Defence Research and Development Canada
Recherche et développement pour la défense Canada

Evaluation of ATV Track Systems for Winter Mountain Operations

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Technical Memorandum

DRDC Suffield TM 2011-073

June 2011

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Abstract

This document evaluates the utility of All-Terrain Vehicles (ATVs) fitted with after- market track systems for winter mountain operations. Trials undertaken at Defence R&D Canada – Suffield and Fernie, British Columbia evaluated both Honda Foreman and Yamaha Rhino tracked vehicles against mountain and touring snowmobiles. On and off-trail tests conducted in deep snow assessed the speed, control, pulling capacity, mobility and overall utility. Given this limited data set, it is predicted that small tracked ATVs could be useful in situations requiring manoeuvrability and high mobility on steep slopes and deep snow, while snowmobiles would be preferred for long-range on-trail operations.

Résumé

Le présent document traite de l'évaluation de véhicules tout terrain (VTT) munis de systèmes de chenilles achetés sur le marché des pièces de rechange pour les opérations hivernales en montagne. Les essais menés aux installations de R & D pour la défense Canada à Suffield (RDDC Suffield) et à Fernie (Colombie-Britannique) visaient à comparer des véhicules à chenilles Honda Foreman et Yamaha Rhino à des motoneiges de montagne et de tourisme. Les essais sur piste et hors piste effectués dans une couche épaisse de neige ont servi à évaluer la vitesse, la maniabilité, la capacité de traction, la mobilité et le fonctionnement général. Compte tenu de l'ensemble de données limité, il est prévu que les petits VTT à chenilles seront utiles dans les situations nécessitant une bonne maniabilité et une grande mobilité sur des pentes abruptes et dans une couche épaisse de neige, alors que l'utilisation de motoneige est préférable pour les opérations à grande portée sur piste.

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Executive summary

Evaluation of ATV Track Systems for Winter Mountain Operations

Jared Giesbrecht; DRDC Suffield TM 2011-073; Defence R&D Canada – Suffield; June 2011.

Background: Recently, a number of after-market track systems have become available for commercial All-Terrain Vehicles (ATV), replacing wheels and enabling travel over snow. This study was conducted in response to a request from the Canadian Forces regarding the feasibility of using these systems in winter mountain environments. The vehicles were assessed for speed, pulling capacity, mobility, control, and overall utility.

Principal Results: Two ATVs were tested against touring and mountain snowmobiles: a 2003 Honda Foreman ATV with Camoplast Tatou tracks and a 2004 Yamaha Rhino with Commander Trek HD tracks. In the tests at DRDC Suffield and near Fernie, BC, despite encountering snow up to 2.5 meters deep, no snow was encountered that these vehicles could not navigate on flat terrain.

In mountainous terrain and deep snow, the CF members participating in this exercise found the Honda ATV to perform better than the snowmobile in the off-trail mobility tests. When climbing slopes, the Honda ATV was more stable, safer, and easier to control. The ATV could also manoeuvre on narrow trails and in treed areas where the snowmobile could not go, and could navigate obstacles that would immobilize a snowmobile. The snowmobile was a better machine for moving quickly on-trail or in open meadows; however, the ATV allows a user to mount packs to the vehicle without towing a sled.

Although able to drive in the snow on flat-terrain, the Yamaha Rhino did not perform well in off-trail tests in the mountains due to its weight and drive train, becoming easily immobilized on hills in heavy snow. Its high payload capacity would make it useful on trails, but a snowmobile towing a sled would be able to travel much faster for the same payload.

Significance of Results and Future Work: Based on these limited tests, when compared with a modern snowmobile, tracked ATVs such as the Honda Foreman can be recommended for mountain winter use, especially in dense forests, on hiking trails, steep slopes, avalanche run-outs, or for spring and fall conditions. In these tests, the ATV was found to be safer, more stable, and required less skill and experience to operate than a snowmobile. However, for long-distances on-trail, a snowmobile was deemed to be a better choice.

Sommaire

Évaluation de systèmes de chenilles de VTT pour des opérations hivernales en montagne

Jared Giesbrecht; RDDC Suffield TM 2011-073; R & D pour la défense Canada – Suffield; juin 2011.

Contexte : Récemment, un certain nombre de systèmes de chenilles sont devenus disponibles sur le marché des pièces de rechange pour les véhicules tout terrain (VTT) commerciaux; ils ont été utilisés pour remplacer les roues et permettre le déplacement sur la neige. La présente étude a été menée en réponse à une demande des Forces canadiennes (FC) relativement à la possibilité d'utiliser ces systèmes en montagne en hiver. La vitesse, la capacité de traction, la mobilité, la maniabilité et le fonctionnement général des véhicules ont été évalués.

