APPENDIX E
AIR QUALITY ANALYSIS

As described in Section 3.9, air quality in a given location is described by the concentration of various pollutants in the atmosphere. The significance of the pollutant concentration is determined by comparing it to the federal and state ambient air quality standards.

The air quality analysis in this Environmental Assessment (EA) examined impacts from air emissions associated with the proposed construction and operation activities associated with the Proposed Action. As part of the analysis, emissions generated from construction equipment, motor vehicles and Unmanned Aerial Systems (UAS), and other area (nonmobile) sources (i.e., generators) were examined for carbon monoxide (CO), nitrogen oxides (NO_X), sulfur dioxide (SO_X), ozone (in the form of volatile organic compounds [VOCs]), and particulate matter (PM_{10} and $PM_{2.5}$). Air quality at Wallops Island is regulated by the United States Environmental Protection Agency (USEPA) and Virginia Department of Environmental Quality (VDEQ). The Northeastern Virginia Intrastate Air Quality Control Region (AQCR), including Accomack County, is attainment/unclassifiable for all criteria pollutants.

CONSTRUCTION

Air quality impacts from proposed construction activities were estimated from (1) combustion emissions due to the use of fossil fuel-powered equipment; (2) fugitive dust emissions (PM_{10} and $PM_{2.5}$) during earth-moving activities, and the operation of equipment on bare soil; and (3) VOC emissions from application of asphalt materials during paving operations.

Factors needed to derive the construction source emission rates were obtained from *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling* (USEPA 2010a); *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling—Compression-Ignition* (USEPA 2010b); *Nonroad Engine and Vehicle Emission Study—Report* (USEPA 1991); *Conversion Factors for Hydrocarbon Emission Components* (USEPA 2005); and *Western Regional Air Partnership (WRAP) Fugitive Dust Handbook* (WRAP 2006).

The analysis assumed that all construction equipment was manufactured before 2000. This approach is based on the well-known longevity of diesel engines, although use of 100% Tier 0 equipment may be somewhat conservative. The analysis also inherently reduced PM_{10} fugitive dust emissions from earth-moving activities by 50 percent as this control level is included in the emission factor itself.

Off-Road Equipment Emissions. The NONROAD model (USEPA 2008) is the EPA standard method for preparing emission inventories for mobile sources that are not classified as being related to on-road traffic, railroads, air traffic, or water-going vessels. As such, it is the starting place for quantifying emissions from construction-related equipment.

The NONROAD model uses the following general equation to estimate emissions separately for CO, NOx, PM (essentially all of which is PM2.5 from construction sources), and total hydrocarbons (THC), nearly all of which are nonmethane hydrocarbons:

EMS = EF * HP * LF * Act * DF

Where:

EMS = estimated emissions

EF = emissions factor in grams per horsepower hours

HP = peak horsepower

LF = load factor (assumed percentage of peak horsepower)

Act = activity in hours of operation per period of operation

DF = deterioration factor

The emissions factor is specific to the equipment type, engine size, and technology type. The technology type for diesel equipment can be "base" (before 1988), "tier 0" (1988 to 1999), or "tier 1" (2000 to 2005). Tier 2 emissions factors could be applied to equipment that satisfies 2006 national standards (or slightly earlier California standards). The technology type for two-stroke gasoline equipment can be "base" (before 1997), "phase 1" (1997 to 2001), or "phase 2" (2002 to 2007). Equipment for phases 1 and 2 can have catalytic converters. For this study, all diesel equipment was assumed to be either tier 0 or tier 1 and all two-stroke diesel equipment was assumed to be phase 1 without catalytic converters.

The load factor is specific to the equipment type in the NONROAD model regardless of engine size or technology type, and it represents the average fraction of peak horsepower at which the engine is assumed to operate. NONROAD model default values were used in all cases. Because Tier 0 equipment was conservatively used throughout the analysis period (begin in 2016; complete within 9 months), deterioration factors were not used to estimate increased emissions due to engine age. Based on the methodology described, it is possible to make a conservative estimate of emissions from off-road equipment if the types of equipment and durations of use are known.

Fugitive Dust. Emission rates for fugitive dust were estimated using guidelines outlined in the *WRAP Fugitive Dust Handbook* (WRAP 2006). The WRAP handbook offers several options for selecting factors for PM_{10} (coarse PM) depending on what information is known. After PM_{10} is estimated, the fraction of fugitive dust emitted as $PM_{2.5}$ is estimated, the most recent WRAP study (MRI 2005) recommends the use of a fractional factor of 0.10 to estimate the $PM_{2.5}$ portion of the PM_{10}. For site preparation activities, the emission factor was obtained from Table 3-2 of the WRAP Fugitive Dust Handbook. The areas of disturbance and approximate durations were used in conjunction with the large scale of land-disturbing activities occurring, resulting in the selection of the first factor with worst-case conditions for use in the analysis.

