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Design for a motorized, wearable, and concept sports vehicle

Hung-Chih Wang

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Rochester Institute of Technology

A Thesis Submitted to the Faculty of
The College of Imaging Arts and Sciences
In Candidacy for the Degree of
MASTER OF FINE ARTS

Design for a Motorized, Wearable, and Concept Sports Vehicle

By
HUNG-CHIH WANG

January 2004
Chief Adviser, David Morgan:  

Date: 1/17/04

Associate Adviser: Craig McArt

Date: 1/17/04

Associate Adviser: Stan Rickel

Date: 1/17/04

School of Design Chairperson: Patti Lachance

Date: 1/20/04

I, ________________, prefer to be contacted each time a request for production is made. I can be reached at the following address:

5F, #102, Chiao-Jen Rd.

Kaoshiung, TAIWAN, 807

Date: 1/17/04
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Chapter I
INTRODUCTION

Objective

The objective of this thesis is to develop a concept design for a motorized sports vehicle that attaches to one’s body and operates in such a way as to provide enjoyable outdoor activity requiring skill, stamina, coordination and physical prowess. The operator’s limbs can provide suspension for the vehicle.

The vehicle would support the body while allowing the driver to control it through body dynamics. An engine would not only prevent the driver from becoming tired by propelling the vehicle, but also assist in controlling it. Therefore, a person could recreate and train simultaneously, and find there's more to having a great time than just an easy ride.

The goal for the design of vehicle would be to provide a unique driving experience. That is fun and exciting while providing physical benefits.
Motivation

I was born in Taiwan which has 23 million people, and is geographically smaller than New York State. It's too crowded to do outdoor activities easily there, and we don't have an environment to do activities like skiing, water-skiing, hang gliding or horse back riding. Even recreational vehicles like ATVs, snowmobiles, and boats are not easy to get in my country. I found there is a quite different lifestyle in the United States compared to Taiwan. So the United States should be a good market to develop a novel recreation for transportation at vehicle.

People in the United States have good environments and resources for doing their outdoor activities in their leisure time. Sometimes the youth don't want to regard vehicles as just transportation. They are also used to a lot of exciting games or activities that can satisfy them. That's why vehicles such as an ATV, snowmobile or off-road motorcycle are so popular in the United States. People willingly spend time enhance their skill and safety knowledge for such outdoor activities. Because these vehicles are so fun, people are often willing to overlook how much they cost to purchase and maintain. I don't have such opportunities in Taiwan to do these activities like surfing, skating, skiing, hang gliding, and riding an ATV or watercraft. For my personal desire, I wanted to create an exciting concept vehicle inspired by the environment in the United States.
Chapter II
THE RESEARCH OF CURRENT ACTIVITIES

Ergonomics

Following are several illustrations that show different driving postures.

This posture accommodates automobile long-time driving and makes the driver comfortable like sitting in a chair. The driver can relax and take it easy as long as one holds the steering wheel and can step on the brake and gas pedal when appropriate.

Fig. 1  Auto vehicle posture

The hang glider pilot uses a prone posture supported by a sling under the frame of the glider to control pitch and roll.

Fig. 2  Hang glider posture
The horseback rider sits in a saddle on the back of the horse with feet in stirrups and holds the reins. Owing to the bouncing of the horse, one always has to bend or extend one's legs to absorb shock and to keep one's balance. Therefore, the rider's legs are the suspension.

![Fig. 3. Horseback riding](image)

The motorcycle rider's posture is similar to the horse rider's. But the motorcycle rider has to bend one's back and waist more than horseback rider. It is not very comfortable for extended riding.

![Fig. 4. Motorcycle](image)
The skateboarder steers by twisting the waist, knees and ankles. One also has to bend the legs waist and ankles to keep the center-gravity low and stay upright. The lower body has to be strong and a high degree of balance is required.

