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<td>Major Kevin C. Trimble, USMC</td>
<td>USMC SCHOOL OF ADVANCED WARFIGHTING</td>
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FUTURE WAR PAPER

TRACKING FOR MOBILITY: Tracking Up the Marine Corps' Wheeled Vehicle Fleet

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

MAJOR KEVIN C. TRIMBLE, USMC

AY 2009-10

Mentor: Lieutenant Colonel David P. Casey

Approved: ____________________________

Date: 27 May 2010
**Executive Summary**

**Title:** Tracking for Mobility: Tracking Up the Marine Corps’ Wheeled Vehicle Fleet.

**Author:** Major Kevin C. Trimble, United States Marine Corps

**Thesis:** With a relatively minimal cost in both time and money, wheeled vehicles of the Marine Corps’ can be quickly transformed into tracked platforms which will increase the mobility, operational flexibility and tactical options of the commander.

**Discussion:** The majority of the vehicles and tactical moving platforms in the Marine Corps today are wheeled. Additionally, the proposed vehicles of the future currently in the procurement process are wheeled as well. Though wheeled vehicles are effective and durable while traveling over improved surfaces, they do have their limitations. The weight of a wheeled vehicle is displaced over the driving surface by tires. The tire’s small surface area prevents a wheeled vehicle from effectively traversing through deep mud or deep snow. Planning procedures such as a MCOO currently mitigate the instances of immobility by directing vehicles through known, improved terrain. The uncertainty of war, primarily in the future dictates a requirement that a solution be more than procedural.

Technology currently exists where modular track systems can be interchanged with existing wheels. For the purpose of this paper, the author will focus on the proposed concept of transforming the Light Armored Vehicle (LAV) and the Medium Tactical Vehicle Replacement (MTVR) from wheeled, to tracked vehicles. It is understood that modifications to the vehicles will be required to enable this capability. The concept envisioned is within the realm of the possible. Though our current systems of mobility and delivery are effective, the uncertain future may not dictate the same. Tracking our wheeled vehicles is a current requirement to enable a future capability.

**Conclusion:** The nature of warfare is unpredictable. As an expeditionary force in readiness, the Marine Corps does not have the option of choosing its “fighting season.” Possessing the ability to interchange wheels with tracks is an existing capability which can support winning battles and saving lives.
“Mobility: “Those activities that enable a force to move personnel and equipment on the battlefield without delays due to terrain or obstacles.” ¹

- FM 1-02

Introduction

The overwhelming majority of the Marine Corps’ vehicle inventory rides on wheels. A small majority are tracked platforms. Due to the Marine Corps’ “expeditionary”² nature, recent combat in built-up and urban areas, and decreased defense spending³; the idea of fighting on wheels is unlikely to change any time soon. Though wheeled vehicles to date have proven effective instruments of maneuver, battlefields of the future are both unknown and unpredictable.

The Marine Corps’ doctrine of Maneuver Warfare sites tempo as “speed relative to the enemy.”⁴ In most cases speed is literal and generated through mobility. Unfortunately, the Marine Corps’ wheeled instruments of mobility have limitations, such as the inability to effectively traverse deep mud or deep snow. These limitations are the result of the vehicle’s weight being displaced by the narrow surface area of tires. Although procedures exist to overcome these limitations, the unpredictable nature of war supports the emergence of a requirement that requires a material solution. To meet this requirement, a capability is needed in which the weight of a wheeled vehicle is exponentially displaced over a larger surface area much like that of a tracked platform, such as a main battle tank. Existing, off-the-shelf technology in the form of Modular and
Over the Tire Track Systems, provides a capability that can overcome these existing limitations of the Marine Corps’ wheeled vehicles.

With a relatively minimal cost in both time and money, wheeled vehicles of the Marine Corps can be quickly transformed into tracked platforms that will increase the mobility, operational flexibility and tactical options of the commander.

**Current Systems and Limitations**

This paper will discuss the mobility limitations of two currently fielded Marine Corps wheeled vehicles and argues that a requirement for the present and unpredictable future currently exists.

