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ANALYSIS OF NON-TACTICAL VEHICLE UTILIZATION AT FORT CARSON COLORADO

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ABSTRACT

The Department of Defense (DOD) is considering integration of electric vehicles into its non-tactical vehicle (NTV) fleet to support efficiency goals and sustainable power initiatives. In order to identify the best vehicles for electrification, DOD needs to understand the duty cycles and daily operating patterns of NTVs on bases. A six-month data acquisition study was conducted on 24 NTVs at Fort Carson, CO using GPS data loggers to monitor a variety of vehicle types and uses. Information was extracted on usage time, distance, vehicle speed and geographic location in order to compare vehicle driving profiles. The regenerative energy recovery potential for specific duty cycles was also quantified through a cumulative assessment of the number and severity of deceleration events. Of the duty cycles analyzed, the work trucks at Fort Carson were judged to be the best electric vehicle candidates.

INTRODUCTION

The DOD owns/operates nearly 200,000 non-tactical vehicles (NTVs) worldwide. DOD is actively replacing NTVs with more efficient models, alternative fuel vehicles, and hybrid-electric vehicles to decrease petroleum demand. DOD is also considering the merits of a large-scale integration of plug-in electric vehicles (PEVs) into its NTV fleet on a number of military installations in the Continental United States (CONUS). This will support efficiency improvement goals as well as DOD sustainable power initiatives involving micrograms and vehicles capable of two-way power flow to the grid.

In order to identify the best vehicle candidates for electrification, DOD needs to understand the duty cycles and daily operating patterns of NTVs on CONUS bases. Vehicle mileage logs exist for the NTV fleet, allowing assessment of periodic usage. However, it is recognized that total mileage accumulated over finite periods of time is not a useful parameter by itself for identifying electrification candidates because it may derive from a mix of very long and very short trips that can make recharging problematic. If a vehicle travels distances during a day that exceed what a battery charge might support, it is useful to ascertain whether there are long stopover periods at a location where recharging could be feasible. Therefore, granular information on vehicle location vs. time and driving profile is desirable to support electrification plans. The key aspect when compiling such information is the ability to extract trends from this granular information for comparing driving profile characteristics of different vehicles in a quantitative way.

DUTY CYCLE DEVELOPMENT

The U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) funded a six-month data acquisition study that was conducted in 2011-2012 at Fort Carson, CO. A total of 24 vehicles representing a variety of NTV types and uses were monitored for approximately two weeks each. Vehicle location data vs. time was acquired on the majority of the vehicles using low-cost, non-intrusive Global Positioning System (GPS) data loggers having vibration sensor activation capability. More sophisticated OBD-II port data loggers were used on some of the vehicles to obtain additional information regarding engine idle time and fuel efficiency. From the data acquired, information was extracted on vehicle utilization including usage days, time, distance, speed and geographic location in terms of quantitative parameters in order to compare vehicle driving profiles.

A standardized summary report was developed that illustrates key utilization profile metrics for each vehicle monitored. Daily usage statistics for mileage, time, number of trips and speed profile are presented in graphical form to provide a method of assessing trends and conditions to identify vehicle electrification candidates. Geo-plots were also developed using mapping software to show a vehicle's daily track on either map or satellite photo backgrounds. This provides an understanding of distance traveled away from potential recharging points. An example of one of these summary reports is shown below in Figure 1 for one of the work trucks at Fort Carson. This truck is judged a good candidate for electrification – the daily usage is predictable with an average of 29 mi/day and a high of 51.3 mi, speed distribution is low with an average of 21.8 mph and 95% of speeds below 40 mph, and the vehicle stays on or near the base and returns to the same parking location each night.