PM_{10}, $PM_{2.5}$, and Mobile Sources. Diesel exhaust is a primary, well-documented source of $PM_{2.5}$ emissions. The vast majority of PM emissions in diesel exhaust is $PM_{2.5}$. Therefore, all calculated PM is assumed to be $PM_{2.5}$. A corollary result of this is that the PM_{10} fraction of diesel exhaust is estimated very conservatively as only a small fraction of PM_{10} is present in the exhaust. However, ratios of PM_{10} to $PM_{2.5}$ in diesel exhaust are not yet published and therefore for the purposes of the EA calculations, all PM emissions are equally distributed as PM_{10} and $PM_{2.5}$.

VOC Emissions from Paving. VOC emissions from the application of hot mix asphalt were calculated throughout the nine month construction period in 2016. The estimates used asphalt volumes as provided in the Final Cost Estimate (NASA 2011) , and used the published California Air Resources Board (CARB) hot mix asphalt emission factor.

OPERATIONS

Air emissions from the air strip operations are due to the UAS themselves and generators that power the mobile command centers that are associated with each UAS.

UAS Operations. The total number of flights per year for each model of UAS was evenly split from the proposed annual total, including the flights for battery-powered UAS. The maximum flight duration for each model was provided by NASA personnel, and these data were conservatively used as the standard flight duration. Brake specific fuel consumption (BSFC) and criteria pollutant emission factors were obtained from) *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling—Compression-Ignition* (USEPA 2010b).

For the GTM AirSTAR, which is a 5.5% scaled version of a Boeing 757, throughput and emission factors were derived from the International Civil Aviation Organization (ICAO) Engine Emissions Databank Datasheets for two common 757 engine models, the PW2037 and PW2040 (ICAO 2004a and ICAO 2004b). The emission factors for these two engines were averaged because the exact engine model that has been scaled for the GTM AirSTAR is not known. In order to appropriately scale the emission factors, the rated turbofan engine output for each engine type was scaled to 5.5% of the actual full-size output (in kilonewtons) as indicated in the datasheets, and the average taken of the scaled outputs for the two engine models. The emission factors were then multiplied by the scaled output and the number of engines (2) to calculate total air emissions from operation of the UAS.

Command Center Generator Operations. Mobile generators are required to power the command centers for the UAS. A generator size of 60 kW was assumed for all command centers, based on the use of this size generator for the GTM AirSTAR Command Center (Jordan *et al*. undated). The total hours of operation of a 60 kW generator for one year was established by adding the total maximum duration flight times X total annual flights for each UAS (including battery operated UAS). Emission factors for the rated generator size were obtained from *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling—Compression-Ignition* (USEPA 2010b) and the use of diesel fuel was assumed for generator operation.

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UAS Airstrip Construction Air Emissions - Wallops Flight Facility, VA

Airstrip Construction Begin in 2016 and completion within 9 months

Construct Airstrip measuring 3,000 ft long by 75 feet wide 14cy
Fill brought from offsite except 978 CY from onsite trenching.

Land Clearing 13 AC

Equipment	*Number*	*Hr/day*	*# days*	*Hp*	*LF*	**VOC** g/hp-hr	**CO** g/hp-hr	**NOx** g/hp-hr	**SO2** g/hp-hr	**PM** g/hp-hr	**VOC** lb	**CO** lb	**NOx** lb	**SO2** lb	**PM** lb
Excavator	1	6	13	95	0.21	0.99	3.49	6.9	0.85	0.722	3	12	24	3	2
Mulching head	1	6	13	150	0.58	0.68	2.7	8.38	0.93	0.402	10	40	125	14	6
Backhoe/loader	2	4	30	98	0.21	0.99	3.49	6.9	0.85	0.722	11	38	75	9	8
Skid/steer Loader	1	8	13	67	0.23	0.5213	2.3655	5.5988	0.93	0.473	2	8	20	3	2
Dump truck	6	0.5	30	275	0.21	0.68	2.7	8.38	0.89	0.402	8	31	96	10	5
										Subtotal	34	130	340	40	23

Site fill 44228 CY

Equipment	*Number*	*Hr/day*	*# days*	*Hp*	*LF*	**VOC** g/hp-hr	**CO** g/hp-hr	**NOx** g/hp-hr	**SO2** g/hp-hr	**PM** g/hp-hr	**VOC** lb	**CO** lb	**NOx** lb	**SO2** lb	**PM** lb
Skid steer loader	2	8	91	67	0.23	0.5213	2.3655	5.5988	0.93	0.473	26	117	277	46	23
Backhoe/loader	4	8	105	98	0.21	0.99	3.49	6.9	0.85	0.722	151	532	1,052	130	110
Dump truck	30	0.5	105	275	0.21	0.68	2.7	8.38	0.89	0.402	136	541	1,680	178	81
										Subtotal	177	649	1,329	176	133

