# Team 512 - Lockheed Martin Low-Cost HOTAS

EML 4551C


Robert Blount

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Robert Craig

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# Team 512 Introductions

**Robert Blount**

*Systems Engineer*

**Connor Chuppe**

*Test Engineer*

**Robert Craig**

*Controls System Engineer*

**Patrick Dixon**

Mechatronics and Geometric Design Engineer

# Important People

**Project Sponsor**

Andrew Filiaut

Lockheed Martin F35 Training Systems Engineer

**Professor**

Dr. Shayne McConomy

Professor and Director of Mechanical Engineering Senior Design at the FAMU-FSU College of Engineering

**Project Adviser**

Dr. Patrick Hollis

Professor at the FAMU-FSU College of Engineering

Robert Blount

# Project Objective


The objective of this project is to create a low-cost Hand-On Throttle and Stick (HOTAS) system to support the Pilot Training Devices (PTD) product line. The product will replicate the throttle control assembly and control stick of various fighter aircrafts.

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# Project Background

| | |
|---|---|
| HOTAS | •Hands on throttle and stick, (the operable controls for an aircraft/ground vehicle like a tank) |
| Throttle | •The throttle side(left hand) of the HOTAS is controlling the forward movement velocity and acceleration of the vehicle |
| Stick | •System currently used with almost all modern aircrafts, uses a constant force feedback to simulate a mechanical system |
| Fly-by-Wire | •System currently used with almost all modern aircrafts, uses a constant force feedback to simulate a mechanical system. |
| AOA | •Angle of attack – used to describe the planes orientation in space, sometimes involved in force feedback on a system |
| Operation Process | •The HOTAS is used in simulated environments with either a desktop computer or a simulator cockpit. |
| Switches-Buttons | •Located on both the throttle-stick, and base of throttle, these have many base functions such as the ones located on the stick, while others must be mapped for specific functionality with each craft chosen |

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# Project Motivation

Create a comparable product to the ones currently used in house by Lockheed Martin

These units are the Bugeye F-35 stick and Wraith System's units





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# Key Goals

CREATE A LOW FIDELITY HOTAS WITH REASONABLE MANUFACTURING COSTS, AND REPAIRABILITY

BE ABLE TO FUNCTION WITH PREPAR3D SOFTWARE (LOCKHEED MARTIN SIMULATION SOFTWARE)

SHALL PROVIDE THE SAME FUNCTIONALITY AS CURRENT MODELS USED (BUGEYE F35 HOTAS, WRAITH SYSTEMS F35 HOTAS)

SHALL BE ABLE TO BE USED FOR DESKTOP TRAINING

BE ABLE TO COMMUNICATE WITH COMPUTER VIA STANDARD IO

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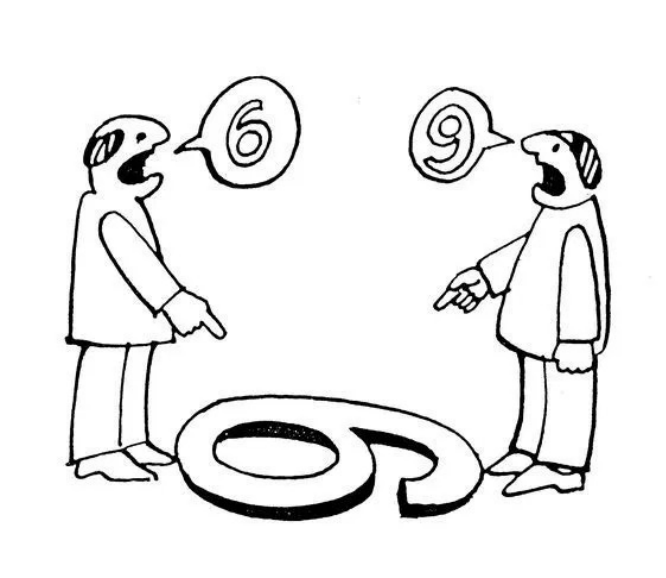
# Assumptions




- The HOTAS is being designed for Lockheed Martin use only, and it will primarily be for desktop vehicle training simulations.
- The HOTAS itself will be crafted from low cost materials, and potentially be mounted in use.
- The Power of the HOTAS will be provided by connected desktop, with software being purchased or provided by the sponsor.
- The hardware for the HOTAS shall be commercially off the shelf product, and we will be designing internal circuitry to encompass functionality.
- The HOTAS is assumed to use an interchangeable outer grip for various vehicles.
- The design and creation will cover all electrical and mechanical aspects of a functional HOTAS.