Principaux résultats : Deux VTT ont été comparés à des motoneiges de montagne et de tourisme : un VTT Honda Foreman 2003 muni de chenilles Tatou de marque Camoplast et un VTT Yamaha Rhino 2004 muni de chenilles Commander Trek HD. Lors des essais effectués à RDDC Suffield et près de Fernie (Colombie-Britannique), malgré l'épaisse couche de neige atteignant parfois 2,5 mètres de profondeur, aucune quantité de neige n'a su empêcher ces véhicules de naviguer sur le terrain.

En terrain montagneux et dans une épaisse couche de neige, les membres des FC qui ont participé à l'exercice ont déterminé que le VTT Honda fonctionnait mieux que la motoneige lors des essais de mobilité hors piste. Lors de l'ascension de pentes, le VTT Honda était plus stable, plus sécuritaire et plus facile à manœuvrer. Le VTT pouvait également être manœuvré sur des pistes étroites et dans les zones fortement boisées où il était impossible de se rendre avec la motoneige. Il pouvait également contourner ou surmonter les obstacles qui immobiliseraient une motoneige. La motoneige était supérieure du point de vue de la vitesse sur les pistes et de la conduite dans les champs, mais le VTT permet au conducteur de transporter une charge dans le véhicule sans avoir à remorquer un traîneau.

Même s'il peut être conduit dans la neige sur un terrain plat, le VTT Yamaha Rhino n'a pas fourni un bon rendement lors des essais hors piste en montagne en raison de son poids et de son groupe motopropulseur, ce qui l'a facilement immobilisé sur les collines dans une couche épaisse de neige. Sa charge utile élevée en ferait un véhicule utile sur les pistes, mais une motoneige remorquant un traîneau serait beaucoup plus rapide avec la même charge utile.

Importance des résultats et perspectives : Selon ces essais limités, comparativement à une motoneige moderne, les VTT à chenilles comme le Honda Foreman peuvent être recommandés aux fins d'utilisation en montagne en hiver, en particulier dans les forêts denses, sur les sentiers de randonnée, sur les pentes abruptes, dans les zones de dépôt d'avalanche ou dans les conditions printanières ou automnales. Lors des présents essais, il a été déterminé que le VTT est plus sécuritaire et plus stable et qu'il demande moins de compétences et d'expérience pour sa conduite qu'une motoneige. Par contre, on a jugé qu'une motoneige représente un meilleur choix pour les longues distances sur piste.

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1 Introduction

Under the Canada First Defence Strategy, the Canadian Forces are required to maintain the capacity to:

- Provide surveillance of Canadian territory and air and maritime approaches;
- Maintain search and rescue response capabilities that are able to reach those in distress anywhere in Canada on a 24/7 basis; and
- Assist civil authorities in responding to a wide range of threats - from natural disasters to terrorist attacks.

The ability to traverse Canada's forests, muskeg, tundra, and mountainous areas at any time of year is a requirement of maintaining the previously mentioned capabilities. However, it poses significant and varied difficulties.

This report addresses a Canadian Forces request regarding the feasibility of using All Terrain Vehicles with after-market track systems to increase mobility in winter or shoulder season mountain applications, which may include not only deep snow, but also mixed terrains with melted snow and exposed terrain on roads and in forested areas. In the past, vehicle options for mountain use were limited to either wheeled All Terrain Vehicles (ATVs) or conventional snowmobiles, forcing a user to choose between summer and winter operating modalities. This is extremely limiting in the fall and spring, as a wheeled ATV can easily become stuck in snow, while a snowmobile cannot be used for extended periods in rough terrain without snow.

(a) Honda Foreman ATV.

(b) Yamaha Rhino UTV.

Figure 1: All-terrain vehicles with aftermarket tracks.

Recently, a number of relatively inexpensive aftermarket track systems have come to the commercial market, allowing a user to quickly swap the wheels on an ATV with tracks (Figure 1). These systems can easily be changed back and forth with the original wheels, providing an ability to adapt the vehicle to the seasonal conditions. It is assumed that in mixed snow/bare ground conditions, an ATV with tracks will outperform either a wheeled ATV or a snowmobile, having the ability to travel over terrains both with and without snow. The salient issue addressed here is the ability of ATVs with tracks in full winter conditions. Evaluating tracked ATV performance, particularly against snowmobile performance on and off-trail is the goal of this document.