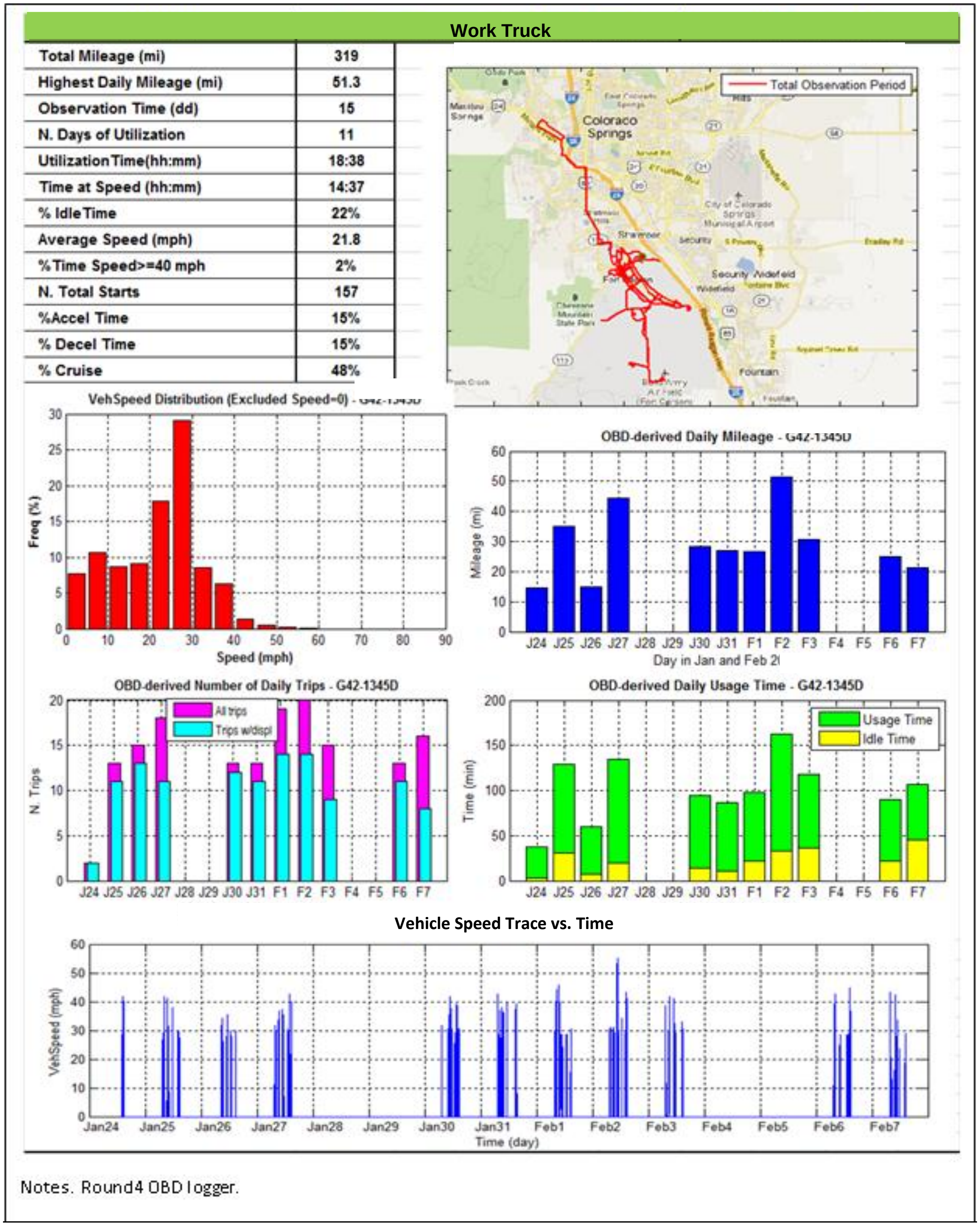

Figure 1: Vehicle Utilization Summary Report –Work Truck

TRIP STATISTICS

The geo-map plot provided in the summary report for each vehicle shows whether it operated only within the base or also outside the base. For on-base driving, the vehicle speed distribution typically shows an appreciable drop in the percentage of speed values greater than 35 mph, which reflects the speed limit on the base. When the vehicle speed reflects approximately equal times spent within and outside the base, the speed distribution tends to develop a bimodal appearance. Separating vehicle speed values by location, it is possible to show that all vehicles monitored have the same qualitative speed patterns regarding the speed bin at which the cumulative sum crosses the 50% and the 75% mark. More precisely, the quartile values can be calculated.

