APPENDIX D

Air Quality Methodology and Calculations

This page intentionally left blank.

1 Introduction

This appendix summarizes the methodology used to estimate criteria air pollutant and greenhouse gas emissions resulting from the proposed strike fighter transition at Naval Air Station (NAS) Oceana. Emissions associated with the affected environment are also presented for purposes of comparison.

2 Methodology

Annual emissions from airfield operations at NAS Oceana and Naval Auxiliary Landing Field (NALF) Fentress was modeled based on the estimated number of annual flight operations and on-station maintenance operations for the affected environment and Proposed Action conditions using established methodology and emission factor documents and models. A complete list of references used can be found in Section 4.

3 Air Emissions Analysis

Aircraft engines emit criteria pollutants during all phases of aircraft operations. Operation types at NAS Oceana and NALF Fentress include: tactical jet arrival, departures, and patterns as well as maintenance operations. Departures consist of normal and interfacility departures. Arrivals consist of the following types: Visual Flight Rules (VFR), overhead, Instrument Flight Rules (IFR), interfacility VFR, and interfacility overhead. Patterns consist of touch and go (T&G), field carrier landing practice (FCLP), and ground controlled approach (GCA).

The methodology for estimating aircraft emissions involves the evaluation of several variables, including:

- The types of operation conducted by each type of aircraft;
- The number of arrivals, departures, and patterns;
- The type of aircraft engine and the mode of operation used for each type of aircraft; and
- Engine runups during maintenance and pre-flight, as applicable.

Procedures to calculate emissions from each aircraft type include the following steps:

- Obtain emission factors for each aircraft engine type using established data sources.
- Consider the range of operation types for each aircraft.
- Apply the applicable aircraft operating mode associated with annual flight operations.
- Calculate the emission rates for each aircraft type and operating mode by multiplying the respective emissions rates by annual flight operation numbers.
- Determine the total annual emissions by combining the emissions from all operations for all aircraft types. This includes the operation of ground support equipment that are used as part of aircraft operations while they are on the ground.

The aircraft operations data used for this estimate are from the *Report Aircraft Noise Study to Support the Environmental Assessment for Strike Fighter Transition at NAS Oceana, VA* (Blue Ridge Research and

consulting, LLC, September 2017) established for the No Action Alternative and the Proposed Action conditions, as well as engine runup maintenance estimates. The operational inputs used for the analysis are presented in Attachment 1 of this appendix.

Calculated aircraft emissions are presented in:

- Attachment 2: NAS Oceana Operational Emissions.
- Attachment 3: NALF Fentress Operational Emissions.
- Attachment 4: NAS Oceana and NALF Fentress Combined Emissions.

Although air pollutant emissions occur during all phases of aircraft operation (parking, idling, and in-flight), only those emissions occurring in the lower atmosphere's mixing layer have the potential to result in ground-level ambient air quality impacts. The mixing layer is the air layer extending from ground level up to the point at which the vertical mixing of pollutants decreases significantly. The USEPA recommends that a default mixing layer of 3,000 feet (914 meters) be used in aircraft emission calculations (USEPA 1992). Consistent with this recommendation, aircraft emissions released above 3,000 feet (914 meters) were not included in this study.

Differences in total estimated emissions under the affected environment and the Action Alternative are presented in Table D-1.

Table D-1 -Affected Environment and Action Alternative Operational Emissions at NAS Oceana and NALF Fentress

Action	Annual Emissions (Tons per Year)[1]						
	VOC[2]	CO	NO_X	SO_2	PM_{10}	$PM_{2.5}$[3]	CO_2e[4]
Affected Environment	415.22	1,372.22	617.91	94.61	249.06	249.04	121,373.18
Action Alternative	378.30	1,649.42	747.73	96.78	255.28	255.25	122,563.37
Net Change	-36.92	277.20	129.82	2.17	6.22	6.21	1,190.17

[1] Include additional GSE emissions within NAS Oceana and NALF Fentress Airfield.

[2] VOC emissions = HC emissions multiplied by 1.15 (VOC conversion from *Recommended Best Practice for Quantifying Speciated Organic Gas Emissions from Aircraft equipped with Turbofan, Turbojet, and Turboprop Engines*, version 1.0, USEPA, May 2009, Table 4)

[3] Conservatively assumed to be the same as PM_{10}.

[4] Metric tons.

4 Reference Documents

Air Force Civil Engineer Center, July 2016, Air Emissions Guide for Air Force Mobile Sources.

Aircraft Environmental Support Office (AESO) Memorandum Report No. 2012-01D, December 2014. Sulfur Dioxide Emission Index Using JP-5 and JP-8 Fuel.