Assuming that there is a need to travel from one location to another off road in the mountains, there are a number of potential requirements. Depending on the intended destination, vehicle travel in the mountains can be accomplished over logging roads, established trails, cut-lines, hiking trails, through meadows and logged areas, or even through the forest itself. A vehicle may encounter rocky terrain, steep slopes, logs, avalanche run-outs, etc. To traverse the most challenging areas a vehicle with high mobility is required. For a CF operation in the mountains, a presumed list of requirements is:

- Off-trail mobility - As indicated above, a variety of challenging terrains may be encountered, and the ability to cross them could allow quicker response and the ability to reach areas otherwise only accessible on foot.
- Manoeuvrability - Similarly, the ability to navigate around obstacles, down narrow trails, and through the forest could enable the vehicle to travel more safely and to otherwise inaccessible areas.
- On-trail Speed - If traveling on established prepared trails, moving quickly to the destination would be important, allowing the mission to cover more distance in a day.
- Pulling power - On established trails, pulling large sleds of equipment on "Bog- gans" or Komatiks is an established mode of operations for the CF. However, for areas requiring high mobility, this would be impractical.
- Payload - The ability to load equipment on the vehicle itself, especially while traversing difficult terrain is a valuable consideration, especially where towed sleds are unusable.
- Fuel consumption - Lower fuel consumption reduces the logistical requirements of the vehicle, and allows for more vehicle payload.
- Reliability - Traveling long distances in remote areas means that any mechanical breakdown can have severe consequences.
- Usability - CF operators are not necessarily well trained on all vehicles. A safe and user-friendly vehicle would reduce the training burden and chance of injury to the operator, as well as allowing him to focus on his mission.

In order to provide an initial estimate of the feasibility of using these systems in the winter, the evaluation was undertaken in two steps:

1. Winter trials at DRDC Suffield evaluating technical aspects such as speed, drawbar pull, sinkage, etc.

2. Mountain trials near Fernie, British Columbia evaluating more subjective aspects such as overall mobility and usability.

The experiments tested a number of factors in the snow including ground pressure, sinkage, speed on and off road, and drawbar pull. More subjectively, mobility, manoeuvrability, and usability were assessed.

This document describes these trials and analyzes the benefits and costs of using an ATV with tracks versus a snowmobile in deep snow winter conditions. It does not provide a full comparison of all the track systems available, or a full scientific assessment of the vehicle mobility. However, it does provide an initial estimate of the usefulness of these vehicles for the Canadian Forces, such that more extensive trials can now be undertaken.

2 Test systems

A number of companies produce aftermarket track systems for ATVs (Table 1). A complete comparison of these systems is outside the scope of this document, but the products seem similar in design, with subtle differences in frame, suspension, track depth, etc. Each of the companies sell different versions of the products to fit the wheel hubs and geometry of specific ATVs. Separate products are also sold for “Utility Terrain Vehicles” (UTVs), being larger and heavier for the added vehicle and cargo weight.

Table 1: Commercially available ATV and UTV track systems.

All Season	Utility Vehicles	OEM Products
Camoplast Tatou 4S Kimpex Trek, Wide Track Mattracks Litefoot TJD XGen, XTrack	Camoplast UTV 4S Kimpex Trex UTV Mattracks Litefoot HD	Polaris Prospector BRP Apache

For the purpose of these tests, two vehicles and track systems were used:

2003 Honda Foreman TRX500A with Camoplast Tatou 4S tracks - A single-rider 4x4 ATV with a 499cc engine and full hydrostatic drive. For the remainder of the document, this will be referred to as the ATV (Figure 1(a)). The Foreman uses a continuously variable hydraulic transmission. The engine drives a hydraulic pump which in turn drives a hydraulic motor with variable fluid capacity, producing continuously variable output speed.

2004 Yamaha Rhino 660 with Commander Trek HD tracks - A side-by-side 4x4 UTV vehicle with a single cylinder 4-stroke 660cc engine, with a locking differential and a V-belt continuously variable automatic transmission. For the remainder of the document, this will be referred to as the UTV (Figure 1(b)).

The initial track installation was completed at DRDC Suffield in about 3 hours per vehicle. Subsequent time to change back and forth between tracks and wheels is about 1–2 hours per vehicle.

3 Technical evaluation at DRDC Suffield

Preliminary trials were undertaken on the Experimental Proving Ground at DRDC Suffield on 18–19 January 2011. The purpose of these tests was to evaluate the objective technical performance of the ATV and UTV with tracks against a snowmobile. The snowmobile used for these tests was a 1998 Polaris Transport Indy snowmobile. During the trials, the average depth of the loose, un-melted snow was observed to be 40 to 60 cm, with density approximately 200 g/1000 cm^3, and a temperature around $-12\,^\circ$C.

3.1 Ground pressure and sinkage

Ground pressure and sinkage are not performance measures themselves, but a vehicle with greater sinkage will encounter more motion resistance, resulting in slower speed for a given engine size, and a greater tendency to get stuck. The surface area and resultant ground pressure were estimated for driving in soft snow by measuring the weight of the vehicle and the surface area of the bottom of the tracks, which was inexact due to their curved geometry. Results of these tests are presented in Table 2.

The UTV is by far the heaviest vehicle, with the most ground pressure and sinkage. This extra sinkage, combined with the Rhino's belt driven transmission and lower engine size/weight ratio [1] limits the UTV in deep snow to flat terrain.