Grading 95571 SY

Equipment	*Number*	*Hr/day*	*# days*	*Hp*	*LF*	**VOC** g/hp-hr	**CO** g/hp-hr	**NOx** g/hp-hr	**SO2** g/hp-hr	**PM** g/hp-hr	**VOC** lb	**CO** lb	**NOx** lb	**SO2** lb	**PM** lb
Dozer	1	6	22	90	0.59	0.99	3.49	6.9	0.93	0.722	15	54	107	14	11
Skid steer loader	2	4	55	67	0.23	0.5213	2.3655	5.5988	0.93	0.473	8	35	84	14	7
Backhoe/loader	2	6	22	98	0.21	0.99	3.49	6.9	0.85	0.722	12	42	83	10	9
Small diesel engines	2	4	44	10	0.43	0.7628	4.1127	5.2298	0.93	0.4474	3	14	17	3	1
Grader	2	2	22	150	0.59	0.68	2.7	8.38	0.93	0.402	12	46	144	16	7
										Subtotal	49	191	434	58	35

Trenching 978 CY

Equipment	*Number*	*Hr/day*	*days*	*Hp*	*LF*	**VOC** g/hp-hr	**CO** g/hp-hr	**NOx** g/hp-hr	**SO2** g/hp-hr	**PM** g/hp-hr	**VOC** lb	**CO** lb	**NOx** lb	**SO2** lb	**PM** lb
Backhoe/loader	1	8	10	98	0.21	0.99	3.49	6.9	0.85	0.722	4	13	25	3	3
Excavator	1	8	7	90	0.21	0.99	3.49	6.9	0.85	0.722	2	8	16	2	2
Dump truck	1	4	10	275	0.21	0.68	2.7	8.38	0.89	0.402	3	14	43	5	2
Small diesel engines	1	8	7	10	0.43	0.7628	4.1127	5.2298	0.93	0.4474	0	2	3	0	0
Trencher	1	8	8	100	0.21	0.99	3.49	6.9	0.85	0.722	3	10	20	3	2
										Subtotal	13	47	107	13	9

Gravel Work 2666 CY

Equipment	*Number*	*Hr/day*	*# days*	*Hp*	*LF*	**VOC** g/hp-hr	**CO** g/hp-hr	**NOx** g/hp-hr	**SO2** g/hp-hr	**PM** g/hp-hr	**VOC** lb	**CO** lb	**NOx** lb	**SO2** lb	**PM** lb
Backhoe/loader	1	8	28	98	0.21	0.990	3.49	6.9	0.85	0.722	10	35	70	9	7
Skid steer loader	2	6	83	67	0.23	0.521	2.3655	5.5988	0.93	0.473	18	80	189	31	16
Small diesel engines	1	8	83	10	0.43	0.763	4.1127	5.2298	0.93	0.4474	5	26	33	6	3
Dump truck	8	0.5	28	275	0.21	0.680	2.7	8.38	0.89	0.402	10	39	119	13	6
										Subtotal	42	180	412	59	32

Construct/pave airstrip 225,000 SF

Equipment	Number	Hr/day	# days	Hp	LF	VOC g/hp-hr	CO g/hp-hr	NOx g/hp-hr	SO2 g/hp-hr	PM g/hp-hr	VOC lb	CO lb	NOx lb	SO2 lb	PM lb
Grader	1	4	38	150	0.59	0.68	2.7	8.38	0.93	0.402	20	81	251	28	12
Roller	1	4	13	30	0.59	1.8	5	6.9	1	0.8	4	10	14	2	2
Paver	1	8	13	107	0.59	0.68	2.7	8.38	0.93	0.402	10	39	121	13	6
Delivery truck	1	2	13	180	0.21	0.68	2.7	8.38	0.89	0.402	1	6	18	2	1
Skid steer loader	1	4	38	67	0.23	0.5213	2.3655	5.5988	0.93	0.473	3	12	29	5	2
Small diesel engines	1	4	26	10	0.43	0.7628	4.1127	5.2298	0.93	0.4474	1	4	5	1	0
Dump truck (12 CY)	1	0.5	26	275	0.21	0.68	2.7	8.38	0.89	0.402	1	4	14	1	1
										Subtotal	40	157	452	52	24

Volume of hot mix asphalt	56,250	ft^3
Average density of HMA	145	lb/ft^3
CARB EF for HMA	0.04	lb/ton
VOC emissions from HMA paving	163	lb

Fugitive Dust Emissions:

PM_{10} tons/acre/mo	acres	days of disturbance	PM_{10} Total	$PM_{2.5}/PM_{10}$ Ratio	$PM_{2.5}$ Total
0.42	2.5	180	6.3	0.1	0.63

Heavy duty truck trips to/from site (primarily for fill and gravel):
Assume 50 mile roundtrip:

Equipment	Distance	# Trips	VOC g/mi	CO g/mi	NOx g/mi	SO2 g/mi	PM g/mi	VOC lb	CO lb	NOx lb	SO2 lb	PM lb
Dump Truck (Heavy Duty Diesel Vehicle)	50	3694	0.4216	2.0378	7.853	0.0132	0.22902	172	830	3,198	5	93

2016 Emission Totals:

VOC T/yr	CO T/yr	NOx T/yr	SO2 T/yr	PM_{10} T/yr	$PM_{2.5}$ T/yr
0.34	1.09	3.14	0.20	6.47	0.80

generator for mobile ops center
fuel

UAS ops 1040 flights per year total

Model	Engine (HP) Rating	[1]annual # flights	flight time in hours	[2]BSFC lb/hp-hr	[3]VOC lb/hp-hr	CO lb/hp-hr	[3]NOx lb/hp-hr	[3]PM lb/hp-hr	[4]CO2 g/hp-hr	VOC lb	CO lb	NOx lb	PM lb	CO2 lb
Viking 100	16	130	12	0.408	0.000966	0.004764	0.00978836	0.000588	188	9.83	48.52	99.68	5.98	4220.84
Viking 300	25	130	9	0.408	0.000966	0.004764	0.00978836	0.000588	188	11.52	56.86	116.81	7.01	4946.30
Viking 400	38	130	10	0.408	0.000615	0.003378	0.01042329	0.000747	188	12.39	68.09	210.08	15.06	8353.75
Exdrone	8	130	2	0.408	0.0016817	0.009067	0.011529796	0.0009864	188	1.43	7.69	9.78	0.84	351.74
Shadow 200	38	130	4	0.408	0.000615	0.003378	0.01042329	0.000747	188	4.96	27.24	84.03	6.02	3341.50
	GTM AirSTAR	turbofan 757 engines rated output scaled to 5.5% in kN	# engines	[1]annual # flights	[5]VOC g/kN	[5]CO g/kN	[5]NOx g/kN	[5]PM g/kN	[6]CO2 g/kN	VOC lb	CO lb	NOx lb	PM lb	CO2 lb
	average flight	9.5978	2	130	3.23	33.6	51.6	11.6	NA	17.77	184.85	283.88	63.82	NA
Grand Total in Tons/yr for All Flight Ops										**0.03**	**0.20**	**0.40**	**0.05**	**10.61**
										CO2 in metric tons (CO2*e*)				**9.6**

[1]Total number of flights per year/number of aircraft that may fly (1040/8) - includes battery operated aircraft (2)

[2]Brake Specific Fuel Consumption

[3]From Table A-4 of Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling - Compression-Ignition, EPA, July 2010.

[4]Converted from emission factor for Distillate Fuel Oil #2 (diesel) as listed in Table C-1 to Subpart C of Part 98 Default CO2 Emissions Factors and High Heat Values for Various Types of Fuel.

Listed factor 73.96 kg CO2/mmBtu
393 hp-hr = mmBtu
188 g CO2/hp-hr

[5]Averaged and scaled EFs from ICAO Engine Emissions Databank Datasheets for engines PW2037 and PW2040 (common 757 engine models)(could find no data on the scaled engines).

[6]Scaled EF from Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Sect 2.5, Table 2, IPCC, 2001.

Operational Emissions - Mobile Generators Assume 60kW generators used for all mobile control centers

Generator size HP	hours of operation	BSFC lb/hp-hr	[1]CO lb/yr	[1]NOx lb/yr	[1]PM lb/yr	[1]VOC lb/yr	CO2 lb/yr
80.46	15210	0.408	3475	15479	360	7490	539,263
	Tons/yr		**1.74**	**7.74**	**0.18**	**3.74**	**269.63**
			CO2 in metric tons (CO2*e*)				**244.6**

Pollutant	Emission Factors Diesel Fuel [a, b] lb/hp-hr
CO	0.00696
NO_x	0.031
PM	0.00072
VOC	0.015
CO2	1.08

[a] Emission factors used to estimate emissions from the consumption of diesel fuel from AP-42, Section 3.3, Table 3.3-1, EPA 1996.

[b] Emission factors from From Table A-4 of Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling - Compression-Ignition, EPA, July 2010.

	VOC	CO	NOx	PM	CO2
Total Annual Operation Emissions/Year in Tons	**3.79**	**1.77**	**7.94**	**0.58**	**280.24**
	CO2 in metric tons (CO2*e*)				**254**