**14. ABSTRACT**

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**15. SUBJECT TERMS**

Vehicle Platooning, speed, ground transportation, convoys
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FUTURE WAR PAPER

VEHICLE PLATOONING: INCREASING GROUND UNIT SPEED BY DECREASING COLUMN LENGTH

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF OPERATIONAL STUDIES

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AY 2013-14

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Date: 27 MAY 2014
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Introduction

Military ground formations do not advance much faster on the modern battlefield with the benefit of motorized transportation than Napoleon’s Army travelled on foot in the 1800s. One reason is that as vehicles have been incorporated into military units, the length of military columns has also grown. Gaps in columns are one of the most significant and overlooked factors that contribute to overall column length. An emerging technology, Vehicle Platooning, promises to increase ground unit speed by reducing gaps. This technology electronically connects and directs vehicles within a column, managing the distance between vehicles operating at high speeds and eliminating the requirement for human operators in some situations. When techniques enabled by Vehicle Platooning technology are adopted, such as the Regimental Transit Formation proposed below, the speed of military ground units can be increased up to 30 percent.

The Need for Speed

According to Marine Corps Doctrinal Publication-1, “superior speed allows us to seize the initiative and dictate the terms of action, forcing the enemy to react to us...we should take all measures to improve our own speed.” A military ground unit that moves quickly has the ability to deny to an enemy key terrain, bypass obstacles, or quickly move through choke points. Improvements in the movement rate of a force increase its ability to outmaneuver enemy forces, exploit opportunities, and enhance security by decreasing exposure to enemy threats. The rapidity of a force is an important factor in warfare, and improving the rate a ground unit projects power can achieve tactical and operational advantages.

Despite technological advances in vehicle speed, the rate ground forces move during campaigns has not improved significantly since the Napoleonic era of the early 1800s. In his
book *Understanding War: History and Theory of Combat*, T.N. Dupuy analyzes 33 battles that occurred from the Napoleonic Wars (1800) to the Vietnam Conflict (1967). He finds no substantial improvement to the advance rate during campaigns of the same duration despite dramatic advancements in the means of movement over this period. It is counter-intuitive that groups of troops marching at eight kilometers per hour (KPH) advance faster than groups of vehicles traveling in excess of 90 KPH. Yet, Napoleon advanced faster on foot in 1812 at 14 kilometers per day (KPD) than German blitzkrieg forces did in 1941 with tanks and trucks at 10 KPD. Even in the Operation: IRAQI FREEDOM campaign in 2003 it took coalition forces 30 days to travel the 724 kilometers from the Kuwait border to Tikrit, an advance rate of only 24 KPD. This rate is comparable to the campaigns of Ulm in 1805 (22 KPD), Marne in 1914 (20 KPD), and the Normandy breakout in 1944 (28 KPD).

While the effects of terrain, weather, enemy responses, chance, and increased logistical requirements explain why increased vehicle speed has not led to increased campaign movement rates, this paper focuses only on decreasing the negative effects of column length to increase military ground unit movement rates.

**The Problem: Column Length and Pass Time**

Technological advances in motor transportation have increased individual vehicle speed but also increased column length. A column with motorized vehicles is longer than a footmobile column because each element of the column is longer and the gaps between elements are larger. A truck with four passengers has a greater length than four people walking, and gaps between vehicles are larger than gaps between individuals marching. For example, in 1870 the Prussian Second and Reserve Army, a force of about 150,000 men, had a column 78 miles long when stretched along a single route. By 1940, Panzer Group Kleist, a mechanized German
Army Corps of 134,370 men, had a theoretical march movement column approximately 956 miles long if lined up on a single avenue of approach. This column length increased 12.25 times based on the effects of mechanization/motorization. This example demonstrates how increased column length degrades the advantages of faster individual vehicle speed when applied to the unit as a whole.

The effect of column length on military combat power is significant because the rate a force moves from point A to point B must include the time it takes the force at the end of a convoy to be brought to bear on the enemy. Longer columns mean vehicles at the end of the line have a farther distance to travel and a longer time to wait before movement for that vehicle can begin. The impact these delays have on the column are best represented by a term called pass time, or the length of time it takes for all the vehicles to pass a given point. The numerous variables used to calculate pass time can be grouped into four broad categories: vehicle speed, vehicle length, number of vehicles, and gaps. The gaps between units and individual vehicles play a significant role in determining the duration of pass time for a unit. Therefore, reducing vehicle gaps directly relates to increasing the rate a military ground unit moves. An emerging technology called Vehicle Platooning is being developed which could provide opportunities to reduce vehicles gaps, consequently increasing unit speed, for future military ground forces.