In the early 1980s the Marine Corps procured the Light Armored Reconnaissance Vehicle, or LAV. In keeping with the newly adopted doctrine of Maneuver Warfare, LAV’s were light, lethal and expeditionary. The LAV is a 14 ton vehicle that rides on eight wheels. Originally employed primarily as a reconnaissance platform, since 2003 LAV battalions have been used as independent battalion task forces in both Iraq and Afghanistan and it has served as more of an infantry fighting vehicle than a reconnaissance platform. Lighter than both a main battle tank, such as the M1A1, or an Amphibious Assault Vehicle, or AAV, the LAV is faster, and lighter than heavier, tracked vehicles.

For the transportation of both troops and logistics the Marine Corps has traditionally relied upon wheeled platforms such as today’s current vehicle, the Medium Tactical Vehicle Replacement (MTVR). This six wheeled, general purpose, transport vehicle provides both range and speed over improved surfaces. With a curb weight of approximately 14 tons, the MTVR, like the LAV, is much lighter than a tank or AAV.
Where the LAV and MTVR come up short is in the range of operability in regards to terrain. As stated, each vehicle is a multi-wheeled combat platform. Unlike a tracked vehicle, the weight of a wheeled platform is displaced only over the narrow surface area provided by its tires. This limitation does not allow for unimpeded continuous movement over terrain encompassed by deep mud or deep snow.

One of the first steps in military planning is Intelligence Preparation of the Battlefield, (IPB). Initially, a Modified Combined Obstacle Overlay (MCOO) is created in which the proposed area of operation is broken down by specific terrain. By depicting on a map what is “go” terrain, “slow-go” terrain and “no-go” terrain, a commander can route vehicles accordingly and still maneuver to the objective. Additionally, the use of tire chains is a technique used by both the LAV and MTVR for improved traction over soft surfaces, primarily snow. Though these chains may improve the vehicles traction, they do not displace the weight of the vehicle in connection with the surface. This limitation was evident during Exercise ARCTIC JIHAD in December 2001 at the Mountain Warfare Training Center in Bridgeport, California. Though equipped with snow chains, the Marines of 1st Light Armored Reconnaissance Battalion discovered that off-road travel in un-groomed snow was limited to approximately 50 meters. This immobility was a result of a “snow plow” effect and center lining. The snow plow effect occurs when snow is built up in front of the vehicle’s skid plate, which though 24 inches off the ground, cannot maintain clearance through a soft surface area. Center-lining occurs when the 14 ton LAV sinks in existing tire tracks and the axles come in contact with the snow in the center of the road, thus causing the chained tires to lose traction.
Tactics, techniques, and procedures such as the MCOO and the use of tire chains are currently in practice to mitigate wheeled vehicle limitations. However history has shown where the perceived mobility of both wheeled and heavy tracked vehicles was put in check due to unpredictable terrain and environmental conditions. From the flooded roads of Burma and the Philippines in WW II, to the snow covered mountain roads near Korea’s Chosin Reservoir in 1950, the lack of mobility slowed operational tempo, which in turn cost lives despite the mission accomplishment of the respective units. Surprisingly these lessons are not left in antiquity.

In March of 2003, three Marine Corps main battle tanks, two Amphibious Assault Vehicles and numerous wheeled HMMWV’s were literally stuck in their tracks on the outskirts of the Iraqi city of An Nasiriyah. The culprit in stopping the Marine vehicles was not a mine field or Improvised Explosive Device (IED), but mud. Classified as type I mud. What most likely appeared on the MCOO as “go terrain” was actually a mud bog capable of fixing a formidable armored force. Despite the presence of tracks on both the AAV’s and M1A1’s, their excessive weight could not be displaced enough to allow traction or maneuverability. Conversely, of the HMMWVs that were present, their weight, minimal in comparison to the AAV’s and tanks, could also not be displaced in the mud as they are equipped with tires vice tracks. Vehicle recovery, vice maneuver became the primary objective of this combat force.
Emergence of a Requirement

“Countless minor incidents-the kind you can never really foresee-combine to lower the general level of performance, so that one always falls short of the intended goal.”
- MCDP 5

Prussian military theorist Carl Von Clausewitz said that “war is in the realm of uncertainty” As the Marine Corps prepares to operate in the austere environments of the future, providing an optional tracked capability for the Corps’ lighter, wheeled vehicle inventory is within the realm of the possibility. Though the Marine Corps is in the process of procuring new tactical vehicles, specifically, the Marine Personnel Carrier (MPC) and the Joint Light Tactical Vehicle (JLTV), these vehicles are several years from fielding, and they are wheeled platforms. The requirement to enable the rapid transformation of the range and capability of our wheeled vehicle inventory is paramount. No longer is the Marine Corps able to fund, train, and equip separate forces that focus solely on specific environments. Like the individual Marine, vehicle platforms must be, or have the capability to become, a hybrid form of multiple capabilities.