Aircraft Environmental Support Office (AESO) Memorandum Report No. 2013-04 Revision A, January 2014. PM2.5 and PM10 Ratio for Aircraft Emitted Particles.

Aircraft Environmental Support Office (AESO) Memorandum Report No. 2013-04. May 2013. PM2.5 To PM10 Ratio For Aircraft Emitted Particles.

Aircraft Environmental Support Office (AESO) Memorandum Report No. 9926 Revision A. December 2009. C-9 and DC-9 Landing and Takeoff Cycle and In-Frame Maintenance Testing Using JP-5.

Aircraft Environmental Support Office (AESO) Memorandum Report No. 9943, Revision E. September 2015. Aircraft Emission Estimates of E-2C and E-2D Mission Operations Using JP-5.

Aircraft Environmental Support Office (AESO) Memorandum Report No. 9920, Revision E. September 2015. Aircraft Emission Estimates: E-2C/D Landing and Takeoff Cycle and In-Frame, Maintenance Testing Using JP-5.

Aircraft Environmental Support Office (AESO) Memorandum Report No. 2000-09, Revision D January 2015. Aircraft Emissions Estimates C-130 Landing and Takeoff Cycle and In-Frame Engine Maintenance Testing Using JP-5.

Aircraft Environmental Support Office (AESO) Memorandum Report No. 9734, Revision C. November 2002. F404-GE-400 Engine Fuel Flow and Emission Indexes by Percentage of Core RPM (% N2)

Aircraft Environmental Support Office (AESO) Memorandum Report No. 2012-01, Revision B. March 2013. Sulfur Dioxide Emission Index Using JP-5 and JP-8 Fuel.

Blue Ridge Research and Consulting, LLC. May 2016, Initial Draft Aircraft Noise Study to Support the EIS for Strike-Fighter Transitions at NAS Oceana, VA.

AP 42, Fifth Edition, Volume 1, Chapter 3, 1996, Table 3.3-1 Emissions Factors for Uncontrolled Gasoline and Diesel Industrial Engines.

U.S. Environmental Protection Agency, 2009, Recommended Best Practice for Quantifying Speciated Organic Gas Emissions from Aircraft Equipped with Turbofan, Turbojet, and Turboprop Engines, version 1.0, Table 4.

U.S. Environmental Protection Agency, 2010, Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling - Compression Ignition, Table A4 (Tier 1).

U.S. Environmental Protection Agency, 2013, OTAQ/OAQPS Guidance, Commercial Marine, Airports, and Trains Approach, EPA Docket #OAR-2003-0053-1696.

U.S. Environmental Protection Agency, 2008, Direct Emissions from Mobile Combustion Sources.

Aircraft Environmental Support Office (AESO), January 2016, Aircraft Emission Estimates: H-60 Mission Operations Using JP-5.

Aircraft Environmental Support Office (AESO), January 2016, Aircraft Emission Estimates: H-60 Landing and Takeoff Cycle, Cruise Time and In-Frame Maintenance Testing Using JP-5.

Aircraft Environmental Support Office (AESO), May 2016, Aircraft Emission Estimates: T-34 Mission Operations Using JP-5.

Aircraft Environmental Support Office (AESO), May 2016, Aircraft Emission Estimates: T-34 Landing and Takeoff Cycle, Cruise Time and In-Frame Maintenance Testing Using JP-5.

Aircraft Environmental Support Office (AESO), December 2015, Aircraft Emission Estimates: EA-6B Mission Operations Using JP-5.

Aircraft Environmental Support Office (AESO), December 2015, Aircraft Emission Estimates: EA-6B Landing and Takeoff Cycle, Cruise Time and In-Frame Maintenance Testing Using JP-5.

Aircraft Environmental Support Office (AESO), November 2015, Aircraft Emission Estimates: F/A-18 Mission Operations Using JP-5.

Aircraft Environmental Support Office (AESO), November 2015, Aircraft Emission Estimates: F/A-18 Landing and Takeoff Cycle, Cruise Time and In-Frame Maintenance Testing Using JP-5.

Aircraft Environmental Support Office (AESO), May 2016, Fuel Flows and Emission Indexes of the CFM56-7B Engine Burning Jet A.

Aircraft Environmental Support Office (AESO), May 2016, Fuel Flows and Emission Indexes of the F117-PW-100 Engine Burning Jet A.

Aircraft Environmental Support Office (AESO), May 2016, Fuel Flows and Emission Indexes of CFM56-7B Engine Burning JP-8.