Fig. 5. Skateboard posture

Dynamic Physiology

This section describes the dynamic movement required and how the operators use their body to control the machine. Sometimes they have to hold the handle or steering wheel very hard; sometimes they need to bend their legs or waists to keep their balance. In different conditions and movement, they have to adjust their posture for each situation. These various positions, will affect the operators’ timing, endurance, observation and determination.
Sitting

In general, sitting automobile drivers don’t have to be very strong to drive safely considering they pay attention and have visual acuity. Designers have to consider not only the static fit for the dimension of the operator but also the dynamic fit. Static fit considers the size and position of the user. Dynamic fit, also called functional anthropometry, considers the moving, bouncing, and shocking experienced during the driving process. It is important that there is enough clearance for safe operation and adjustment. Also, it needs to fasten the seat belts to hold the body. Additionally, seated operators like fighter jet pilots or racecar drivers, experience powerful gravitational and centripetal forces that are beyond those of general driving. The concept vehicle, envisioned would also have similar needs like dynamic consideration to be met.

Fig. 6. Static/dynamic fit. (Shan Shung Hsu, You Pong, Shuai Pie Wu, ERGONOMICS/HUMAN FACTORS, 1991, Chinese Version. P55)
Prone

The vision of the user has to be improved for the prone posture. Because the body is horizontal, the rider faces down so that he has to raise his/her head and upper body to enhance the field of view. This position facilitates streamlining (so does the recumbent one).

Standing

The center of gravity is high with the standing position. Some vehicles designed for the standing position should not move too fast and may roll over easily unless the rider has a well developed skill to control them, as with skiing, snowboarding, and skating. In order to go fast, the operator has to control the body balance and the center of gravity very well.

Marketing

In the U.S. there are a lot of sporting goods and outdoor stores that sell equipment for hunting, skiing, climbing, fishing, workout, etc. Because recreation is so important to American people, a lot of that equipment is sold every year. For example, Polaris Industries, an ATV, snowmobile and watercraft manufacturer,
has annual sales of more than $1.5 billion and over 1.6 million owners.\textsuperscript{1} It's a huge market to exploit, and it's still growing. As this market is developed, more companies keep investing to generate new styles of transportation. Traditional vehicles, like cars, motorcycles or bicycles are not enough to satisfy the users' demand and desire.

\textsuperscript{1} Polaris Industries. About us.\texttt{<http://www.polarisindustries.com/aboutUs/abo_general.asp>
Chapter III
DESIGN PROCESS AND CONCEPT EVOLUTION

Concept generation and development

The direction of the concept development focused on how to take advantage of the flexible human body to control the vehicle and assist in providing its suspension. I decided to explore concepts that used both 3 and 4-wheeled configurations. The 4-wheeled layout has more stability and can run faster than a 3-wheeler.

But 3-wheeled vehicles are lighter, smaller, and energy-efficient. It also has lower manufacturing costs and superior handling characteristics. Yaw response time is the time that the vehicle takes to reach steady and stay cornering after a quick steering. 3-wheeled vehicle is quicker than 4-wheeled one because it is lighter and has approximately 30 percent less polar moment.¹

The 3-wheeled vehicle also gives a different driving experience than the 4-wheeled one and motorcycle. The center of gravity has to be considered more carefully with a 3-wheeled vehicle. Most importantly, however, this project focuses on the interactive response of the vehicle to the driver/rider. So whichever configuration supports such intimacy is the one that I would focus on.

Dynamics and Engineering definitions

These two graphics below represent the driving characteristic of a 3-wheeled vehicle. The single front wheel layout naturally oversteers and the single rear wheel layout naturally understeers. The advantage of dual front wheel layout causes less rollover than the single front wheel. But the appropriate position of the center of gravity will solve this problem wherever the single wheel layout is in the front or rear position.

