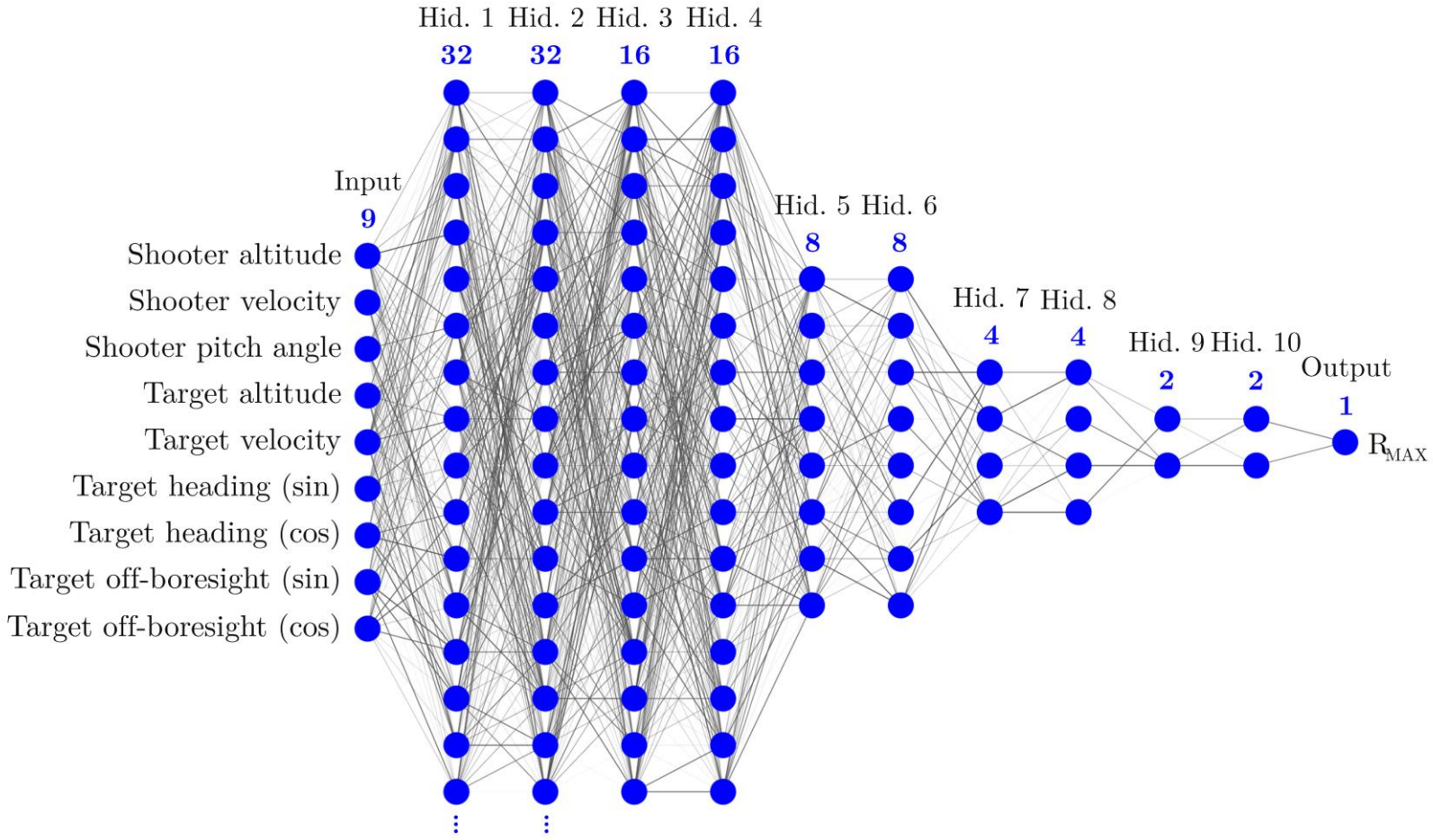
SIMULATIONS SAMPLING

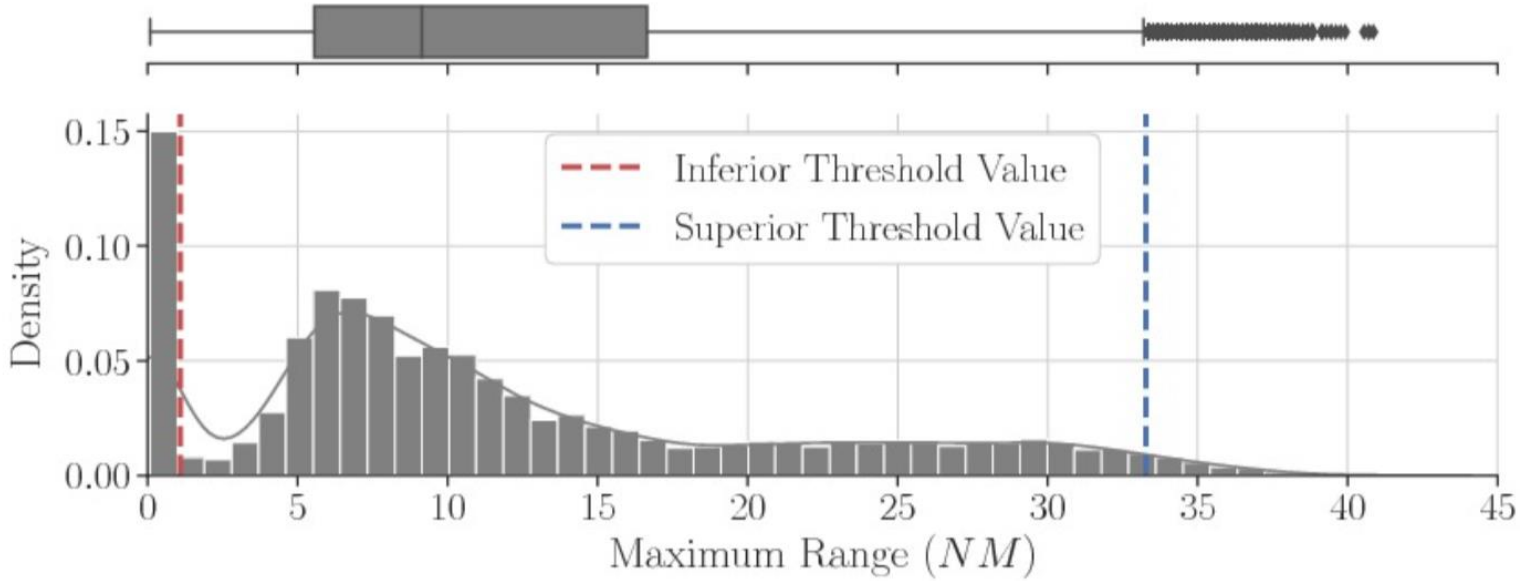
- Latin Hypercube Sampling
- 50,000 construtive simulations
- 2 Intel Xeon Silver 4210R CPUs
  - 2.40GHz
  - 128 GB RAM
- 7 hours

DEEP NEURAL NETWORK



DATA ANALYSIS

	alt_sht (ft)	vel_sht (kt)	pit_sht (deg)	alt_tgt (ft)	vel_tgt (kt)	hdg_tgt (deg)	rgt_tgt (deg)	max_range (NM)
mean	23,000.00	500.00	0.00	23,000.00	500.00	0.00	0.00	12.38
std	12,701.83	57.74	25.98	12,701.83	57.74	103.92	34.64	9.37
min	1,000.22	400.00	-45.00	1,000.82	400.00	-180.00	-60.00	0.08
25%	12,000.34	450.00	-22.50	12,000.32	450.00	-90.00	-30.00	5.55
50%	22,999.96	500.00	0.00	22,999.99	500.00	0.00	0.00	9.14
75%	33,999.75	550.00	22.50	33,999.76	550.00	90.00	30.00	16.64
max	44,999.38	600.00	45.00	44,999.42	600.00	179.99	60.00	40.87



