A Encounter Model Details

Table 1: Parameters for data generation.

Parameter	Minimum	Maximum	Unit
Ownship Horizontal Speed	60	70	$\mathrm{m/s}$
Intruder Horizontal Speed	60	70	$\mathrm{m/s}$
Horizontal Miss Distance	0	100	meters
Vertical Miss Distance	-30	30	meters
Relative Heading	100	260	degrees

In order to simplify the representation of encounters in this study, we adopt a model where the ownship and intruder aircraft move along straight-line trajectories with constant horizontal speeds. To generate an encounter, we follow a two-step process. First, we randomly sample a set of encounter features from uniform distributions within the specified ranges presented in table 1. We then use these features to generate trajectories for both the ownship and intruder aircraft. The horizontal and vertical miss distance parameters indicate the range between the ownship and intruder aircraft and their relative altitude at the point of closest approach. These distances are deliberately chosen to ensure that all encounters result in a near mid-air collision (NMAC) if no collision avoidance action is taken.

Each simulated encounter has a duration of 50 seconds, with the closest point of approach occurring 40 seconds into the encounter. The range of relative headings is selected to generate encounters that are nearly head-on, with the intruder aircraft typically within the ownship's field of view. The features specified in table 1 completely determine the relative trajectories of the ownship and intruder aircraft. Once the relative trajectories are generated, we randomly position both trajectories around the origin region by applying rotations and shifts.

B Dataset Details

The AVOIDDS dataset was generated to include 72,000 images, of which 64,800 are training images and 7200 are validation images. These images are accompanied by 72,000 label files. Table 2 shows the number of images for each variable category while table 3 shows the exact distributions used to generate the images. Equal amounts of each cloud covering, region, and aircraft type are represented, and the other variables were randomized for each image.

The range between the ownship and intruder aircraft was sampled from a gamma distribution with shape and scale parameters dependent on the aircraft type. We sampled the distances for the Cessna Skyhawk and King Air C90 from a gamma distribution with shape 2 and scale 200, and the Boeing 737-800 distances were sampled from a gamma distribution with shape 3 and scale 200. The expected value of $\Gamma(3, 200)$ is about $200\,\mathrm{m}$ more than that of $\Gamma(2, 200)$ which we intended to account for the larger size of the Boeing 737-800 aircraft relative to the smaller aircraft. A gamma distribution allows us to sample from a distribution that is skewed toward closer ranges, where aircraft are more likely to be visible in the image. To ensure that the aircraft were not positioned too close together, we verified that the sampled values were greater than $20\,\mathrm{m}$ for the Cessna Skyhawk and King Air C90 and $50\,\mathrm{m}$ for the Boeing 737-800. The position vertically and horizontally of the intruder was sampled uniformly within the ownship field of view. The time of day for each sample was randomized between 08:00 and 17:00 on January 1st in each respective location's local time. We split the day into 4 time windows for evaluation purposes: morning (08:00-10:00), midday (10:00-13:00), afternoon (13:00-15:00), and late afternoon (15:00-17:00).

C Additional Results

Table 4 shows the specific test set evaluation values for the baseline and alternative models discussed, specifically precision, recall, and mAP. These can be compared to the downstream task metrics shown in table 5, which includes the frequencies of NMAC and advisory.

Table 2: AVOIDDS dataset overview.

Attribute	Value	Number of images Total	Training	Validation
All	-	72,000	64,800	7200
Clouds	Clear	12,000	10,800	1200
	High Cirrus	12,000	10,800	1200
	Scattered	12,000	10,800	1200
	Broken	12,000	10,800	1200
	Overcast	12,000	10,800	1200
	Stratus	12,000	10,800	1200
Region	Palo Alto, CA (PAO)	18,000	16,200	1800
	Boston, MA (BOS)	18,000	16,200	1800
	Oshkosh, WI (OSH)	18,000	16,200	1800
	Reno, NV (RNO)	18,000	16,200	1800
Aircraft type	Cessna Skyhawk	24,000	21,600	2400
	Boeing 737-800	24,000	21,600	2400
	King Air C90	24,000	21,600	2400
Range	$0-150\,\mathrm{m}$	9124	8268	856
	$150-500\,\mathrm{m}$	35,932	32,303	3629
	$>500\,\mathrm{m}$	26,944	24,229	2715
Intruder rel. alt.	Below	36,048	32,482	3566
	Above	35,952	32,318	3634
Time of day	Morning	15,930	14,385	1545
	Midday	24,142	21,722	2420
	Afternoon	15,954	14,269	1685
	Late Afternoon	15,974	14,424	1550

Table 3: Parameters for the AVOIDDS Dataset.

Parameter	Minimum	Maximum	Distribution	Unit
Ownship distance east/north from origin	-5000	5000	$\mathcal{U}(-5000, 5000)$	meters
Ownship distance vertically from origin	-1000	1000	$\mathcal{U}(-1000, 1000)$	meters
Ownship and intruder heading	0	360	$\mathcal{U}(0, 360)$	degrees
Ownship pitch	-30	30	$\mathcal{N}(0, 5)$	degrees
Ownship roll	-45	45	$\mathcal{N}(0, 10)$	degrees
Time of day	08:00	17:00	$\mathcal{U}$(08:00, 17:00)	hours

D Experiment Reproduction

The experiments in this work can be reproduced using the AVOIDDS repository, available at this link: https://github.com/sisl/VisionBasedAircraftDAA.