Fig. 7. Comparison of 3-wheeled layouts (Robert Q. Riley. Comparison of 2F/1R and 1F/2R layouts, <http://www.rqriley.com/3-wheel.html>, 1999)
In addition, tilting three-wheelers, vehicles that lean into turns like motorcycles, offer increased resistance to rollover and much greater cornering power - often exceeding that of a four-wheel vehicle. And designers are no longer limited to a wide, low layout in order to obtain high rollover stability. Allowing the vehicle to lean into turns provides much greater latitude in the selection of a cg location and the separation between opposing wheels.²

![Diagram of CG evolution in turn](image)

Fig. 8. The evolution of CG in turn (Robert Q. Riley)

**Users' Behaviors**

Through investigating the relative products in the market today, most of these specific vehicles and activities are designed for the young users. The range

² Robert Q. Riley. [Rollover threshold of tilting three-wheelers](http://www.rqriley.com/3-wheel.html), Three Wheel Cars- Primary Factors That Determine Handling & Rollover Characteristics, 1999
is from 15 to 50 years old. For example, we can obviously see young people using
the hang glider, snow boarding, car or boat racing, even thought ATV. The users in
this age range have more physical strength, agility, and faster reaction times to
allow for such demanding recreation. Also, they may lack the wisdom of older
people to avoid reckless activities, especially when they are “blowing off steam.”
A good example of such behavior is riding an ATV. Because I had an experience
of attending ATV racing before, riding an ATV is not as easy as it looks. The rider
has to have strong arms to control the steering. While strong legs and waist are
required to brace against the shock from the ground constantly. They have to
make use of the strength of the whole body to keep their balance and not easily
roll over.
Function

This concept focuses on the interaction between the vehicle and the rider. I tried to take advantage of the flexible human body as the suspension. The rider leans his/her body to make turns like on a motorcycle. The “wearable” concept comes from wanting to make an intimate interaction between the rider and the vehicle. The user can control the vehicle with his/her own body movement. In general, this idea is for flat ground conditions, because if it is running in the off-road conditions, the rider won’t be strong enough to withstand the shock and bouncing from rough ground conditions. Also, using electric motors is better for saving gasoline and reducing pollution. Because this is to be a recreational vehicle, it won’t need much power and energy to ride for an extended period. The maximum speed would be under 30 miles/hr for safety. The user will have to train and practice to control this vehicle. With the physical support and cover from the vehicle, the user would be somewhat protected from dangerous body injuries caused by riding.
Form

The vehicle takes its form from the human anatomy to which it is attached, and it supports the rider as well as the mechanical requirements involved. It is styled to appeal to adventurous, macho adolescents. This style draws from toy robots and uses highly contrasting color including glossy metallics.

Materials

To promote lightweight, styling and strength, it would be made of aluminum frames, injection-molded plastic, carbon fiber shell and foam urethane for the inside cushion. It would include an electric-power motor with rechargeable battery.

The Consideration of Safety

The rider would put his/her arms into the control arms of the vehicle to not only be a part of the vehicle but also protect him/herself from scrapes. There would be resilient padding on surfaces of the vehicle that are in the contact with the boot in order to absorb shock. A driving vest to support the chest would be made of carbon fiber reinforced epoxy for lightweight strength. An aluminum frame would give the vehicle lightweight strength as well. A helmet with face shield would be required. Lastly, because the rider has to lift up the face forward, the neck should have a support to protect from fatigue and shock.
Idea development

I tried to develop the different postures to promote excitement while riding and take the advantage of the human body to create exercise. The user would be required to do training and practicing to get used to it.

Preliminary idea sketches

Idea 1 (Fig.9)  The driver wears the driving safety suit. It uses an electro-magnet system to connect the driver’s body with the vehicle, and makes use of the universal joint steering arm to make turns. I rejected this idea because it’s too much like an ATV and motorcycle in the market, but I liked the position of the rider.
The driver presses on the accelerator pedal with his/her foot to control the speed. (See Fig. 10)

![Diagram of accelerator pedal](image1)

**Fig. 10.** Preliminary concept 1: View showing accelerator pedal

**Idea 2** (Fig. 11) The driver lies on the suspension of the vehicle connected by the electrical magnet, and twists his/her waist to turn the rear steering arm.