Oceana Regional Supply Office, May 13, 2014, Personal Email on hot refuel percentage.

International Civil Aviation Organization (ICAO), 2013, Aircraft Engine Emissions Databank for CFM56-7B18.

Attachment 1
NAS Oceana and NALF Fentress Aircraft Operations

This page intentionally left blank.

Table 1-1 - NAS Oceana Aircraft Operations – Affected Environment

Aircraft Type	Based	Transient	Total Operations	Percent Operations
F/A-18C/D	33,600	0	33,600	40.0%
F/A-18E/F	44,400	40	44,440	53.0%
C-40A	800	237	1,037	1.2%
T-34C	800	2048	2,848	3.4%
E2		414	414	0.5%
SH-60		554	554	0.7%
B-190		418	418	0.5%
C130		157	157	0.2%
C17		172	172	0.2%
EA6		122	122	0.1%
F16		138	138	0.2%
Total	79,600	4,300	83,900	100.0%

Table 1-2 - NAS Oceana Aircraft Operations – Action Alternative

Aircraft Type	Based	Transient	Total Operations	Percent Operations
F/A-18C/D	0	0	0	0.00%
F/A-18E/F	78,000	40	78,040	93.02%
C-40A	800	237	1,037	1.24%
T-34C	800	2,048	2,848	3.39%
E2		414	414	0.49%
SH-60		554	554	0.66%
B-190		418	418	0.50%
C130		157	157	0.19%
C17		172	172	0.21%
EA6		122	122	0.15%
F16		138	138	0.16%
Total	79,600	4,300	83,900	100.00%

Table 1-3 - NALF Fentress Aircraft Operations – Affected Environment

Aircraft Type	Other		Total Operations	Percent Operations
F/A-18C/D	18,500		18,500	21.9%
F/A-18E/F	57,600	849	58,449	69.3%
E-2 (C-2)	4,300		4,300	5.1%
C-130		24	24	0.0%
EA-6B		573	573	0.7%
FA-16E		0	0	0.0%
SH-60		2,218	2,218	2.6%
B-190		36	36	0.0%
MQ-4		200	200	0.2%
Total	80,400	3,900	84,300	100.0%

Table 1-4 - NALF Fentress Aircraft Operations – Action Alternative

Aircraft Type	Other		Total Operations	Percent Operations
F/A-18C/D	0		0	0.0%
F/A-18E/F	76,100	849	76,949	91.3%
E-2 (C-2)	4,300		4,300	5.1%
C-130		24	24	0.0%
EA-6B		573	573	0.7%
FA-16E		0	0	0.0%
SH-60		2,218	2,218	2.6%
B-190		36	36	0.0%
MQ-4		200	200	0.2%
Total	80,400	3,900	84,300	100.0%

Attachment 2
NAS Oceana Operational Emissions

This page intentionally left blank.

Table 2-1 - NAS Oceana Airfield Emissions – Affected Environment

Aircraft Type	VOCs[1]	CO	NOx	SO_2	PM_{10}	$PM_{2.5}$	$CO2e$[2]
F/A-18 C/D Operations	160.06	334.26	88.80	22.41	62.93	62.93	28,426
Engine Maintenance Runups	38.95	97.11	13.01	4.06	12.31	12.31	5,008
F/A-18E/F Operations	195.94	808.98	258.53	34.59	97.06	97.06	44,132
Engine Maintenance Runups	8.86	82.00	12.92	2.28	6.88	6.88	2,853
C-40 Operations	0.96	8.81	14.71	2.43	0.25	0.25	3,144
T-34 Operations	1.09	4.82	0.80	0.30	0.50	0.50	392
E-2C Operations	0.03	0.22	0.93	0.21	0.05	0.05	284
H-60 Operations	0.17	1.35	0.38	0.16	0.24	0.24	210
EA-6B Operations	0.72	1.54	0.34	0.13	0.84	0.84	171
B190 Operations	0.80	2.55	0.10	0.03	0.02	0.02	78
C-130 Operations	0.09	0.80	0.94	0.19	0.13	0.13	247
C-17 Operations	0.22	2.42	3.85	0.26	0.11	0.11	699
F-16 Operations	0.01	0.20	0.24	0.03	0.06	0.05	81
Subtotal Aircraft Operations	407.92	1,345.07	395.56	67.09	181.39	181.38	85,725
GSE	0.55	2.37	6.39	0.24	0.47	0.46	135
Total Airfield Operations	408.47	1,347.44	401.94	67.33	181.86	181.84	85,860

[1]VOC conversion from *Recommended Best Practice for Quantifying Speciated Organic Gas Emissions from Aircraft Equipped with Turbofan, Turbojet, and Turboprop Engines*, version 1.0, USEPA, May 2009, Table 4.