**The Solution: Vehicle Platooning**

Vehicle Platooning is an experimental technology developed by researchers in Europe and the United States to increase driver safety and the throughput of vehicles on highways and interstate roads. A human operated Leader Vehicle coordinates the movement of Follower Vehicles through a combination of radios, radar, and/or Global Positioning Systems “producing the illusion of mechanical coupling.” This system allows Follower Vehicles within a convoy to
turn, accelerate or decelerate based on their relative location to the Leader Vehicle. In other words, Follower Vehicles are driven by the Leader Vehicle rather than by a human operator. Ongoing testing of Vehicle Platooning typically evaluates configurations of about twelve vehicles to ensure appropriate gaps are available for vehicles entering highways at on ramps. However, hundreds or thousands of vehicles could potentially be linked together in one massive column.

Vehicle Platooning increases throughput on roads by significantly reducing the distance between vehicles. This technology safely reduces the gaps between vehicles because sensors and computer systems produce and interpret updates more quickly than humans can, at a rate up to 50 times per second. This system also allows the same messages to be sent to all Follower Vehicles in the group simultaneously, allowing them to turn or slow down at the same time, drastically increasing reaction time. Figure 1 depicts how vehicles at the back of the column can slow down at the same time as vehicles in the front which results in a smaller safety gap. Successful test have already been conducted demonstrating vehicles can travel at max highway speed with gaps less than two meters wide, a significant reduction of the approximately 11 meter wide gap currently in use.

Figure 1: Graphic illustrating how Vehicle Platooning wirelessly connects elements of a column. Source: Southwest Research Institute, “DSRC-Enabled Vehicle Platooning”  

With Vehicle Platooning, a column may be arranged in any configuration because the vehicles measure both lateral and longitudinal distance. Vehicle Platooning does not restrict the
convoy to a single line with a Leader Vehicle followed by a straight line in trace. Wedge, echelon, line or other formations could be programmed using Vehicle Platooning. In a similar manner, the Leader Vehicle could be located in any position within the convoy. The term Leader Vehicle, as it relates to Vehicle Platooning, indicates that the Follower Vehicles calculate their positions relative to the lead vehicle. Follower vehicles could also be linked to multiple leaders for redundancy and resiliency. The distances between vehicles can also be programmed at set space intervals to maximize fuel efficiency or create tactical dispersion in a military setting.

**Closing Gaps: How Vehicle Platooning Can Reduce Pass Time**

Pass time is the most effective metric to analyze how a force projects combat power over time and space because it accounts for the arrival of the entire unit at a given destination. Vehicle Platooning can clearly reduce pass time by reducing the gaps between individual vehicles, but it can also close the distances between different units. Time gaps, or the gaps between different units within the column, are the predominant factor in reducing pass time other than individual vehicle speed. The example of a company formation run helps demonstrate why this occurs.

Assume a company commander has three platoons set to run along a single route and he/she staggering the start of each platoon at two minute intervals. The first platoon begins to run at 0700 and it takes nine seconds for the last Marine in the first platoon to cross the starting line. Each platoon begins to run two minutes after the last Marine from the previous platoon crosses the starting line. The third platoon, however, breaks into three squad level units with an eight second interval between each squad. If they ran in one mass formation, it would take 27 seconds for all of the company to cross the starting point. However, by imposing gaps between units, the company commander has significantly increased the time it takes to conduct the formation run.
The last Marine in the company has to wait 283 seconds (4 minutes, 42 seconds) before even beginning the run. If each platoon reduced its own pass-time by 90% and only took one second to cross the starting point it would only represent a 9.2 percent reduction in pass time for the company.

Time gaps are required in modern ground movements due to limitations in command and control. A current ground convoy typically has a convoy commander, assistant convoy commander, security force commander at a minimum. These leaders make decisions and issue instructions to other human operators either during a pre-departure brief or during transit. These decisions deal with a number of issues such as formations, dispersion, vehicle breakdown responses, route changes and tactical decisions for each vehicle in the formation. Convoys containing hundreds of vehicles of numerous different types can be beyond the capabilities of this small command team. This is particularly true when elements of a convoy come from different units. For this reason, convoys are typically limited to fewer than fifty vehicles.