![Diagram of rear steering](image2)

**Fig. 11.** Preliminary concept 2: Rear steering controlled by lower body
Idea 3

Fig. 12. Preliminary concept 3: Kneeling position

Idea 4

Fig. 13. Preliminary concept 4: Recumbent position
Idea 5

Fig. 14. Preliminary concept 5: Four wheeler

Idea 6

Fig. 15. Preliminary concept 6: Wearable rear wheels
Idea 7

Fig. 16. Preliminary concept 7: Semi-enclosed rider

Idea 8

Fig. 17. Preliminary concept 8: Limbs as suspension

Spider
Evaluation of preliminary concepts

Table 1. Comparison of preliminary ideas

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<th>Driver's strength</th>
<th>Compare with ATV/Motorcycle/Snowmobile</th>
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○ Poor/Least ○ Fair/Average ● Excellent/Most

Analysis Table 1:

• 3-wheeled configurations are more economical and lighter than 4-wheeled ones. 3-wheeled configuration would give more sensitive interaction between the rider and the vehicle.

• The wearable function needs to be enhanced. Also, some parts of the vehicle need to cover the body of the rider and hold him/her more securely. The rider should be able to don the driving/safety vest before other components. The function of driving arms and driving vest is more interesting and unique.
• The rider can use one’s arms to make turns. The vehicle can be guided and controlled by flexing and twisting one’s arms and wrists while grasping the steering mechanism.

• The kneeling position would give the users a fresh and unique riding posture to attract their interest.
Advanced ideas

Advanced concept 1

Fig. 18. Advanced concept 1: Front view

Put hands into the driving arms

Fig. 19. Advanced concept 1: Rear view

Safety Vest

Soft Texture

Rear Suspension
Fig. 20. Advance concept 1: Front suspension and steering.

Fig. 21. Advance concept 1: Operation of steering.
Advanced concept 2

Rear Engine-Part

Fig. 22. Advanced concept 1: Rear motor housing

Fig. 23. Advanced concept 2
Advanced concept 3

Fig. 24. Advanced concept 3

Fig. 25. Advanced concept 3: Details
I decided to choose advanced concept 3.

- **Advanced concept 1**
  
  It didn't have such a wearable function, but I felt it's valuable to keep the idea with full cover of driving arms.

- **Advanced concept 2**

  The rider had to wear the extra vest that didn't really belong to one part of the whole vehicle. It came with 4-wheeled configuration so that the rider couldn't turn using inclining body.

- **Advanced concept 3**

  Advanced concept 3 was composed of concept 2 and 3. It had the full cover of driving arms that could protect the arms of rider more. The driving vest belonged to one part of the vehicle. 3-wheeled configuration gave the vehicle the cornering agility similar to a motorcycle.
Mock-up

A full-size frame mock-up was constructed to examine ergonomic issues. It was important to ascertain if the rider would feel comfortable and have enough strength to operate the vehicle. An adjustable mock-up was constructed to represent different vehicle configurations. Adjustments could be made in the tilting angle of the user's body, the length of the front suspension arms, the angles of various components, and the exact position of the body support.

Fig. 26. Mock-up adjustments
Dynamic experiment

The adjustable mock-up allowed me to determine dimensions and angles for the final design. However, I felt it necessary to confirm them in a dynamic trial. In order to do this, I fashioned four short skis, which I strapped to my forearms and shins. Then on a snowy hill, using gravity for propulsion, I coasted in a kneeling posture using my arms to steer (Fig. 28).
After I slid down the hill a couple of times, I could figure out which body parts needed to be supported. The shoulders, arms, waist, abdomen and legs felt too weak to comfortably operate a vehicle for an extended period. I found that I needed to enhance the support for those parts.
Computer modeling/ Rendering

Preliminary computer generated models

I created two different 3D-computer generated models with Alias Studio when I started to develop the preliminary concepts. It was easy for me to recognize what the configurations of the future models would be, and find out some shortcomings before the final design. It also allowed me to easily change cosmetic and styling ideas.