During WW II where the large force structure supported the fielding of units which were solely tracked, primarily wheeled, or in some cases half tracked. The Marine Corps’ current structure requires that its existing inventory must be able to meet the entire spectrum of operational requirements. The battlefields of the future are also uncertain. For example, excessive rainfall occurs on the Korean peninsula during the months of June to September. A road that may have previously appeared on a MCOO as “go terrain” during the fall and winter, will possibly be transformed to deep mud in the summer months, making it either “slow-go” or “no-go” terrain for wheeled vehicles. The uncertainty of war requires forethought and preparedness, as the Marine Corps does not
have the luxury of choosing its own “fighting season.” From this uncertainty emerges the requirement for a capability in which wheeled vehicles can rapidly transform into tracked platforms. Though both half tracks and lightly tracked vehicles are a thing of the past, current technology allows the Marine Corps to go “back to the future” in order to maintain operational tempo in the face of uncertainty. For the purpose of this paper, the track transformation concept will focus primarily on the transformation of the LAV as a fighting platform and the MTVR as a logistics provider.

**Tracked Capability**

Fully tracked vehicles were first seen in the late 19th century primarily for use on farm machinery and heavy, industrial earth moving equipment. Placing tracks instead of wheels on a vehicle served two purposes: Tracks displace the weight of the vehicle over a larger surface area, thus applying less pressure on to the driving surface. In addition, a solid manufactured tread produces more adequate traction allowing the unimpeded movement of the heavier vehicles across soft or unimproved terrain. In line with many industrial technological innovations, the military adopted a tracked system in the form of an armored tank in the early years of the WW I. Though equipped with tracks, many of these early tanks were quickly made immobile on the battlefields of the western front, despite the weight displacement benefits of a tracked system. Due to their excessive weight, these machines were only effective if employed over suitable terrain.

Despite the limitations of heavy tracked vehicles, by the end of WW I armored tracked vehicles became the primary ground fighting platform of every modern nation for the next ninety years. Though experiments were conducted with wheeled, armored platforms and even hybrid half track armored vehicles, from the end of WW II until the
mid 1980s, tracked vehicles were the primary fighting platforms of most modern armies.

Since the end of WW II to present day, the Marine Corps’ tracked vehicle inventory has consisted mainly of main battle tanks, tank recovery vehicles, Amphibious Assault Vehicles, earth moving tracked bulldozers, and tracked bridging vehicles. Each of these vehicles is in excess of 27 tons. Additionally, none of these vehicles can be classified as readily deployable in large numbers. (see Table I)

<table>
<thead>
<tr>
<th>Platform</th>
<th>Purpose</th>
<th>Weight</th>
<th>Per MEF</th>
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<td>M1A1 Main Battle Tank</td>
<td>Offensive</td>
<td>68 Tons</td>
<td>58</td>
</tr>
<tr>
<td>M88A2 Recovery Vehicle</td>
<td>Recovery</td>
<td>70 Tons</td>
<td>22</td>
</tr>
<tr>
<td>M9 ACE Armored Bulldozer</td>
<td>Earth moving</td>
<td>27 Tons</td>
<td>16</td>
</tr>
<tr>
<td>AAV</td>
<td>Offensive</td>
<td>31 Tons</td>
<td>238</td>
</tr>
<tr>
<td>AVLB</td>
<td>Bridging</td>
<td>56 Tons</td>
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Table -1