While the trip table indicating the trip distance, length and maximum speed for each trip is too granular to perceive trends between vehicles, the mean and the median of the trip distance and trip duration (usage time) can be valuable metrics for comparing driving profile characteristics. For example, the driving profile for one of the work trucks monitored can be summarized at the trip level by the statistical parameters shown in Table 1 below.

Table 1: Statistical Analysis of Driving Profile Based on Trips -- Work Truck

	N. Trips	153
	N. Trips>0.2 mi	135
Param	**Time(sec)**	**Distan(mi)**
average	430.4	1.7
median	385	1.5
1st Quartile	229	0.3
3rd Quartile	552	2.4
Max	1734	6.9
Min	4	0

The statistical analysis for this vehicle indicates that the distance travelled in 25% of the trips is less than or equal to 0.3 miles with an average trip time of just under 4 minutes, while the distance traveled during 50% of the trips (median value) is equal to or less than 1.5 miles with an average trip time of approximately 6.5 minutes. The average values of time and distance are larger than the median values which points to the existence of some longer trips. However, the maximum trip distance is still relatively short at only 6.9 miles. Thus, this vehicle would likely be a good candidate for electrification.

The statistical results in Table 1 correlate with the daily values of the summary report which show that the daily distance during a number of the days observed is approximately 30 miles, and is made up of short trips since the number of trips ranges between 10 and 15. The two ways of summarizing duty cycle profiles are equivalent tools for understanding usage characteristics consistent with electrification benefit. In case the daily distance values are higher than the range for an electric vehicle, the quartile analysis may provide more insight on evaluating potential recharging issues.

FLEET DUTY CYCLE OBSERVATIONS

The types of non-tactical vehicles monitored can be grouped into those that operate mainly within the base and its immediate proximity (work trucks, maintenance and delivery vehicles) and the ones that may make long trips away from the base, sometimes with overnight rest (pool vehicles, ambulances and shuttle vans).

Summary Trends by Vehicle Functional Type

- **Support Vehicles: Engineering, Maintenance & Supply, DPW Fleet Mgr. –** Utilized nearly every work day on the base or in the adjacent city area but rarely on weekends or for longer trips. Average daily mileage was 16 – 27 mi for four of the vehicles with an average speed below 30 mph, so this group appears to contain good candidates for electrification.
- **Pool Vehicles –** Usage varied considerably with short-distance, low-speed trips on some days and long-distance, high-speed trips on others. This suggests there is an opportunity to have some pure EVs as pool vehicles for local trips plus a mix of PHEVs or charge-sustaining HEVs for longer trips.
- **Work Trucks –** These box trucks on a light or heavy-duty pickup chassis are used to transport an operator and tools to on-base locations for maintenance and repair. They make frequent short trips with low total daily mileage and normally return to their primary storage location, making these the best candidates for electrification of the vehicle types examined.
- **Ambulances –** Tend to be used seven days per week but daily trip count and mileage vary significantly and include some high-speed, long-distance trips. Idle time can also be high due to the need to power on-board equipment during a deployment. As a result, electrification potential is low.
- **Transport and Shuttle Buses –** A Bluebird transport bus used on or around the base averaged 12 trips per day with low total mileage, making it a good

electrification candidate. The shuttle buses monitored were used for much longer trips, including overnight and at high speeds, meaning they would be more difficult to electrify.

Table 2 below shows key metrics summarizing vehicle usage for each of the vehicles monitored in this study, grouped in functional categories. The operational location for each vehicle is also shown.