Model 1

![Computer generated model 1](image1)

![Computer generated model 1: Function](image2)

![Computer generated model 1: Side view](image3)
Model 2

This 3d model shows the concept how the each part works and the concept of a driving situation (Fig. 32).
For example, this steering might do harm to the rider's spine because they have to twist their waist to steer. So I decided to steer with the front driving arms instead of this twisting-waist idea.

Fig. 33. Computer generated model 2: Turning

Fig. 34. Computer generated model 2: Rear view
Advanced Computer Generated Models

Model 1  Texturing and lighting were considered to show the surface.

Fig. 35. Advanced computer generated model 1: Perspective view-1

Fig. 36. Advanced computer generated model 1: Perspective view-2
Model 2

Compared with Model 1, I added protection covers on driving arms and steering motors of the front wheels. This version would be my final design.
Scale Model

I vacuum-formed plastic components for my model from rigid foam patterns which I sculpted. I then composed the components of the scale model together and tested the fit. Next, I used primer-paint and putty to build up the surface before sanding it in order to develop a perfect surface. Last of all, I did the final painting of the body and applied clear coat.

Components: Driving Arms, Vest, and Rear Block
Rear engine parts

Fig. 41. Scale model: Rear part-1

Fig. 42. Scale model: Rear part-2

Suspension details

Fig. 43. Scale model: Suspension of driving arms

Fig. 44. Scale model: Middle suspension

Front view and front wheel details

Fig. 45. Front view of scale model

Fig. 46. Details of front wheel
Fig. 47. Scale model: Full view-1

Fig. 48. Scale model: Full view-2
Technical Drawings

Technical Drawing-Side View

The rotating pivots of driving arms

Height 60.25 inches
7.85 inches
42.5 inches
12 inches
Wheel base 80 inches
Length 96 inches

Fig. 49. Side view of technical drawing

Technical Drawing-Front View

Track, Front 41.65 inches
Width 45.05 inches

Fig. 50. Front view of technical drawing
Chapter IV
OPERATION

Technical Specifications

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<td>Suspension System</td>
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<td>Lead-Acid battery</td>
<td>Tire Size</td>
<td>F/8&quot; R/13&quot;</td>
</tr>
<tr>
<td>Range</td>
<td>60 Miles</td>
<td>Rechargeable</td>
<td>Over 300 times</td>
</tr>
<tr>
<td>Size L x W x H</td>
<td>96&quot;x45.1&quot;x60.25&quot;</td>
<td>Track, Front</td>
<td>41.65&quot;</td>
</tr>
<tr>
<td>CG Height</td>
<td>32.9&quot;</td>
<td>Brake System</td>
<td>Disk</td>
</tr>
</tbody>
</table>

Signals, Side Lights, Rear Light, Hi-beam.

The motor data is from the performance of electrical scooters\(^1\), describing is a very reasonable and economical product in the market. I used the regular motorcycle wheel as the rear wheels, and the front wheels are from the mini electrical scooter.

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\(^1\) Fast Electric Scooter <http://www.superheitinne.com/electric-scooters/scooter-electric-1.html>
Attaching

1. The rider stands to don the driving vest and fasten the belt tightly. Then the arms go in.

   Fasten the vest belt:
   To hold the vest on the upper body

   Fig. 51. The process to get in the vehicle-1

2. The rider kneels on the rear part of the vehicle and pushes the arms forward.

   Fig. 52. The process to get in the vehicle-2
3. The rider lies down on the Body-Seat and keeps driving arms forward until they have been locked at that position.

   Lie down with the upper body against the Body-Seat.

   Lock the arms with this angle.

   Move the driving arms forward until they lock in place.

   Fig. 53. The process to get in the vehicle-3

4. After the driving arms have been locked, the rider is able to remove the hands to adjust the latches of the driving vest.

   Fig. 54. The process to get in the vehicle-4
Latch: To clasp the vest and body supporter
The latch would not be unlocked until the strut of the vehicle is in the parking position.

- The driving arms would be locked when they rotate from A to B.
- The motion of driving arms would be limited between B to C to assist turning.
- They can be unlocked for rotating back when the engine shuts down.