Table 2: Weight, pressure and sinkage of test vehicles.

	ATV	UTV	Snowmobile
Engine Size (cc)	499	660	443
Weight (kg)	385	715	250
Engine/Weight Ratio (cc/kg)	1.3	0.9	1.8
Surface Area (m^2)	1.2	1.0	0.9
Nominal Ground Pressure (kPa)	3.1	7.0	
Sinkage (cm)	8-10	12-16	6-8

3.2 Turning radius

The vehicles' turning radii were also measured in deep snow. Results are shown in Table 3. Of note is that the turning radius of the snowmobile is much greater than the ATV. It is possible that the turning radius of the snowmobile could have been made smaller by "carving" a turn. However, this

1. Although engine size/weight ratio is used for discussion in this document, power/weight or torque/weight would be more appropriate measures. However, this data was not available.

was beyond the skill levels of the drivers present. The key discussion point is that the ATV with tracks is able to turn in a small circle at both low and high speeds, with minimal effort on the part of the driver.

Table 3: Turning radius in deep snow.

	ATV	UTV	Snowmobile
Turning Radius (m)	3.6	5.3	5.6

3.3 Speed

Top speed of the vehicles was measured using two radar guns from a stationary vehicle. Each of the vehicles conducted two runs of approximately 600 meters on a hard, frozen gravel road (Figure 2(a)) and two runs in fresh, deep snow (Figure 2(b)). Multiple speed readings (approximately 10) from the radar guns were taken over each run, with the maximum speed measured from each gun recorded (Table 4).

The track systems significantly reduced the top speed of both the ATV and UTV. Despite the extra weight and sinkage of the UTV, its top speed was about the same as that of the ATV. It is surmised that this is because the transmission of this vehicle seems to be designed for high-speed operation, rather than low-speed torque. It should also be noted that the snowmobile is capable of moving faster than recorded in Table 4: the value given is the top speed that the driver felt comfortable traveling.

(a) ATV (b) UTV

Figure 2: Test area used for speed measurements.

Table 4: Top speed on-road and in deep snow. (T1 means Test 1. Results for each radar gun are separated by a slash).

	ATV	UTV	Snow	ATV(Wheels)	UTV(Wheels)
Road T1 (km/hr)	33/32	37/36	56/55	68/70	57/58
Road T2 (km/hr)	37/36	37/37	58/54	72/72	60/58
Snow T1(km/hr)	22/23	20/21	41/39	N/A	N/A
Snow T2(km/hr)	26/24	22/21	56/52	N/A	N/A

3.4 Drawbar pull

Drawbar pull is frequently used to characterize vehicle mobility, measuring the pulling force a vehicle can generate. In addition to providing an estimate of the residual tractive force the vehicle has for mobility, drawbar pull is important because the Canadian Forces often tow heavy sleds of equipment.

Gross drawbar pull can be calculated using the vehicle's torque, drive train, and wheel characteristics. To find net drawbar pull, the motion resistance of the vehicle must also be accounted for. Further, the net drawbar pull is also often expressed as a function of wheel or track slippage using a series of tests.

The task of calculating and measuring net drawbar pull was prohibitively complicated for these vehicles. Instead, the drawbar pull was empirically tested from a static and moving perspective. The vehicle setup is shown in Figure 3. In the image, the drawbar pull of the snowmobile is being tested by pulling on a tow rope attached to a load cell on the front of the UTV.

The first set of tests measured drawbar pull with both the towing and towed vehicle at a stop, on a snow covered parking lot. The throttle of the towing vehicle was slowly applied until maximum pull

(a) Tow rope setup.

(b) Load cell on towed vehicle.

Figure 3: Test setup for measuring drawbar pull of the snowmobile.

was attained, after which point, 100% slippage would occur, reducing total pulling force. The resultant force between the vehicle was recorded using a load cell and an oscilloscope. The pulling forces attained for this static test are shown in Table 5. A wheeled version of the Honda ATV was also tested for comparison.

Table 5: Measured pulling force generated for a static pull on a snow covered parking lot.

	ATV	UTV	Snowmobile	ATV(wheels)
Static Pull Test 1 (kg)	257	274	150	110
Static Pull Test 2(kg)	228	282	135	118

For the moving tests, drawbar pull was measured by towing a vehicle at a set speed, and then applying a steady braking motion of the towed vehicle until the lead vehicle came to a stall. The brakes were applied slowly enough that the dynamic effects of the braking vehicles and the elastic effects of the tow rope were minimal. The resultant force was again recorded using a load cell and an oscilloscope. Although not perfectly analytical, this method provides a rough gauge of the vehicles pulling power.