Table 2: Key Usage Statistics for Monitored Vehicles Grouped by Function

Function	No. Util. Days	Time at Speed (hh:mm)	Total Mileage (mi)	Highest Daily Mileage (mi)	Percent Idle Time (%)	No. trips	Avg Spd (mph)	Operational Location
Engineering	12	13:17	226	36	23	94	22.5	Base/City
Maint/Supply Activ	9	8:40	244	67	15	65	28.5	Base/City
Maint/Supply Activ	10	9:06	193	37	14	97	21.0	BaseCtr
DPW Fleet Mgr	11	8:34	171	38	26	93	19.9	BaseS/City
Maintenace	11	18:54	694	111	30	74	37.6	Base/City
Pool	11	27:24	1491	314	11	147	54.5	Base/South
Pool (Exec. Van)	7	15:41	958	332	6	42	61.3	Base/NM
Work Truck	15	21:28	494	54	12	165	23.2	Base/South
Work Truck	7	6:06	184	73	20	78	30.0	Base/South
Work Truck	13	12:16	253	30	33	153	20.6	Base
Work Truck	11	9:25	199	66	11	113	21.4	Base/BaseSo
Work Truck	11	14:37	319	51	22	157	21.8	Base/City
Work Truck	11	8:36	215	66	17	79	25.0	Base/BaseSo
Delivery Flat Bed	8	3:18	58	16	19	52	17.8	Base
Work Truck	9	6:28	116	42	18	70	18.1	Base/City
Ambulance	17	15:15	372	52	10	116	30.5	Base/City
Ambulance	8	12:36	394	102	23	142	30.6	Base/City
Ambulance	14	22:08	789	217	42	85	35.6	Base/Pueblo/Denver
Ambulance	15	23:01	669	88	48	102	29.0	Base/BeaverCr./City
Ambulance	15	23:12	778	145	14	166	33.6	City/Pueblo
25-Psgr Bus	1	5:56	273	273	2	7	47.3	WestRange
25-Psgr Bus	3	12:10	546	286	38	10	44.8	Mountains
Transport Bus	5	4:29	90	34	16	60	20.2	Base/City
25-Psgr Bus	9	38:40	1761	290	53	34	45.5	Mountains

ENERGY RECOVERY POTENTIAL ANALYSIS

Recovery of electric energy into the storage medium is an important element of vehicle electrification in order to maximize range. It is recognized that not all kinetic energy is recoverable during deceleration because of maximum battery current limitations at high speeds and efficiency loss at low speeds. However, if vehicles like the work trucks ranging from 4,000 to 6,000 lbs curb weight were to be electrified with a 40 kWh power pack, they could derive substantial benefit from regenerative braking energy recovery.

The mass of the vehicles monitored in this study was not known. However, some useful information could be calculated by looking at the change per unit time of a parameter, the vehicle velocity square (or VSS^2), which is proportional to kinetic energy loss (power) once the appropriate constant for the mass is factored in. If two vehicles can be assumed to have similar mass and loading with both driven on level ground, this parameter can be used as a comparison tool.

The upper left chart in Figure 2 below shows the distribution of VSS^2 changes per second for a work truck that operated primarily on the base. The distribution is skewed to low values indicating braking events from low speed as suggested by the vehicle speed distribution shown to the right. The VSS^2 distribution for a second work truck that was also used on the highway and at higher speeds is shown in the lower left portion of Figure 2. This vehicle has a broader and more centered VSS^2 distribution.