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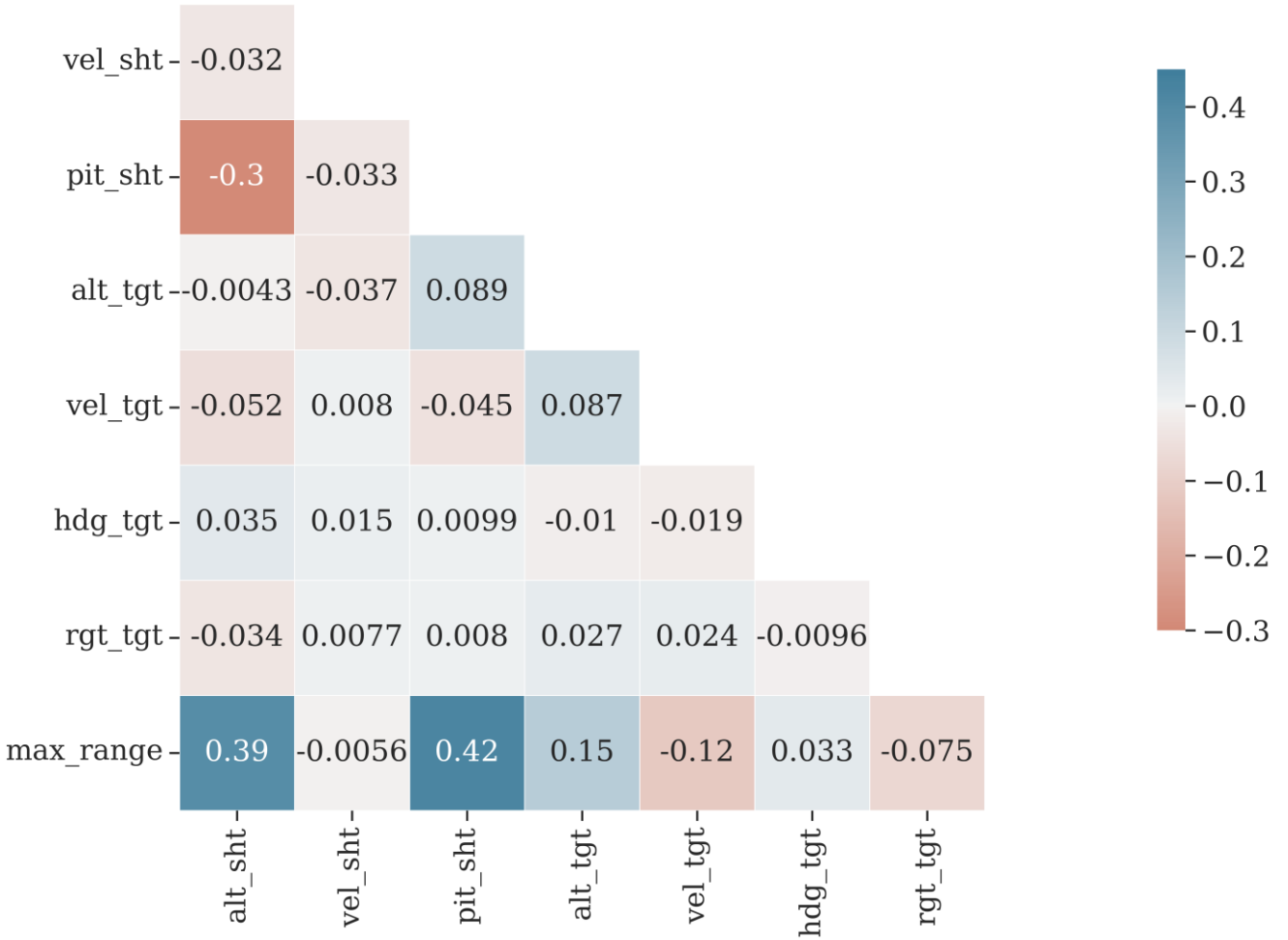
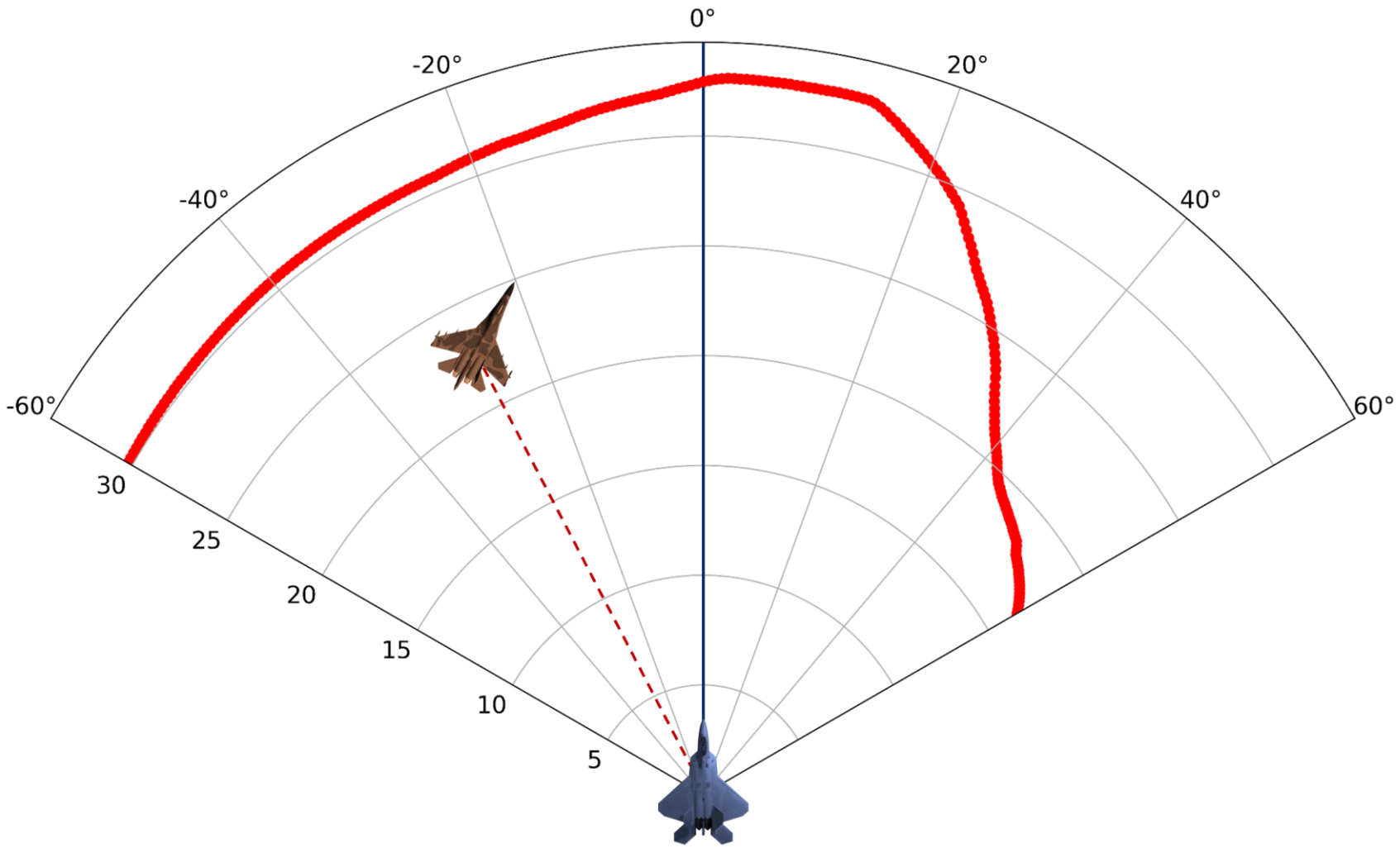
CORRELATION



MODEL RESULTS

	MAE (NM)	MSE (NM^2)	RMSE (NM)	R^2
1º Fold	0.54	1.06	1.03	0.99
2º Fold	0.62	1.22	1.10	0.99
3º Fold	0.71	1.39	1.18	0.98
4º Fold	0.52	1.08	1.04	0.99
5º Fold	0.57	1.34	1.16	0.98
mean	0.59	1.22	1.10	0.99
std	0.08	0.15	0.07	0.01

MODEL REPRESENTATION



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CONCLUSIONS

- No discretizing concerning off-boresight angle
- 50,000 vs 222,000,000
- DNN vs Several ANNs with one hidden layer
- 5-fold cross validation
- Feature engineering: sine and cosine

FUTURE WORK

- Improvement in the DNN architecture
- Results compared with other supervised learning techniques
- More advanced missile models

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