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# Primary Market

LOCKHEED MARTIN

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# Secondary Markets

- Military Service branches
- Industrial applications
- Gaming and E-sports

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# Stakeholders

Dr. Shayne McConomy

End users who use products similar to ours will be affected by our project's success or failure.

Lockheed Martin is the direct company sponsor of our project

Andrew Filiault

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# Customer Needs

- Needs to be able to integrate with Prepar3D software
- Shall be easily repairable
- Final design should be under $4,000


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# Customer Needs

- Be able to support multiple grips
- Should provide feedback proportional to the simulated speed and angle of attack
- Needs to have same functionality as current model


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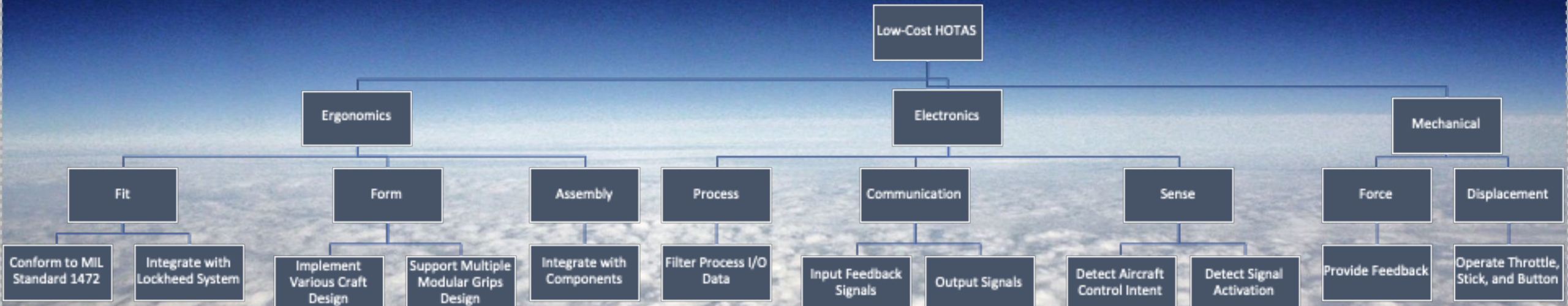
# Functional Decomposition

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# Functional Decomposition

Ergonomics

| Fit | Form | Assembly |
| --- | --- | --- |
| Conform to MIL Standard 1472 | Implement Various Craft Design | Integrate with Components |
| Integrate with Current Lockheed System | Support Multiple Modular Grips | |

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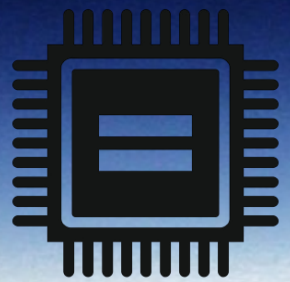
# Functional Decomposition



Electronics

| Process | Communication | Sense |
| --- | --- | --- |
| Filter and Process I/O Data | Input Feedback Signals | Detect Aircraft Control Intent |
| | Output Signals | Detect Signal Activation |

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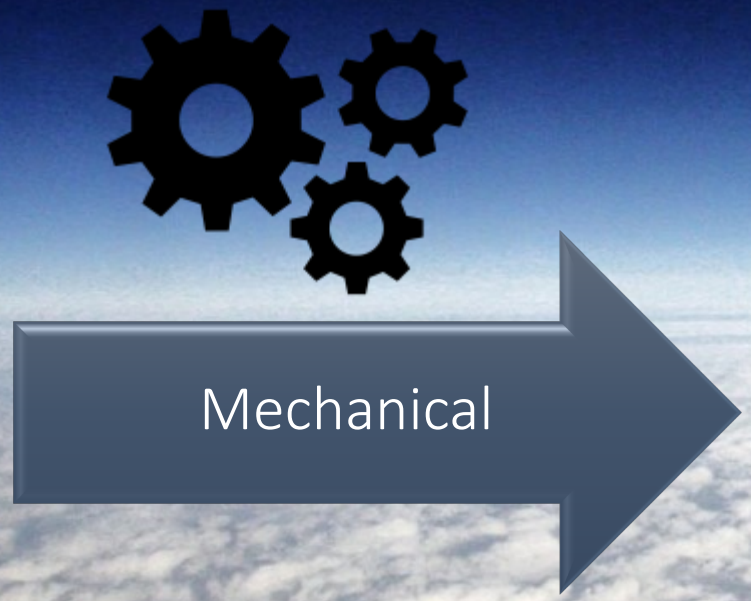
# Functional Decomposition