D.1 Test Set Evaluation

Steps for how to reproduce the test set evaluation experiment results are as follows:

1. **Download AVOIDDS dataset:** Download and extract the AVOIDDS dataset (https://purl.stanford.edu/hj293cv5980) and place the folder in a convenient location.
2. **Download and setup the code repository:** Download the code repository (https://github.com/sisl/VisionBasedAircraftDAA). Navigate to the `src/model` directory and run `pip3 install -r requirements.txt` to install the necessary dependencies for test set evaluation.

Table 4: Test set evaluation results for baseline and alternative model

Attribute	Value	Baseline model			Alternative model		
		Precision	Recall	mAP	Precision	Recall	mAP
All	-	0.997	0.907	0.866	0.884	0.928	0.764
Clouds	Clear	0.991	0.905	0.856	0.818	0.918	0.687
	High Cirrus	1.000	0.930	0.900	0.943	0.931	0.827
	Scattered	0.997	0.923	0.887	0.952	0.936	0.841
	Broken	0.997	0.921	0.888	0.934	0.936	0.826
	Overcast	0.995	0.920	0.882	0.857	0.937	0.747
	Stratus	0.999	0.846	0.783	0.829	0.912	0.684
Region	Palo Alto, CA (PAO)	0.999	0.930	0.900	0.984	0.934	0.865
	Boston, MA (BOS)	0.996	0.922	0.885	0.819	0.938	0.722
	Oshkosh, WI (OSH)	0.999	0.866	0.813	0.912	0.919	0.772
	Reno, NV (RNO)	0.992	0.912	0.865	0.849	0.922	0.719
Aircraft Type	Cessna Skyhawk	0.995	0.844	0.750	0.880	0.867	0.643
	Boeing 737-800	0.999	0.988	0.983	0.914	0.986	0.891
	King Air C90	0.996	0.897	0.852	0.849	0.922	0.761
Range	$0–150\,\mathrm{m}$	0.999	0.983	0.979	0.914	0.997	0.909
	$150–500\,\mathrm{m}$	0.997	0.960	0.942	0.879	0.979	0.843
	$>500\,\mathrm{m}$	0.995	0.818	0.714	0.881	0.838	0.621
Intruder rel. alt.	Below	0.995	0.844	0.847	0.905	0.920	0.764
	Above	0.998	0.917	0.884	0.863	0.937	0.763
Time of day	Morning	0.997	0.911	0.872	0.929	0.916	0.785
	Midday	0.998	0.907	0.866	0.923	0.927	0.799
	Afternoon	0.998	0.914	0.878	0.937	0.940	0.831
	Late Afternoon	0.993	0.897	0.846	0.767	0.930	0.657

3. **Begin evaluation:** Run `python3 eval.py -o baseline_results -d [PATH TO AVOIDDS DATASET]`. Results for baseline model evaluation will appear in `baseline_results.txt`. Run `python3 eval.py -o alternative_results -m "../../models/alternative.pt" -d [PATH TO AVOIDDS DATASET]` to evaluate the alternative model with results outputting to `alternative_results.txt`.

D.2 Downstream Task Evaluation

Steps for how to reproduce the above downstream task experiment results are as follows:

1. **Download and setup the code repository:** Download the code repository (https://github.com/sisl/VisionBasedAircraftDAA). Navigate to the `src/simulator` directory and run `pip3 install -r requirements.txt` to install the necessary dependencies for downstream task evaluation.
2. **Setup X-Plane and aircraft:** Follow the instructions in the "Setup X-Plane" section of the benchmark repository README file (https://github.com/sisl/VisionBasedAircraftDAA/tree/main/src/simulator), setting the intruder aircraft as the one with which you would like to simulate encounters.
3. **Set variables for simulation:** At the bottom of the `simulate.py` file, uncomment and set the variables in the "BULK SIMULATION VARIABLE SETUP". Set `args.craft` to the aircraft you set in X-Plane in the previous step. Set `args.model_path` to the desired model as well.
4. **Begin simulation:** In the command line, run `./simulate.sh` and toggle your screen such that the X-Plane window is visible and full-screen. You will need to leave this visible for the entirety of the simulation.
5. **Repeat:** Repeat steps 2 through 4 for each desired aircraft and model.

Table 5: Downstream task evaluation results for baseline and alternative model

			Baseline model		Alternative model	
Attribute	Value	Total Encs	NMAC frq	Advisory frq	NMAC frq	Advisory frq
All	-	8640	0.143	0.187	0.165	0.191
Clouds	Clear	1440	0.158	0.181	0.188	0.186
	High Cirrus	1440	0.134	0.192	0.153	0.206
	Scattered	1440	0.142	0.191	0.157	0.206
	Broken	1440	0.146	0.184	0.156	0.194
	Overcast	1440	0.138	0.188	0.163	0.183
	Stratus	1440	0.142	0.185	0.174	0.172
Region	Palo Alto, CA (PAO)	2160	0.144	0.199	0.160	0.203
	Boston, MA (BOS)	2160	0.147	0.185	0.163	0.198
	Oshkosh, WI (OSH)	2160	0.140	0.180	0.157	0.190
	Reno, NV (RNO)	2160	0.141	0.183	0.180	0.173
Aircraft Type	Cessna Skyhawk	2880	0.157	0.124	0.179	0.130
	Boeing 737-800	2880	0.141	0.280	0.152	0.287
	King Air C90	2880	0.132	0.156	0.164	0.156
Time of day	Morning	2160	0.140	0.186	0.178	0.193
	Midday	2160	0.140	0.188	0.148	0.195
	Afternoon	2160	0.144	0.188	0.153	0.194
	Late Afternoon	2160	0.149	0.185	0.181	0.182