Vehicle Platooning promises to overcome command and control limitations, eliminating the need for many time gaps currently required. In a convoy using Vehicle Platooning technology, the commander does not merely issue instructions; he/she actually controls each vehicle by directing the actions of a few Leader Vehicles. The convoy commander predetermines rules vehicles will follow in transit, such as dispersion and order of march, and each element of the convoy is guided by the Leader Vehicles according to these restraints. In effect, this formation creates a temporary train with the benefits of efficiency and speed but with the ability to quickly leave the tracks. Leader vehicles are like a train engine and each unit in the column is comparable to a box car. The temporary train effect enabled by Vehicle Platooning simplifies the task of the convoy commander by only having to issue orders to a
limited number of Leader Vehicles. This increases the number of total vehicles that can be coordinated effectively by a small command team and eliminates the need to set gaps between units within the same column.

**Proposal: The Regimental Transit Formation**

A commander could use the technology of Vehicle Platooning in myriad different configurations based on situational conditions. The formation depicted in Figure 2 is one possible technique which could be adopted to increase the movement speed of the whole column by minimizing the number of time gaps in the travel formation. This concept is called a Regimental Transit Formation and groups tactical units into three large, functionally based serials, the subordinate elements of a column.

![Diagram of Regimental Transit Formation](image)

*Figure 2: Regimental Transit Formation, a column of 10 convoys.*

This formation does not change the task organization or command relationships of the units within the column, merely the method of travel. This formation maximizes the benefits of efficiency and speed but adds flexibility by allowing component vehicles to quickly leave the tracks. This design requires a force capable of rapidly transitioning from transit mode into
combat formation. The Regimental Transit Formation is useful when speed is desired and is applicable at any level, from platoon to Regimental Combat Team.

Current convoys are structured by task organization, capability, or functionality. Convoys arranged by task organization are designed to maintain unit integrity, such as when vehicles travel together because they are in the same platoon or squad. Functional convoys are organized to complete certain tasks, such as security, obstacle clearance, or logistical resupply. Other convoys are organized to maximize a particular capability. Examples of this type of convoy include convoys designed to maximize troop carrying capability. However, all current convoys are limited in the number of vehicles that can effectively be managed for the command and control issues listed above. Figure 3 illustrates that the number of convoys in a conventional regimental column is around 26, over twice as many as in the Regimental Transit Formation.

![Figure 3: Conventional regimental column of 26 convoys.](image)

This Regimental Transit Formation decreases pass time by reducing the total number of convoys in the column. Instead of 26 separate convoys that exist in the Figure 3 example, the
number of convoys in the transit formation is reduced to ten. This single variation reduces the pass time from 152.3 min (two hours and 22 minutes) with an 88.8 km span in the notional regimental model to a 72.3 min (one hour and 12 minutes) pass time that stretches only 42.1 km using the transit formation. Pass time and convoy span are reduced by 52% without changing any other factors.

Using the Regimental Transit Formation should not impose changes to the composition of the regiment. This formation assigns travelling vehicles into three functional groups; a screening force, a main body, a support element. The screening force alerts and delays hostile forces to enable the main body to transition from a transit to combat configuration. The main body of the formation retains the bulk of combat power, and the support element comprises of the rest of the battalion. The ability of individual vehicles and units to quickly join or leave the Regimental Transit Formation make it flexible. This concept allows a commander to consolidate to increase speed or disperse for force protection as the situation demands.

**Implications of Adoption**

Once the Regimental Transit Formation and Vehicle Platooning concepts proposed are implemented, implications exist for units operating within this construct. Technological and structural changes will be required to facilitate the change. In addition to the hardware and software modifications Marine Corps vehicles will require, some form of coordination center must be established to execute Vehicle Platooning in practice. Additionally, some existing platforms may require changes to maximize the benefits of the Regimental Transit Formation concept.

Currently, two primary means of organizing and coordinating convoys exist. A command team is established within each individual convoy to facilitate accountability and
execute ground movement. This command team typically consisting of a convoy commander, assistant convoy commander, security force commander within each convoy. At the regiment and battalion level, commanders establish organic unit movement control centers (UMCCs) to deconflict and regulate the flow of traffic within unit battlespace. In a convoy that incorporates Vehicle Platooning, many of the functions provided by the commanders within the convoy and UMCC may be consolidated.