A typical output of the load cell for this test is shown in Figure 4. In the trace, it can be seen that a number of effects occur as the brakes are applied by the towed vehicle. First, the force between the vehicles increases as the driver attempts to keep both vehicles moving by increasing the throttle. As brakes are applied on the follower vehicle beyond the power of the lead vehicle to keep both moving, track slippage begins to occur on the towing vehicle, and maximum pull is attained. After this point, the lead vehicle stalls, and the tracks will experience 100% slippage. This can be seen as a steady state in the oscilloscope trace. Finally, the throttle is released on the lead vehicle, the force between the vehicles becomes zero, and the test is ended.

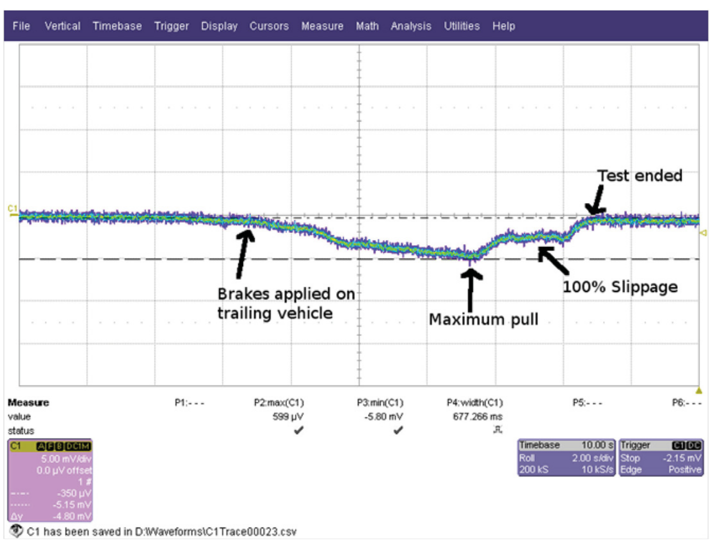


Figure 4: Oscilloscope trace for load cell measurement. Voltage output (measured as a negative voltage) corresponds to the force in pounds as follows: −1mV = 50lbs of pulling force between the vehicles.

This test was repeated for each vehicle at speeds of approximately 10, 15 and 20 km/hr on a snow covered gravel road and in deep snow. The maximum force generated from these tests is shown in Table 6. The wheeled ATV was not tested in the deep snow, as it would immediately get stuck.

Table 6: Average maximum pulling force generated for a moving pull-to-stall test.

	ATV	UTV	Snowmobile	ATV(wheels)
Road 10kph (kg)	243	232	135	145
Road 15kph (kg)	327	295	146	147
Road 20kph (kg)	299	269	161	157
Snow 10kph (kg)	310	274	82	N/A
Snow 15kph (kg)	282	N/A	127	N/A
Snow 20kph (kg)	248	280	93	N/A

These results should not be taken as an accurate measure of drawbar pull, but rather provides the relative pulling power of each of the vehicles. It can also be surmised that a heavier snowmobile with a larger engine, different tracks, etc. would be able to pull more than the snowmobile.

3.5 Mobility

The overall mobility of the vehicles was also evaluated at DRDC Suffield. These tests were rather ad-hoc, with drivers attempting to drive the vehicles over obstacles such as hills and snow-plow berms (Figure 5).

Comparing all three vehicles on flat, open terrain, the snowmobile was clearly fastest, although none of the vehicles had difficulty in deep snow on flat or gently rolling terrain. The ATV has much better mobility than the snowmobile in the presence of obstacles. The ATV was also significantly easier to steer and control, turned tighter, and could climb over more abrupt obstacles. In addition, the ATV was much more difficult to get stuck, as it could slowly crawl over obstacles, stopping and starting, whereas the snowmobile would become stuck if stopped on an obstacle. The snowmobile's belt-driven continuously variable transmission did not lend itself well to low-speed operation. Obstacles could only be cleared by the snowmobile in a "dynamic" fashion at higher speed.

Intuition would suggest that because it has a lower center of gravity, the snowmobile would be harder to tip than the ATV. However, in these tests, the snowmobile tipped many times due to the narrow track width at the back of the vehicle, while the ATV was found to be remarkably stable due to its wide stance.

The UTV did not fare well in obstacle crossing tests. The vehicle is much heavier than the snowmobile or ATV with a smaller engine/weight ratio. Like the snowmobile, it uses a belt driven continuously variable transmission, which is designed for faster speeds and has less torque at lower speeds. This caused the vehicle to dig itself in and get stuck when crossing obstacles

(a) ATV climbing snow piles.

(b) Snowmobile instability on obstacles.

(c) UTV firmly stuck.

Figure 5: Mobility testing at DRDC Suffield.

4 Winter mountain trail

After the tests at DRDC Suffield, it was felt that the Honda ATV with tracks showed promise for all-terrain use in winter. In order to fully qualify this type of vehicle's performance, three DRDC Suffield personnel and two Canadian Forces personnel traveled to Fernie, British Columbia for testing in mountain terrain, from 14–18 March 2011. The vehicles were tested on a variety of logging roads, snowmobile trails, cut lines and alpine meadows. The purpose of the trials was to establish the usefulness of the ATV with tracks as compared to snowmobiles in mountain winter conditions.