The Transformation of Wheels to Tracks

Transforming wheeled vehicles to tracked platforms is not an original concept. In 1911, the French engineer Adolphe’ Kegresse converted numerous cars belonging to the Tsar of Russia into half tracks. This half track design was prominent throughout World War II as 43,000 half track variants were produced by America alone. The concept derived from the requirement to displace the weight the vehicle placed on the surface through a track system, while maintaining speed and maneuverability through the front end wheeled system. These vehicles proved effective as both an armored weapons carrier and a logistics and troop transport platform.
The LAV 25 and the MTVR each weigh in excess of 14 tons. This weight is displaced over eight rubber tires in the case of the LAV and six for the MTVR. On solid ground, such as improved roads, these vehicles are highly mobile and dependable. Whether maneuvering to the front for the LAV, or moving troops or logistics, in the case of the MTVR, adequate terrain for mobility is a steadfast requirement. Numerous studies have been conducted regarding the benefit of wheels over tracks in regards to military capability. A recent RAND corporation study illustrated the deployability, speed over roads, movement in built up areas, and reduced logistical requirements, as benefits wheeled vehicles have over armored tracked platforms.²¹

For operations in unrestricted terrain such as improved roads, wheeled vehicles such as the LAV and MTVR are excellent platforms for the full spectrum of military operations. As stated previously in the case of the Marines in An Nasiriyah, restricted terrain such as deep mud, requires an ability to displace a vehicles weight over a large surface area in order to achieve adequate mobility. Deep mud and unpacked snow present a challenge to any vehicle, wheeled or tracked. For example, a tracked, 70 ton M1A1 Abrams tank is so heavy that weight displacement can be extremely problematic over deep muddy surface. In the case of the LAV and MTVR, displacing 14 tons is not impossible.

### Table-2 ²⁰

<table>
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<th>Platform</th>
<th>Weight</th>
<th>Purpose</th>
<th>Speed On/Off</th>
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<td>LAV 25</td>
<td>14.2 Tons</td>
<td>Recon/Offensive</td>
<td>62 MPH (on road)</td>
</tr>
<tr>
<td>MTVR MK 23</td>
<td>14 Tons</td>
<td>Logistics/Transportation</td>
<td>45 MPH (on road)</td>
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For all vehicles, mobility over terrain is determined by a factor known as Vehicle Cone Index (VCI). VCI is a combination of the soil structure and the vehicle’s ground pressure placed on the ground from either a tire or track.\textsuperscript{22} Hence, “the higher the VCI, the less mobile the platform becomes.”\textsuperscript{23} As brought up in the aforementioned RAND study, for both deployability and movement over improved terrain, wheeled vehicles provide the greatest capability, but over unimproved terrain, the wheeled vehicle’s VCI drastically increases as a result of the excessive pounds per square inch projected onto the driving surface.

The limitations of wheeled vehicles was apparent in Bosnia in the mid 1990s where it was noted that “when operating on roads, wheeled vehicles demonstrated excellent mobility and speed; but when off-road usage was required, and wet or snow conditions prevailed, mobility suffered.”\textsuperscript{24} With the foresight of future Marine Corps operations requiring an expeditionary capability for its LAV’s and MTVR’s, providing the capability to track these platforms could be inherent to future battlefield success.

**Modular and Over The Tire track Systems**

As has been done throughout history, the military continues to utilize existing industrial technology to better equip America’s military arsenal. In some instances, the idea or basic capability is used as a baseline and then further developed to meet military needs. As in the case of the airplane, the Wright Brothers’ initial invention was modified to a combat platform to meet military requirements. Providing the Marine Corps’ LAV and MTVR with a hybrid, tracked-or-wheeled capability should follow the same protocol. Currently numerous manufacturers\textsuperscript{25} produce both modular track systems which can be interchanged with existing wheels, and over-the- tire track system which can
augment existing wheeled platforms. These products are sold to both the industrial market for use on earth moving and farm equipment, as well as to a recreational clientele where both pick up trucks and All Terrain Vehicles (ATV’s) are transformed to tracked platforms. Advertised as providing both a “floating” and “traction” capability, these systems displace the weight the vehicle places on the driving surface, thus allowing for unimpeded mobility over unimproved terrain such as snow or mud.