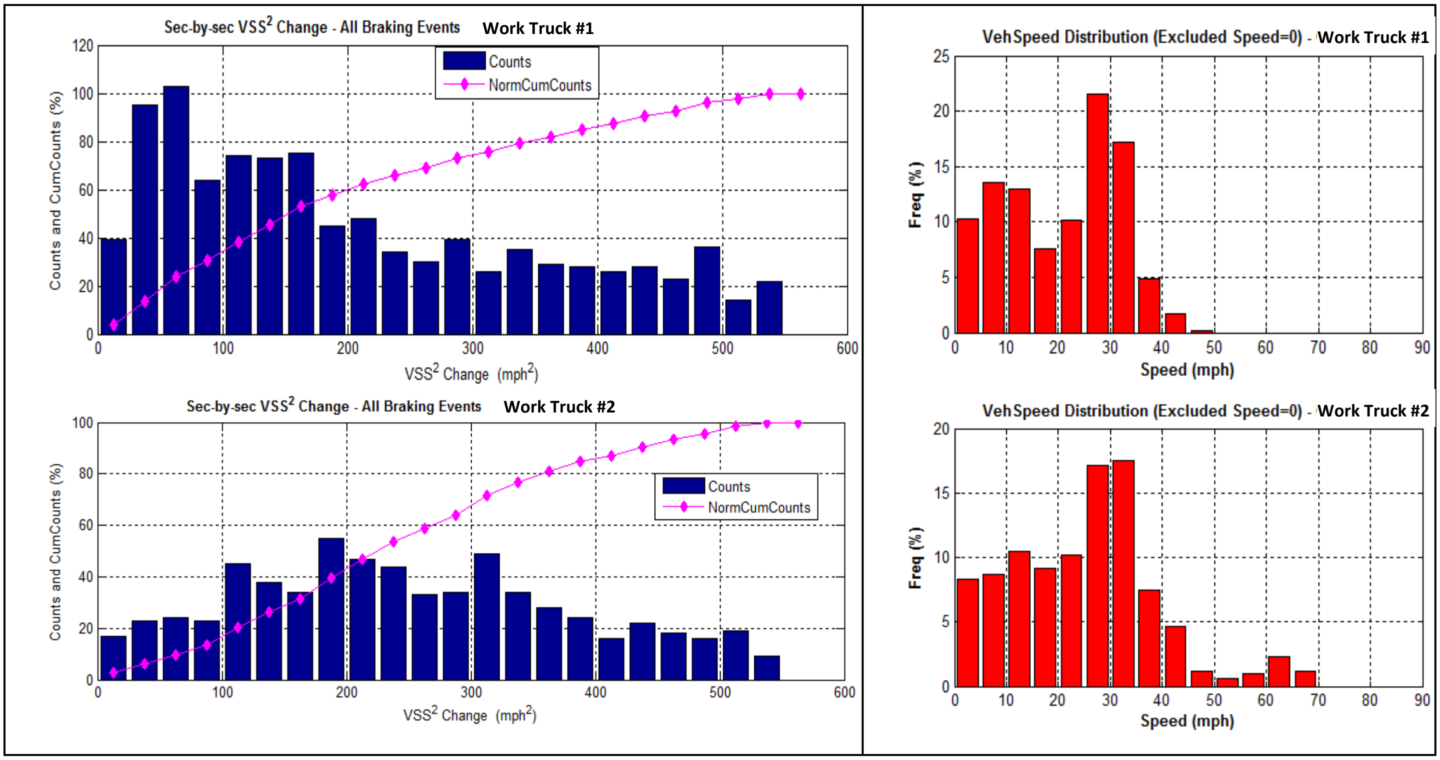

Figure 2: Distribution of changes in vehicle velocity per second squared referenced to vehicle speed distribution

CONCLUSIONS

A variety of non-tactical vehicles at Fort Carson were monitored for two-week periods during 2011-2012 to extract duty cycle and geographic usage information. Data was acquired utilizing either low-cost GPS data loggers with vibration sensor activation or OBD-II port data loggers with GPS capabilities. Data series were taken which enabled statistical analysis of the driving profile described by means of global parameters plus evaluation of driving routes and characteristics on a daily basis.

Vehicles were categorized by usage type and conclusions made regarding the suitability of each type for conversion to electrified propulsion vehicles. These conclusions were derived by examining daily trip statistics along with percent idle time, speed profiles, and the distance vehicles traveled away from potential recharging points during a single day.

Further analysis is required to determine whether the Fort Carson NTV duty cycle results are applicable to the NTV fleets at other military bases. It is anticipated that the duty cycle data will be used for comparison purposes to electrified vehicles running in the Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS) Phase II Demonstration Project at Fort Carson during 2012 and 2013.

Deceleration data obtainable with a simple GPS data logger can be analyzed to provide a useful indicator of kinetic energy recovery potential in an electrified vehicle. The methodology employed utilized the frequency and severity of deceleration events coupled with the vehicle speed profile to provide a comparative analysis tool.

DISCLAIMER

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