A small staff in a Column Coordination Cell (CCC) could perform tasks currently conducted by the UMCC and convoy commanders as well as manage the new processes required by vehicle platooning such as inputting convoy assignments and configuring formations and pre-programming immediate action responses. Each unit within the regimental transit formation would need to retain some point of contact to be able to function autonomously but many functions, such as inter-convoy dispersion, could be handled by the CCC.

Another implication of the Regimental Transit Formation is that vehicles need the ability to rapidly shift from transit to combat formation. Maintaining combat unit integrity within the column is a means to accomplish this. Currently, Marines from separate units are placed in transportation vehicles with a priority on filling all available vehicle space over unit integrity. This method, although spatially efficient, slows transitions from transit to combat formations. However, the time required to adopt combat formations can be reduced if unit integrity at the squad level is maintained throughout transit. Possessing transportation platforms that support maintaining squad integrity would assist in providing command and control and speed up the shift from transit to combat formations.

Marine Corps infantry units are the most likely to require non-organic transportation. Infantry units are organized into squads of thirteen individuals. Therefore, the platforms used
to transport these units should be designed to carry thirteen passengers. One method to achieve this is to incorporate a Marine Personnel Carrier (MPC) that could transport rifle squads quickly while maintaining unit integrity.

![Figure 4: An example vehicle previously under consideration to be adopted as an MPC. Source: Defense Update.com, “Marinepersonnelcarrierdemonstrator”](image)

Several MPC models exist that could replace current troop transport vehicles. Adopting MPCs would increase the total number of vehicles in a formation, but they would facilitate a more rapid transition to a combat formation. Data from the regiment analysis shows increasing the amount of vehicles within the column is not as important as reducing the time gap. It is better to have more vehicles capable of rapid movement into a combat formation than it is to have more individuals on fewer trucks when increasing the movement rate of the force is desired.

**Analysis of Adopting Vehicle Platooning**

The extent that Vehicle Platooning can increase ground movement speed can be determined by analyzing a sample unit operating under notional conditions. Analysis will focus on a regimental-sized unit based on the table of equipment from 7th Marine Regiment. This force includes a regimental headquarters company, one Infantry Battalion mechanized in an Amphibious Assault Vehicle Company, and two Infantry Battalions motorized in trucks as shown in Figure 5.
The column for this sample regiment includes exactly 500 vehicles divided into increments of 20 vehicles per convoy traveling in a single column on a highway for 200 kms. The march rate is 35 KPH, unit march rate gap is 5 minutes, and serial time gap of 10 minutes are based on the planning factors set forth in MSTP pamphlet 5-0.3. Each battalion and the regimental headquarters are individual serials for a total of four serials in the entire regiment. One convoy was created for every 20 vehicles as depicted in Figure 3. A list of key terms and definitions is provided in Table 1.

Table 1: Road Clearance Time Definitions and Calculations

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrive time</td>
<td>The arrive time represent the amount of time it takes for the first vehicle</td>
<td>Arrive time = distance/march rate</td>
</tr>
<tr>
<td></td>
<td>in a column to arrive at a given point</td>
<td></td>
</tr>
<tr>
<td>Clear time</td>
<td>Clear time is the amount of time it takes the last vehicle in the column</td>
<td>Clear time = Arrive time + pass time</td>
</tr>
<tr>
<td></td>
<td>to pass through a specific point</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>The average number of vehicles per kilometer</td>
<td>Density = 1,000/vehicle gap + average vehicle length</td>
</tr>
<tr>
<td>Time Gaps</td>
<td>The time measured between vehicles, convoys, serials, or columns as they</td>
<td>Time gaps = [(number of convoys-1) X (convoy time gap)] + [(number of serials-1) X (serial time gap)] - (convoy time gap)]</td>
</tr>
<tr>
<td></td>
<td>pass a given point</td>
<td></td>
</tr>
<tr>
<td>Road space</td>
<td>The length of the column plus space added to prevent conflict with</td>
<td>Road space = number of vehicles/density + time gaps X rate/60</td>
</tr>
<tr>
<td></td>
<td>proceeding or succeeding traffic</td>
<td></td>
</tr>
<tr>
<td>Pass time</td>
<td>Time required for a column to pass a given point on a route</td>
<td>Pass time = road space X 60/march rate</td>
</tr>
</tbody>
</table>

Source: All definitions and calculations were taken from MSTP pamphlet 5-0.3. USMC, “MAGTF Planner’s Reference Manual 5-0.3” (book, Marine Corps Combat Development Command, 2012)
The movement speed of the sample regiment will be measured by calculating road clearance time. Road clearance time represents how fast a military ground unit advances by measuring the time it takes all the vehicles in a column to move to and pass a given point. This metric is determined by adding clear time to the column start time.