**Modular Track System**

![Heavy Duty Pick-up with modular track system.](image)

Modular Track Systems (MTS) are designed to be placed over the existing hub of a vehicle wheel. These triangular shaped modules are engineered with a road wheel and bracket system, over which rides a rubber track. Depending on the existing weight of the vehicle to be displaced (VCI) these tracks can range in width from 18” – 36”. Though implementing this capability may require some modifications to tactical vehicles, these modules can replace all existing wheels or just the rear wheels, for increased mobility. Mattracks Corporation out of Karlstad, Minnesota, is a producer of MTS. The Model 200-M1-A1 System© consists of four modules, each to replace the wheels of a heavy duty truck. This model with a 20” track has been tested to produce a surface pressure rating of 4PSI for a 21,000 lb vehicle. In the case of wheeled military vehicles, this
limited ground pressure equates to mobility. Systems such as these are relatively inexpensive in comparison to a developing an entirely new combat system. One complete modular track system (4 modules) cost between $75,000 – 80,000. Though not designed for speed, the addition these modules does support mobility. Transforming a wheeled vehicle with track modules is an existing, proven capability, which provides an excellent baseline to minimize the required research and any modifications to existing military platforms such as the MTVR and LAV.

**Over the Tire Track System**

![Over-The-Tire-Track System](image)

Similar to the track modules, Over the Tire Track Systems (OTTS) are currently in production, though primarily for the industrial, earth moving market. Placed over the top of all existing tires, the OTTS provides reduced VCI in addition to added traction through a manufactured track system. Like the modules, these products are available in different widths depending on the existing weight of the vehicle to be displaced. The only current disadvantage to the OTTS in regards to a military capability is that OTTS is designed for skid-steer platforms, thus the OTTS would only be applicable to the LAV and MTVR as augmentation to a half track type system, meaning the OTTS could only be placed over the non-turning rear wheels. The weight displacement capabilities of the
OTTS are equal to, if not better than, the modular track system. McLaren Industries of Torrance, California is one producer of OTTS. Their product, PROTRAC©, primarily for industrial, skid-steer loaders, is advertised to reduce ground pressure PSI by up to 60%.\textsuperscript{32} As an example, a standard 5 ton, wheeled commercial loader produces 37-38 PSI on a gravel surfaced road. After installing the 12” PROTRAC© OTTS with rubber track, the PSI was reduced to 8.5PSI\textsuperscript{33}. Though transforming civilian technology to military capability is not an exact science, at the minimum it should not always be as costly and time consuming as creating a new capability from scratch. The cost of a complete OTTS is $2,766.94.\textsuperscript{34}

**Cost and Availability**

Procuring the additional tracked capability for the MTVR and LAV can be both cost effective and expedient. Unlike recent projects such as the Marine Corps’ Expeditionary Fighting Vehicle (EFV),\textsuperscript{35} the wheel to track systems already exist and are in use throughout the world in the industrial and civilian sector. The long and sometimes arduous procurement process of identifying a requirement, designing a capability, and then years of research and testing, could be minimized. With the required capability already in production the Marine Corps could move to testing, training and implementation more rapidly than other programs of record. In regards to cost, the process can be more streamlined as the product currently exists. Even though modifications to existing platforms would be required in order to create a wheeled to track process, the idea of prospective budget overages could be kept to a minimum.
Concept

The Marine Corps would be well advised to acquire the capability to transform the LAV and MTVR into tracked platforms. This concept would require the integration of civilian expertise with the technical and tactical knowledge of both the maintainers and operators of the Marine vehicles. Through evaluation and testing, the required modifications to either the track system or the vehicle would be implemented. Along with the standardization of driver requirements, assembly and disassembly standards would be developed. Throughout testing the use of both MTS and OTTS will be evaluated for use as a singular method, or use with the MTS on the front wheels and the OTTS on the rear. Tactical training will be highlighted by establishing techniques and procedures of identifying “no-go” terrain and quickly applying the tracks, similar to a “pit crew” drill in stock car racing. Testing over different soil and snow compositions will determine the parameters of the capability as well as the limitations.