[2] Metric tons.

Table 2-2 - NAS Oceana Airfield Emissions – Action Alternative

Aircraft Type	VOCs[1]	CO	NOx	SO_2	PM_{10}	$PM_{2.5}$	CO2e[2]
F/A-18E/F Operations	350.74	1,447.80	446.14	60.01	168.32	168.32	76,481.31
Engine Maintenance Runups	17.16	154.95	24.48	4.38	13.36	13.36	3,716.11
C-40 Operations	0.96	8.81	14.71	2.24	0.24	0.24	2,895.60
T-34 Operations	1.09	4.82	0.80	0.30	0.50	0.50	391.60
E-2C Operations	0.03	0.22	0.93	0.20	0.05	0.05	284.06
H-60 Operations	0.17	1.35	0.38	0.16	0.24	0.24	210.29
EA-6B Operations	0.72	1.54	0.34	0.13	0.84	0.84	171.00
B190 Operations	0.59	1.91	0.10	0.02	0.02	0.02	67.54
C-130 Operations	0.09	0.80	0.94	0.19	0.13	0.13	247.01
C-17 Operations	0.21	2.39	1.61	0.17	0.04	0.04	463.45
F-16 Operations	0.01	0.20	0.24	0.03	0.06	0.05	81.15
Subtotal Aircraft Operations	371.79	1,624.79	490.66	67.84	183.80	183.79	85,009.12
GSE	0.53	2.29	6.15	0.24	0.46	0.44	129.65
Total Airfield Operations	372.32	1,627.08	496.81	68.08	184.25	184.23	85,138.78
Net Change from Affected Environment	-36.15	279.64	94.87	0.74	2.39	2.39	-722.21

[1]VOC conversion from *Recommended Best Practice for Quantifying Speciated Organic Gas Emissions from Aircraft Equipped with Turbofan, Turbojet, and Turboprop Engines*, version 1.0, USEPA, May 2009, Table 4.

[2] Metric tons.

Attachment 3
NALF Fentress Operational Emissions

This page intentionally left blank.

Table 3-1 - NALF Fentress Airfield Operations Emissions – Affected Environment

Aircraft Type	VOCs[1]	CO	NOx	SO_2	PM_{10}	$PM_{2.5}$	CO2e[2]
F/A-18 C/D Operations	1.17	4.46	23.01	4.86	12.00	12.00	6,263.05
F/A-18E/F Operations	1.23	6.38	183.19	19.83	49.97	49.97	25,829.63
E-2C Operations	0.16	0.83	6.38	1.27	0.31	0.31	1,692.01
C130 Operations	0.01	0.12	0.14	0.03	0.02	0.02	37.76
EA6 Operations	3.40	7.23	1.58	0.63	3.92	3.92	803.13
F16 Operations	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SH-60 Operations	0.70	5.41	1.52	0.65	0.98	0.98	841.93
B-190 Operations	0.05	0.16	0.01	0.00	0.00	0.00	5.85
MQ4 Operations	0.02	0.18	0.14	0.01	0.00	0.00	38.83
Total Airfield Operations	6.76	24.78	215.96	27.28	67.20	67.20	35,512.18

[1]VOC conversion from *Recommended Best Practice for Quantifying Speciated Organic Gas Emissions from Aircraft Equipped with Turbofan, Turbojet, and Turboprop Engines*, version 1.0, USEPA, May 2009, Table 4.

[2] Metric tons.

Table 3-2 - NALF Fentress Airfield Emissions – Action Alternative

Aircraft Type	VOCs[1]	CO	NOx	SO_2	PM_{10}	$PM_{2.5}$	$CO2e^2$
F/A-18E/F Operations	1.62	8.40	241.17	26.10	65.79	65.79	34,005.10
E-2C Operations	0.16	0.83	6.38	1.27	0.31	0.31	1,692.01
C130 Operations	0.01	0.12	0.14	0.03	0.02	0.02	37.76
EA6 Operations	3.40	7.23	1.58	0.63	3.92	3.92	803.13
F16 Operations	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SH-60 Operations	0.70	5.41	1.52	0.65	0.98	0.98	841.93
B-190 Operations	0.05	0.16	0.01	0.00	0.00	0.00	5.85
MQ4 Operations	0.02	0.18	0.14	0.01	0.00	0.00	38.83
Total Airfield Operations	6	22	251	29	71	71	37425
Net Change from Affected Environment	-0.78	-2.44	34.97	1.42	3.82	3.82	1,912.42

[1]VOC conversion from *Recommended Best Practice for Quantifying Speciated Organic Gas Emissions from Aircraft Equipped with Turbofan, Turbojet, and Turboprop Engines*, version 1.0, USEPA, May 2009, Table 4.