A variety of snow conditions were encountered during the trials. On trails, the snow was generally hard-packed, un-melted snow, although in places it had melted and packed to ice. In lower regions off-trail, snow was generally heavy and wet, with a depth of 1.25 m and a density of around 350 g/1000 cm^3 . Snow temperature was 0 ˚ C and air temperature was in the 0 ˚ C to 5 ˚C range. In higher regions, the snow was un-melted and lighter, with a depth up to 2.5 m and a density around 250 g / 1000 cm^3. Snow and air temperature were in the −5 to 0 ˚C range.

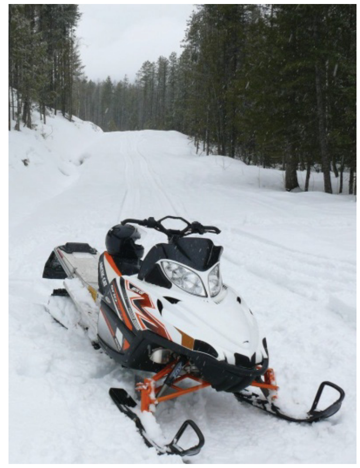
4.1 Trail riding

One day of testing was committed to riding on established trails covering long dis tances. The goal of this exercise was to analyze the use of the ATVs on long range operations. For this trial, the test vehicles consisted of the ATV and UTV as indicated earlier, as well as a 2010 Arctic Cat 370cc Panther Touring snowmobile (Figure 7(a)), and a BV206 (Figure 6).

Figure 6: Vehicles used for tests around Fernie, BC.

There are a large number of logging roads and trails used by local snowmobilers to access the back-country in the Fernie area (Figure 8(a)). These roads are inaccessible by wheeled vehicles, but provide smooth packed terrain and no obstacles for tracked vehicles.

(a) Arctic CatPanther (Touring).



(b) Arctic Cat Sno Pro800 (Mountain).

Figure 7: Snowmobiles used for mountain testing.

Two key issues emerged from this test: speed and fuel consumption. From the results in Table 7, it can be seen that the ATV and UTV use approximately twice the fuel and move at almost half the speed of a snowmobile. This effect is due in large part to the gear reduction introduced by the track systems: the ATV and UTV engines were operating at their top end, while the snowmobile's transmission was better suited to speeds in this range.

Table 7: Fuel consumption and speed traveling over longer distances on established trails.

	ATV	UTV	Snowmobile	BV206
Approx. Fuel Consumption (L/100km)	45	41	23	109
Approx. Moving Speed (km/hr)	30-35	25-30	40-50	20

The speed advantage of the snowmobile is negated on narrower or rougher trails, as the top speed of the vehicles was limited by the trail hazards. Furthermore, although there were still mostly winter conditions when this trial was undertaken, there were places where the roads had melted to the point that snowmobiles could not be used (Figure 8(b)). As the spring progresses, the amount of terrain exposed would have become greater, and the mobility on trail of a snowmobile would have been negated. Finally, on icy trails, the steering control of the snowmobile was considerably worse than the ATV and UTV.

(a) Typical logging road trail.

(b) A trail inappropriate for snowmobile use.

Figure 8: Logging roads in the Fernie area.

4.2 All terrain mobility

The other two days of the trials in Fernie were focused on the vehicle mobility aspects. A 2010 Arctic Cat SnoPro "Mountain" style snowmobile with an 800cc two-stroke engine and a 163" track (Figure 7(b)) was used for comparison in these trials.

Unfortunately, in the mountains, the UTV would become stuck on a slope of any size if it was taken off trail. For that reason, it will not be discussed further in this section. However, both the ATV and snowmobile were able to function well in all of the snow conditions encountered, including high meadows, cut lines, logged areas, etc.

For climbing slopes, the ATV and snowmobile offered two very different experiences. Over the course of the trials, both vehicles were able to climb snow-covered slopes in the 30° to 33° range (65% grade). The snowmobile had more than enough power to climb, but the front skis would lift off the ground on steep slopes. In general, the snowmobile was difficult to steer going up both steep and shallow slopes. In addition, climbing was committing and dangerous: if the snowmobile were to be slowed down or stopped on a slope, the rider would need to immediately turn down the hill, risking rolling the snowmobile during the turn. The alternative was to become stuck on the uphill, forcing the rider to get off the machine and turn it around by hand. Although the snowmobile has a reverse gear, the vehicle would immediately dig in and become stuck if it was used.

The ATV seemed much more stable on steep slopes than the snowmobile and unlike the snowmobile; when driving on slopes the driver could maintain steering and could stop and start the ATV mid-climb without becoming stuck. The limiting factor for the ATV was engine power, as the vehicle would stall when climbing steep slopes beyond 30°. However, in contrast to the snowmobile, the user was able to easily reverse down the hill to get out of trouble.