B-C: Arm-Locked Angle. Dynamic Fit

Fig. 56. The process to get in the vehicle-5
5. The rider puts his/her arms back into the driving arms and then holds the control handles.

6. The rider presses the start-button on the right handle to start the engine.

7. The rider presses the button of the left handle to lift and collapse the strut underneath. Now it is ready to run.
Detaching

To detach from the vehicle, the rider just has to follow the opposite directions of attaching process.

1. The rider presses the button of the left handle again to put down the strut, and then the strut would hold up the whole vehicle.

2. The rider presses the start-button on the right handle to stop the engine. At this time the driving arms have been unlocked.

3. The rider draws out his/her hands to detach the latches of the driving vest.

4. The rider puts the hands in again to pull the driving arms back and lift his/her upper body.

5. The rider then stands up and takes off the driving suit.
**Electro-Connection**

Some computerized assistance is probably required to help the driver. The small computer processor inside the vest assists driving, steering and braking.

Two steering motors are connected by electro-wire to turn with the same degree and direction through the control handles.

![Central Assistant System](image1.png)

![Central Assistant System](image2.png)
The battery is mounted under the seat. One can detach the seat to change
the battery or maintain the motor.

![Diagram](image)

**POWER SUPPLY**

- Lift the Engine cover for maintenance
- Change Battery
- The Latch is also the Electrical Connector that can serve to power the Motor of the Steering System in the front

Fig. 62. Power supply and connection

**Miscellaneous functions**

**Protection**

- Soft Texture

![Images](image)

Fig. 63. Soft texture for protection

**SUSPENSION**

- Dynamic fit
- Dynamic fit

![Images](image)

Fig. 64. Suspension setting

Fig. 65. Body supporting
Steering

The rider uses the handles and twists the arms to steer. Once the rider pulls one of the controlling handles and pushes the other one to the opposite direction to steer, both steering motors would turn the in same direction, controlled by the central assistant system simultaneously.

POWER STEERING SYSTEM

Fig. 66. Steering function

Fig. 67. Steering motor

Left Turn

Fig. 68. Left turn-front view
Left Turn

Pivot of right arm

Original angle
15 degrees

Right arm rotates back to steer

Left arm keeps the same position

Fig. 69. Left turn-side view
Chapter V
Final presentation

Committee meeting

Three advisors (David Morgan, Stan Rickel, Craig McArt) oversaw all processes, including the installation in the gallery, and made the final review of the project. They recommended to refine the display and gave some feedback for the improvement of this project.

Exhibition

A 1/6 scale model with clear acrylic-cover show case and a 3'x2 - 3/4' display panel were shown in the Bevier Gallery from April 22 to May 8, 2002. The pedestal is 3 feet high.
Chapter VI

CONCLUSION

What evokes your passions and desires? Recreation and leisure is more and more important for busy people today. This project leads the youth to adventure through an innovative driving experience. It requires little training and practice to get used to driving. After that, people will ride this exciting vehicle on their own and get lots of enjoyment from driving. There are a lot of concept vehicles similar to this announced and developed recently. Each unique design wants to catch the users' curiosity. So far, we haven't seen a vehicle that uses a kneeling position. This is an adult toy for recreation. Why shouldn't we explore more possibilities to make vehicles more fun and exciting? There is a huge demand for an innovative, fun vehicle in the U.S. market, and this vehicle could meet those demands.

I tried to make this concept impressive to the user market and reasonable. At the beginning of the process, I developed various ideas and discussed them with my advisors to narrow down my thinking. I did a lot of brainstorming to provide many different ideas in advance, and focused on the wearable and exercise functions to develop a final direction. Using references and research in mechanisms, ergonomics, electronics and materials, I started to make concepts that supported the criteria better. The new kneeling, driving posture provides a
different driving experience; the wearable driving suit, and the individual driving arms provide intimate and sensitive operation because the vehicle attaches to the rider’s upper body and responds immediately.