Enhanced Capability

*Marine Corps Vision and Strategy 2025*, states that Marines must “be prepared to live hard in uncertain, chaotic and austere environments, and must be trained, equipped and deployed with the expectation of operating in inhospitable conditions.”36 The idea of inhospitable conditions is not reserved only for the current operating environment of Iraq and Afghanistan. The snow covered terrain of Korea’s Chosin Reservoir is still a stark reality some 60 years after the Marine’s successful breakout in 1950. Providing our wheeled vehicles with a capability to maintain tempo through uncertain and inhospitable conditions is a requirement that must be considered. A tracked LAV extends the range of a battlefield for a MAGTF commander. Where deep snow may have inhibited mobility
and tempo in 1950, the extended range of a tracked LAV will allow a commander to seek battle at a time and place of his choosing. The knowledge that tactical vehicles can effectively traverse “no-go” terrain will provide operational flexibility that is currently absent.

A tracked MTVR will be a combat multiplier across the entire spectrum of warfare. The MTVR is multitasked as both a vehicle for troop transportation and logistics sustainment. Providing relief to both Marines and civilians, the tracked MTVR will be an essential asset in the conduct of Humanitarian Assistance and Disaster Relief (HA/DR) operations. Throughout the undeveloped countries in Africa and Asia, the MTVR’s ability to remain mobile could mean the difference between mission success and mission failure. Undetected on a MCOO, certain operating environments in Africa may entail washed out trails and swampy terrain that could make the 14 ton, wheeled MTVR an immovable object. Following a rapid transformation to a tracked vehicle, a static MTVR can quickly become a rapid means of both sustainment and life support.

**Counterargument**

A counterargument centers on the assumption that procedures are in place to mitigate the chance happening of a wheeled vehicle formation being rendered immobile due to “no-go” terrain. The instances of tactical formations becoming immobile are few. Additionally, in most cases such as Nasiriyah and even the Chosin Reservoir, the unit in question eventually accomplished their mission, though considerably delayed. The concept of a “tracking team” following in support of a vehicle formation raises the question of an adding additional rolling stock to an already cluttered battlefield. To mitigate unnecessary support requirements, unit priorities will have to be determined.
With the aforementioned factors as a reference point, one may ask if the investment in this new capability is worth it, or more succinctly, “is the juice worth the squeeze”? Stuck vehicles not accounted for in planning are a result of the fog and friction of war. In many cases lives are lost as a consequence. The capability of tracking up wheeled vehicles is a current investment that can save lives in an uncertain future.

**Conclusion**

The concept of taking a proven, off–the-shelf capability and integrating it into the current Marine Corps arsenal is both cost effective and expedient. In many ways the idea of adding tracks to existing wheeled platforms may appear counterintuitive, as incredible amounts of money, time, and research have determined that wheeled vehicles best support Marine Corps doctrine. With the battlefields and operating environments of the future being uncertain, the Marine Corps must prepare for any eventuality. With a relatively minimal cost in both time and money, wheeled vehicles of the Marine Corps can be quickly transformed into tracked platforms that will increase the mobility, operational flexibility, and tactical options of the commander.
NOTES

2 The for the term “Expeditionary”, will be used as described by General James T. Conway, USMC in, Marine Corps Vision and Strategy 2025, Executive Summary, page 4: “Truly expeditionary forces must have the ability to engage rapidly and in all conditions against enemies that adapt weapons or tactics to fight us asymmetrically.”
7 “Type 1” is identified as “bottomless mud”, with “Type II” mud being all others. Wood, C.E., Mud: A Military History, Potomac Books, Washington D.C., 2006, 131.
8 Wood, 133
15 Ibid
17 Ibid.
18 Donald Osborne, The ultimate trip was the great Sahara crossing, which established the Autochenille’s reputation internationally: http://www.sportscarmarket.com/Profiles/2009/August/Etceterini/, Aug 2009.
23 Ibid.
24 Ibid.
25 In order to prevent endorsement of a specific manufacturer, this paper will discuss capabilities provided by the products in general.


Tom Wollin, MATTRACKS Corp, Phone interview with author, 24 February 2010.


“Skid steer” is a mechanical process on both wheeled and tracked vehicles, where the wheels on either side of the platform are driven totally independent of the other side. This technology is seen in industrial loaders and bulldozers, as well as military tracked vehicles. http://www.mclarenusa.com/protrac/protrac-over-the-tire-tracks-for-skid-steer-loaders.html (accessed April 20, 2010)


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