The improvements achieved by implementing Vehicle Platooning represent significant increases to military ground movement rates. Three variables are modified based on the Vehicle Platoon technology and its implications. The number of convoys are reduced from 26 to ten based on the Regimental Transit Formation, vehicle gaps are reduced from eleven to two meters based on Vehicle Platoon, and the total vehicle number is increased from 500 to 537 when MPCs replace MTVRs for troop transport. Table 2 indicates Vehicle Platoon decreases the time it takes the last vehicle in the regiment to arrive at a destination 200 km away from 512 to 410 minutes, a reduction of 20 percent. A 29.7 percent change in trip length is achieved when the same variables are calculated over a 100 km distance. The space the column takes over the road is also decreased from 92.25 to 39 km, a 42.3 percent reduction. A summary of calculations can be found in Appendix 3.

Table 2: Sample Regiment Analysis Results

<table>
<thead>
<tr>
<th></th>
<th>Sample Regiment</th>
<th>Sample Regiment with Vehicle Platoon</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Clearance Time</td>
<td>8 hours, 32 minutes (512 min)</td>
<td>6 hours, 50 minutes (410 min)</td>
<td>1 hour, 42 minutes (102 min)</td>
</tr>
<tr>
<td>(200 km)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road Clearance Time</td>
<td>5 hours, 40 minutes (340 min)</td>
<td>3 hours, 59 minutes (239 min)</td>
<td>1 hour, 41 minutes (101 min)</td>
</tr>
<tr>
<td>(100 km)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road Space</td>
<td>92.25 km</td>
<td>39 km</td>
<td>53.25 km</td>
</tr>
</tbody>
</table>
Additional Benefits of Vehicle Platooning

Vehicle Platooning entails numerous benefits beyond improving ground unit movement rates. Follower Vehicles use electronic links to a Leader Vehicle to operate and do not require human operators. In some cases this removes the need for operators altogether. Manpower requirements may be significantly reduced if drivers are not required for many vehicles. This is particularly true in administrative movements in secure rear areas. For example, in port operations several vehicles could be moved from one staging area to another with only one operator rather than requiring an operator for every vehicle. Even in scenarios when drivers are required, Vehicle Platooning can temporarily free individuals for other activities such as operating weapons systems, planning actions on objective, or sleeping.

Safety is another beneficial element Vehicle Platooning provides. As seen above, reaction time to accidents is significantly reduced by allowing the entire column to receive warnings simultaneously. Vehicles can be enabled to slow down at pre-designated intervals to avoid bumping into cars in front of them even when a formation is not in a transit mode.

Studies have also shown that drag reductions created by reducing vehicle gaps have been found to reduce fuel consumption for some convoys up to 20 percent. The implications of this phenomenon could lead to increased distances a unit can travel without the need for resupply or a reduction in logistics requirements.

Potential Disadvantages

Despite the opportunities Vehicle Platooning offers, some may be reluctant to implement this new technology. Critics may argue both Vehicle Platooning and the Regimental Transit Formation are too centrally controlled to effectively function in a combat environment. That argument might contend that vehicles grouped together in the Regimental Transit Formation
model are essentially administrative movement that lacks the dispersion necessary for combat, despite the advanced warning of a screening force.

Vehicle Platooning enables a few leader vehicles controlled by a CCC to allow units to join or leave a Regimental Transit Formation with the flip of a switch. This allows subordinate commanders to break from the main formation as required to exploit opportunities, regain unit cohesion, or for whatever reason the tactical situation requires. Achieving squad level unit integrity is another method to mitigate these concerns because it facilitates a rapid transition. In these ways unit cohesion is maintained during transit which allows for a rapid shift into combat formations. Additionally, coordination measures, such as assault lines, could trigger pre-planned points where units could transition from transit to combat formations.