However, these advantages caused certain shortcomings. I found that human limbs are poorly suited to be the suspension because body dynamics and strength are limited. Further, the main support point of the vehicle on the abdomen and the solar plexus of the rider might cause stress to the rider when riding, and also doesn’t provide enough shock protection. Thirdly, this vehicle will need power assisted steering. Finally, the neck support is inadequate because the rider has to lift his/her head up to see and support the weight of the helmet. In conclusion, I have to admit that it’s necessary to make improvements to be viable. This was just an investigation and exploration of a hypothesis through the development of a concept design. I enjoyed the design exploration and working through the evolution of concept development.

I think in the future, we will see more innovative vehicle concepts come out. For recreational transportation and sport, there is still a lot to explore.
APPENDIX

BACKGROUND RESEARCH

Concept vehicles

"Mercedes F300-3 wheels vehicle provides an innovative active tilt angle control system that responds at lightning speed. This gives the F300 the cornering prowess and agility of a motorcycle with active safety akin to a car".¹

Fig. 73. Mercedes F300

Peugeot-Moon is a concept vehicle designed by Peugeot and inspired by an insect. Each wheel can move independently so that it has the ability to handle different ground conditions easily.

Fig. 74. Peugeot-Moon

The rider steps over the rear wheels of this three-wheeled design. The scooter is for entry users, so it's easy to control and operate for beginners.

![Entry-level scooter, sponsored by Aprilia, Art Center College.](image)

SoloTrek XFV is a wearable helicopter developed by Trek Entertainment, Inc.

In the year 2003, the world's first exoskeleton backpack aircraft, the *SoloTrek XFW* (Exoskeleton Flying Vehicle), demonstrated conclusively that its technology was both viable and practical.²

![SoloTrek XFV](image)

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² Trek Entertainment, Inc., [Wearable Helicopter](http://www.solotrek.com/devhistory.html)
Products and Activities in the market

Sitting position

The all-terrain ATV with on-demand all-wheel drive adapts to all off road conditions and is the most popular utility vehicle in the U.S. market. It is very useful for rescuing, hauling or outdoor adventure.

![ATV](image1)

Fig. 77. ATV

The two-wheel motorcycle layout provides high speed and mobility. The motorcycle is useful for touring, racing and general transportation.

![Motorcycle](image2)

Fig. 78. Motorcycle
The unicycle rider has to have a good sense of body balance to ride a unicycle. It takes a lot of practice to learn to steer and stop.

Recumbent position

Three-wheeled and human-powered bicycle with recumbent posture. There is a lot of variety in this configuration.
The form of these solar powered vehicles is very streamlined to reduce the wind resistance. Therefore, the vehicle is able to run faster with less energy. Because of the flat shape, the driver has to use a recumbent posture to drive it.

![Solar-power car](image1)

**Prone posture transportation**

The hang glider pilot controls with the prone posture and turns by inclining the whole body.

![Hang glider](image2)

**Standing posture transportation**

BMW-Street Carver has all wheel-individual suspensions to help the rider ride on many different ground conditions.

![BMW-Street Carver](image3)
People have to have good amount of skill to do these activities well. They need to bend their knees and waist to keep center of gravity lower and maintain body balance well.

Fig. 84. Surfboard / skiing and ice skating

The learning curve of a Wheelman is very similar to skate/snow/surf board riding.

Fig. 85. Wheelman—a motor and frame supported at each end by a spokeless wheel into which feet can be inserted while standing upright

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Inspiration from imagination

In Japanese animation films, we see a lot of ideas about transforming robots from various formats like cars, airplanes, etc. Although those are wild concepts based on simple mechanisms, some seem credible. The Macross robot (Fig. 86) is a famous animation. Some people doubt it's possible to make such a thing, but there are still some reasonable ideas that could provide inspiration for the development of many products.

Fig. 86. Transformable motorcycle package

Fig. 87. Macross robot: Wearable robot
Workout Machine

Body building machines provide various kinds of simulation for training and doing exercise, like skiing, running, rowing or riding. The advantage is that you are able to do the exercise and training indoors without experiencing the conditions of the environment, and still get similar effects.
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