[2] Metric tons.

Attachment 4
NAS Oceana and NALF Fentress Combined Operational Emissions

This page intentionally left blank.

Table 4-1 - NAS Oceana and NALF Fentress Airfield Emissions – Affected Environment

Aircraft Type	VOCs[1]	CO	NOx	SO_2	PM_{10}	$PM_{2.5}$	CO2e[2]
F/A-18 C/D Operations	161.23	338.72	111.81	27.27	74.93	74.93	34,689.04
Engine Maintenance Runups	38.95	97.11	13.01	4.06	12.31	12.31	5,008.02
F/A-18E/F Operations	197.17	815.36	441.72	54.41	147.03	147.03	69,961.95
Engine Maintenance Runups	8.86	82.00	12.92	2.28	6.88	6.88	2,853.41
C-40 Operations	0.96	8.81	14.71	2.43	0.25	0.25	3,144.11
T-34 Operations	1.09	4.82	0.80	0.30	0.50	0.50	391.60
E-2C Operations	0.20	1.05	7.31	1.49	0.36	0.36	1,976.07
H-60 Operations	0.87	6.76	1.89	0.81	1.22	1.22	1,052.22
EA-6B Operations	4.13	8.78	1.92	0.77	4.76	4.76	974.12
B190 Operations	0.85	2.72	0.11	0.03	0.02	0.02	84.05
C-130 Operations	0.10	0.93	1.08	0.22	0.15	0.15	284.77
C-17 Operations	0.22	2.42	3.85	0.26	0.11	0.11	699.26
F-16 Operations	0.01	0.20	0.24	0.03	0.06	0.05	81.15
MQ-4 Operations	0.02	0.18	0.14	0.01	0.00	0.00	38.83
Subtotal Aircraft Operations	414.67	1,369.85	611.51	94.37	248.59	248.58	121,238.58
GSE	0.55	2.37	6.39	0.24	0.47	0.46	134.58
Total Airfield Operations	415.22	1,372.22	617.91	94.61	249.06	249.04	121,373.18

[1]VOC conversion from *Recommended Best Practice for Quantifying Speciated Organic Gas Emissions from Aircraft Equipped with Turbofan, Turbojet, and Turboprop Engines*, version 1.0, USEPA, May 2009, Table 4.

[2] Metric tons.

Table 4-2 - NAS Oceana and NALF Fentress Airfield Emissions – Action Alternative

Aircraft Type	VOCs[1]	CO	NOx	SO_2	PM_{10}	$PM_{2.5}$	CO2e[2]
F/A-18E/F Operations	352.36	1,456.20	687.30	86.11	234.10	234.10	110,486.41
Engine Maintenance Runups	17.16	154.95	24.48	4.38	13.36	13.36	3,716.11
C-40 Operations	0.96	8.81	14.71	2.24	0.24	0.24	2,895.60
T-34 Operations	1.09	4.82	0.80	0.30	0.50	0.50	391.60
E-2C Operations	0.20	1.05	7.31	1.47	0.36	0.36	1,976.07
H-60 Operations	0.87	6.76	1.89	0.81	1.22	1.22	1,052.22
EA-6B Operations	4.13	8.78	1.92	0.77	4.76	4.76	974.12
B190 Operations	0.64	2.07	0.11	0.03	0.02	0.02	73.39
C-130 Operations	0.10	0.93	1.08	0.22	0.15	0.15	284.77
C-17 Operations	0.21	2.39	1.61	0.17	0.04	0.04	463.45
F-16 Operations	0.01	0.20	0.24	0.03	0.06	0.05	81.15
MQ-4 Operations	0.02	0.18	0.14	0.01	0.00	0.00	38.83
Subtotal Aircraft Operations	377.77	1,647.13	741.58	96.54	254.82	254.81	122,433.72
GSE	0.53	2.29	6.15	0.24	0.46	0.44	129.65
Total Airfield Operations	378.30	1,649.42	747.73	96.78	255.28	255.25	122,563.37
Net Change from Affected Environment	-36.92	277.20	129.82	2.17	6.22	6.21	1,190.17

[1]VOC conversion from *Recommended Best Practice for Quantifying Speciated Organic Gas Emissions from Aircraft Equipped with Turbofan, Turbojet, and Turboprop Engines*, version 1.0, USEPA, May 2009, Table 4.

[2] Metric tons.