(a) Slowly navigating obstacles with the ATV.

(b) Dynamically driving over the same obstacles with a snowmobile.

Figure 9: Navigating obstacles with the ATV and snowmobile.

There are two other major considerations when comparing the off-trail mobility of the ATV and snowmobile. The first, as discovered earlier at DRDC Suffield, was the low-speed operation and obstacle climbing ability of the ATV. The snowmobile used was one of the most powerful and mobile sleds available. However, if it were stopped in deep snow or climbing over an obstacle, it was very difficult to get moving because the variable speed transmission is tuned for high speed movement. From a stop, the user would tend to bury the snowmobile in a trench dug by the track. Once again, the only way to clear obstacles was at high speeds, a potentially dangerous undertaking (Figure 9). During the course of the trials, a conservative estimate would be that the snowmobile became immobilized in the snow about 5 times as often as the ATV. In fact, there were several occasions when the ATV did not become stuck when it was purposely driven through a spot where the snowmobile had become stuck. An example is shown in Figure 10.

The second major consideration is the steering ability of the ATV tracks, which is very positive and controllable. The ATV was able to manoeuvre where the snow- mobile could not, such as in forested areas on slopes (Figure 11). By contrast, even in open logging areas which contained a few dead trees and logs, it was extremely difficult to navigate the snowmobile on hills. In deep snow, the steering mechanism of the snowmobile is no longer effective, and the user must steer by leaning and lifting the snowmobile to “carve” a turn (Figure 12). This requires skill, experience, and a minimum speed to be maintained, which is impractical in the presence of obstacles. Furthermore, on side hills the snowmobile requires strength and skill to keep the downhill ski off the ground at all times and prevent it from steering down the slope. This was not required at all on the ATV. In summary, in open meadows, the snowmobile has the advantage, but in obstacle strewn areas, narrow trails, or in the forest, the ATV was able to go many places that a snowmobile could not.

(a) Digging the snowmobile out of a ditch. (b) Driving the ATV through the same location without issue.

Figure 10: The difference in low speed mobility between the snowmobile and the ATV.

It should also be mentioned that the ATV tracks proved themselves very durable in the course of these trials. In the three days of work, no ATV or track malfunction was observed, while one of the snowmobiles suffered several thousand dollars worth of damage.

Figure 11: Navigating the ATV in trees where the snowmobile could not manoeuvre.

(a) Steering the ATV in deep snow.

(b) Carving a turn on a snowmobile.

Figure 12: In deep snow, steering the ATV was much simpler.

5 Analysis

In assessing the pros and cons of using ATVs and UTVs with tracks, as compared to a snowmobile in variety of situations, it should be kept in mind that these tests were undertaken with a limited variety of vehicles, track systems, and snow conditions. Therefore the results might not be generally applicable.

The UTV did not perform well off-trail in a mountain environment, becoming stuck easily. It is suitable for on-trail or flat-land use, providing the ability to carry supplies in the cargo bed. However, for this purpose, a snowmobile towing a sled would be more practical, traveling faster and consuming less fuel. Because of the UTV's lack of off-trail mobility, it will not be discussed further in this section.

The two Canadian Forces (CF) personnel participating in this trial were both Light Over Snow Vehicle (LOSV) qualified before these trials. Both had significant experience driving snowmobiles in Ontario, and one of them is an LOSV instructor. However, in the steep off-trail conditions encountered in these trials, both experienced difficulties with the snowmobiles, getting stuck multiple times, and felt that the amount of experience and skill required to drive snowmobiles in the mountains was beyond what the average LOSV qualified CF soldier would have. By contrast the ATV was very easy for even novice users (the DRDC Suffield personnel) to use effectively off-trail.

Table 8: *Advantages and disadvantages of using an ATV with tracks in mountain winter environments when compared with a snowmobile.*

Advantages	Disadvantages
Start and stop on slopes Manoeuvre in trees and around obstacles Climb obstacles slowly Greater pulling capacity Ability to load packs on vehicle Reduced training requirements No snow required	Slower top speed Increased fuel consumption Noise

From the point of view of the CF members participating in this exercise, the ATV was the better performer in the off-trail mobility tests, while the snowmobile was by far a better machine for moving quickly on-trail or in open meadows. Table 8 summarizes the advantages and disadvantages of the Honda ATV with tracks when compared with a snowmobile. It is based solely on the experiences and vehicles used in these trials.

The author and the trial personnel assembled a table indicating their opinions regarding the perceived applicability of these vehicles. Table 9 describes which vehicle would be preferred for conditions which may be encountered in mountain winter operations. This table assumes adequate depth of snow for snowmobile operations. Otherwise, the ATV would always be the vehicle of choice.