Some may oppose Vehicle Platooning by arguing that gaps between military convoys should not be eliminated because they reinforce sub-unit cohesion by distinguishing units and reinforcing a sense of camaraderie within each sub-unit. Others may argue that gaps between convoys provide flexibility allowing units to change course or that reducing gaps interferes with tactical dispersion. Dispersion is a fundamental element of force protection that minimizes damage inflicted by enemy actions by creating space between combat forces. Critics may conclude the removal of column gaps would erode this essential force protection measure.

Concerns regarding tactical dispersion are unfounded. The Regimental Transit Formation calls for the removal of gaps between separate serials and convoys, not between individual vehicles. The reduction of gaps between units in our sample regiment and formation run scenarios produced the greatest reductions in pass time, not decreases in gaps between units. Dispersion within the tactical unit could be increased and overall column pass time reduced as long as the number of convoys is adequately reduced.
Conclusion

Speed always gives one side an advantage over another on the battlefield. Unfortunately, the movement of ground formations during campaigns has remained relatively stagnant over the last 200 years. One reason for the lack of progress in this area is that as military units have motorized, gaps between vehicles within the overall formation have also increased. With current technology, vehicle gaps are necessary for effective command and control but have significant bearing on the amount of time it takes to move over distance.

The emerging technology of Vehicle Platooning promises to eliminate many of the column gaps required today. The ability to control hundreds of vehicles in transit possible with Vehicle Platooning technology may be able to significantly reduce column lengths and gaps. Increases in safety and fuel efficiency as well as reductions in manpower and unit travel times are some of the possibilities achievable by implementing this new technology. These benefits have applications for units moving to contact with the enemy, performing logistics runs, or offloading equipment at a port. A military organization that adopts measures to eliminate column gaps may considerably reduce ground unit transit times and enjoy an advantage on the future battlefield.
### Appendix 1-
**Key Terms and Definitions**

<table>
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<td>Density = 1,000 / vehicle gap + average vehicle length</td>
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<tr>
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<td>The time measured between vehicles, convoys, serials, or columns as they pass a given point</td>
<td>Time gaps = [(number of convoys - 1) X (convoy time gap)] + [(number of serials - 1) X (serial time gap)] - (convoy time gap)]</td>
</tr>
<tr>
<td>Road Space</td>
<td>The length of the column plus space added to prevent conflict with proceeding or succeeding traffic</td>
<td>Road space = number of vehicles / density X time gaps X rate / 60</td>
</tr>
<tr>
<td>Pass Time</td>
<td>Time required for a column to pass a given point on a route</td>
<td>Pass time = road space X 60 / march rate</td>
</tr>
<tr>
<td>Rate of march (march rate)</td>
<td>The average number of kilometers traveled in a specified time period.</td>
<td>Rate of march = distance / time</td>
</tr>
<tr>
<td>Clear time</td>
<td>Clear time is the amount of time it takes the last vehicle in the column to pass through a specific point.</td>
<td>Clear time = Arrive time + pass time</td>
</tr>
<tr>
<td>Speed</td>
<td>The rate a vehicle moves at a given time</td>
<td>Measured by speedometer</td>
</tr>
<tr>
<td>Column</td>
<td>All elements of unit in transit</td>
<td>N/A</td>
</tr>
<tr>
<td>Serial</td>
<td>The subordinate elements of a column</td>
<td>N/A</td>
</tr>
<tr>
<td>Convoy</td>
<td>The subordinate elements of a serial</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Source: USMC, "MAGTF Planner's Reference Manual 5-0.3" (book, Marine Corps Combat Development Command, 2012)
Appendix 2-
Column Factors and Terms

<table>
<thead>
<tr>
<th>VEHICLE FACTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
</tr>
<tr>
<td>Vehicle Gap</td>
</tr>
<tr>
<td>Lead</td>
</tr>
<tr>
<td>(Vehicle Distance)</td>
</tr>
<tr>
<td>Time Length</td>
</tr>
<tr>
<td>Time Gap</td>
</tr>
<tr>
<td>Time Lead</td>
</tr>
<tr>
<td>(Pass Time)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COLUMN/ELEMENT FACTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
</tr>
<tr>
<td>Column Gap</td>
</tr>
<tr>
<td>Lead</td>
</tr>
<tr>
<td>Time Length (Pass Time)</td>
</tr>
<tr>
<td>Time Gap</td>
</tr>
<tr>
<td>Time Lead</td>
</tr>
</tbody>
</table>