Table 9: Analyzing the preferred vehicle for different mountain conditions (assuming snow cover).

Condition	Snowmobile	ATV	Reasoning
Paved Roads		√	Roads normally ploughed of
Gravel Roads	√		Snowmobile speed and fuel
Logging Roads	√		Snowmobile speed and fuel
Cut Lines	√		Snowmobile speed and fuel
Hiking Trails		√	ATV is more manoeuvrable
Forests		√	ATV is more manoeuvrable
Alpine Meadows	√		Snowmobile speed and fuel consumption are better
Steep Slopes		√	ATV is more stable and easier to control
Avalanche Run-Outs		√	ATV is more stable and manoeuvrable
Melting in spring and fall		√	Snowmobile is poor on ice or bare ground

In these trials, the Honda Foreman ATV had much better mobility than the Yamaha Rhino, even though the Rhino has a larger engine. This is due to two factors: 1) the large weight of the Rhino vehicle causes significant sinkage, and 2) the drive train of the Rhino uses a belt-driven continuously variable transmission, functioning optimally at higher speed.

Any ATV purchased for use with track systems should have a high power/weight ratio. When climbing steep hills, the 500cc Honda Foreman was limited by a lack of engine power. Any vehicle selected for this purpose should have as much power as possible. Secondly, and more importantly, an ATV used with track systems requires a drive train which can deliver torque at low speed, such as shaft and gear drive, chain drive, or hydrostatic drive.

6 Conclusions

This study evaluated the suitability of a Honda Foreman ATV and a Yamaha Rhino UTV for winter mountain use, comparing them to mountain and touring snowmobiles. The results were gathered under a limited set of conditions, with a limited selection of vehicles, so the results may not be conclusive.

In these tests, the Yamaha Rhino UTV was found to be suitable for on-trail use only, with the ability to carry supplies in its cargo bed. However, a snowmobile towing a sled would travel farther and faster for this purpose. Therefore, this vehicle is suitable for short distances and flat terrain only.

Compared to a snowmobile, the Honda Foreman ATV was found to be particularly useful off-trail vehicle due to its higher mobility and control. For on-trail use, a snow- mobile provides much faster travel and lower fuel consumption. If any of the following conditions apply, the ATV would provide superior performance:

- Areas requiring manoeuvrability such as narrow trails or forests.
- Areas requiring high mobility or obstacle crossing, such as logging areas.
- Steep vertical or side slopes.
- Exposed or ice covered terrain in spring and fall.

From these trials, if any all-terrain vehicles were to be purchased for use with track systems, the vehicle should be chosen with a high power to weight ratio and an appropriate drive train capable of delivering torque at low speeds. Judging from these limited tests, the combination should provide highly effective mobility for mountain winter operations.

DOCUMENT CONTROL DATA	
(Security classification of title, body of abstract and indexing annotation must be entered when document is classified)	
1. ORIGINATOR (The name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's report, or tasking agency, are entered in section 8.) Defence R&D Canada – Suffield PO Box 4000, Station Main, Medicine Hat, AB, Canada T1A 8K6	2. SECURITY CLASSIFICATION (Overall security classification of the document including special warning terms if applicable.) UNCLASSIFIED (NON-CONTROLLED GOODS) DMC A REVIEW:GCEC JUNE 2010
3. TITLE (The complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title.) Evaluation of ATV Track Systems for Winter Mountain Operations	
4.AUTHORS (Last name, followed by initials – ranks, titles, etc. not to be used.) Giesbrecht, J.	

5. DATE OF PUBLICATION (Month and year of publication of document.)	6a. NO. OF PAGES (Total containing information. Include Annexes, Appendices, etc.)	6b. NO. OF REFS (Total cited in document.)
June 2011	34	0

7.DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Technical Memorandum

8.SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the research and development – include address.)

Defence R&D Canada – Suffield
PO Box 4000, Station Main, Medicine Hat, AB, Canada T1A 8K6

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.)	9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)
42zz78	
10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document.)	10b. OTHER DOCUMENT NO(s). (Any other numbers which may be assigned this document either by the originator or by the sponsor.)
DRDC Suffield TM 2011-073	

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This document evaluates the utility of All-Terrain Vehicles (ATVs) fitted with after-market track systems for winter mountain operations. Trials undertaken at Defence R&D Canada – Suffield and Fernie, British Columbia evaluated both Honda Foreman and Yamaha Rhino tracked vehicles against mountain and touring snowmobiles. On and off-trail tests conducted in deep snow assessed the speed, control, pulling capacity, mobility and overall utility. Given this limited data set, it is predicted that small tracked ATVs could be useful in situations requiring manoeuvrability and high mobility on steep slopes and deep snow, while snowmobiles would be preferred for long-range on-trail operations.

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All-Terrain, Vehicle Mobility, Snowmobile, Mountain.

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