# Hypothetical Regiment Calculations in Current Conditions

<table>
<thead>
<tr>
<th>Unit</th>
<th>Pass Time (Min)</th>
<th>Time across Start Point</th>
<th>Time First Vehicle Crosses End Point</th>
<th>Time Last Vehicle Crosses End Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/7</td>
<td>42</td>
<td>0800</td>
<td>1342</td>
<td>1424</td>
</tr>
<tr>
<td>2/7</td>
<td>35</td>
<td>0852</td>
<td>1434</td>
<td>1509</td>
</tr>
<tr>
<td>3/7</td>
<td>35</td>
<td>0937</td>
<td>1519</td>
<td>1554</td>
</tr>
<tr>
<td>Regt HQ Co</td>
<td>18</td>
<td>1032</td>
<td>1614</td>
<td>1632</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit</th>
<th>Density (Ave)</th>
<th>Time Gaps (Min)</th>
<th>Road Space (Km)</th>
<th>Pass Time (Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/7</td>
<td>41.4</td>
<td>35</td>
<td>24.3</td>
<td>41.7</td>
</tr>
<tr>
<td>2/7</td>
<td>48.2</td>
<td>30</td>
<td>20.15</td>
<td>34.5</td>
</tr>
<tr>
<td>3/7</td>
<td>48.2</td>
<td>30</td>
<td>20.15</td>
<td>34.5</td>
</tr>
<tr>
<td>Regt HQ Co</td>
<td>52.3</td>
<td>15</td>
<td>10.3</td>
<td>17.6</td>
</tr>
<tr>
<td>Total</td>
<td>47.2</td>
<td>140</td>
<td>92.25</td>
<td>158.1</td>
</tr>
</tbody>
</table>

# Hypothetical Regiment Calculations with Vehicle Platooning

<table>
<thead>
<tr>
<th>Unit</th>
<th>Pass Time (Min)</th>
<th>Time across Start Point</th>
<th>Time First Vehicle Crosses End Point</th>
<th>Time Last Vehicle Crosses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/7</td>
<td>13</td>
<td>0800</td>
<td>1342</td>
<td>1355</td>
</tr>
<tr>
<td>2/7</td>
<td>12</td>
<td>0823</td>
<td>1405</td>
<td>1417</td>
</tr>
<tr>
<td>3/7</td>
<td>12</td>
<td>0845</td>
<td>1427</td>
<td>1439</td>
</tr>
<tr>
<td>Regt HQ Co</td>
<td>1</td>
<td>0907</td>
<td>1449</td>
<td>1450</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit</th>
<th>Density (Ave)</th>
<th>Time Gaps (Min)</th>
<th>Road Space (Km)</th>
<th>Pass Time (Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/7</td>
<td>124.5</td>
<td>10</td>
<td>7.13</td>
<td>12.2</td>
</tr>
<tr>
<td>2/7</td>
<td>132.9</td>
<td>10</td>
<td>6.9</td>
<td>11.8</td>
</tr>
<tr>
<td>3/7</td>
<td>132.9</td>
<td>10</td>
<td>6.9</td>
<td>11.8</td>
</tr>
<tr>
<td>Regt HQ Co</td>
<td>138.3</td>
<td>0</td>
<td>0.61</td>
<td>1.05</td>
</tr>
<tr>
<td>Total</td>
<td>132</td>
<td>60</td>
<td>39</td>
<td>66.9</td>
</tr>
</tbody>
</table>
End Notes

3 Dupuy, Trevor Nevitt, and Trevor N. Dupuy. 1987. Understanding war: History and a theory of combat Paragon House; pg 151,152..
4 Dupuy, Trevor Nevitt, and Trevor N. Dupuy. 1987. Understanding war: History and a theory of combat Paragon House; pg 151,152..
8 California PATH, “Vehicle Platooning and Automated Highways”
10 California PATH, “Vehicle Platooning and Automated Highways”
14 Madeline El-Zaher
15 Table of Equipment, 7th Marine Regiment
19 MSTP Pamphlet 5-0.3, chapter 4023
20 Shankland, Stephen. Platooning: The future of freeways is lining up.
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