Force

Provide Feedback

Displacement

Operate Throttle and Stick

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# Future work

Targets and Metrics

**Concept** Generation

Concept Selection

**Prototyping**

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# Important Takeaways

- Low-Cost
- Able to integrate with Lockheed Martin's System (prepar3d)
- Why we're doing it
- Comparable to competitor's functionality
- Replicate throttle and control assembly of various fighter aircraft

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# Questions and Comments

Robert Blount

Connor Chuppe

Robert Craig

Patrick Dixon

Robert Craig

# References


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# Backup Slides

Team member Robert Craig

# Input plug and play functionality

When plugged into a computer:

The system will recognize, throttle, and basic stick functions, (thrust, yaw, pitch, roll, triggers)

Small buttons and switches will be programmed inside the simulation software (prepar3d)

Each will be input into the software for testing and validation as a key profile

The key profile will change based on in field pilot needs and craft changes

# Fidelity

- High – exactly what is in the vehicle
- Medium – pretty close representation, leaning away from the real plane
- Low – not physically representative of the actual vehicle, but it functions

# Low Cost Ideas

- Material Selection
- COTS Parts
- Not Decrease Functionality

# I/O Selection

- USB
- PS2
- DV9

# PTD

- VR
- Desktop
- Full Simulator

# Prepar3D

- Various Aircraft
- Interactive cockpit
- Mapping
- Minimum Hardware requirements: windows 10; 4-core @3.0 GHz, 4.0 GB ram
- 4 GB Vram with directX12.0, 1080p screen

| System | Major System | Minor System | Fuction | Fit | Form | Assembly | Process | Communicate | Sense | Force | Displace | Provide Feedback | Row Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HOTAS | Ergonomics | Fit | Conform to MIL standard 1472 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 |
| | | | Integrate with Current Lockheed System | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 5 |
| | | Form | Support Multiple Modular Grips | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 4 |
| | | | Implement Various Craft Designs | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 4 |
| | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Assembly | Integrate with components | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | Electronics | Process | Filter and Process I/O Data | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 4 |
| | | Communication | Input Feedback Signals | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 4 |
| | | | Output Signals | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 3 |
| | | Sense | Detect Aircraft Control Intent | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 2 |
| | | | Detect Signal Activation | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 3 |
| | Mechanical | Force | Provide Feedback | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 5 |
| | | Displacement | Operate Throttle, Stick, and Buttons | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 7 |

| Function | Conform to MIL standard 1472 | Integrate with Current Lockheed System | Support Multiple Modular Grips | Implement Various Craft Designs | Integrate with components | Filter and Process I/O Data | Input Feedback Signals | Output Signals | Detect Aircraft Control Intent | Detect Signal Activation | Provide Feedback | Operate Throttle, Stick, and Buttons |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Conform to MIL standard 1472 | 1 | 5 | 3 | 7 | 1 | 0.11 | 0.14 | 0.14 | 0.11 | 0.14 | 9 | 0.33 |
| Integrate with Current Lockheed System | 0.20 | 1 | 3 | 5 | 1 | 0.20 | 0.33 | 0.33 | 0.11 | 0.33 | 5 | 0.20 |
| Support Multiple Modular Grips | 0.33 | 0.33 | 1 | 1 | 0.33 | 0.14 | 0.14 | 0.14 | 0.11 | 0.14 | 3 | 0.14 |
| Implement Various Craft Designs | 0.14 | 0.20 | 1 | 1 | 0.20 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.33 | 0.11 |
| Integrate with components | 1 | 1 | 3 | 5 | 1 | 0.20 | 0.33 | 0.33 | 0.11 | 0.20 | 0.20 | 0.20 |
| Filter and Process I/O Data | 9 | 5 | 7 | 7 | 5 | 1 | 7 | 7 | 1 | 1 | 5 | 1 |
| Input Feedback Signals | 7 | 3 | 7 | 7 | 3 | 0.14 | 1 | 1 | 0.20 | 0.20 | 3.00 | 0.20 |
| Output Signals | 7 | 3 | 7 | 7 | 3 | 0.14 | 1 | 1 | 0.20 | 0.20 | 3.00 | 0.20 |
| Detect Aircraft Control Intent | 9 | 9 | 9 | 7 | 9 | 1 | 5 | 5 | 1 | 5 | 7 | 1 |
| Detect Signal Activation | 7 | 3 | 7 | 7 | 5 | 1 | 5 | 5 | 0.200 | 1 | 0.14 | 3 |
| Provide Feedback | 0.11 | 0.20 | 0.33 | 3 | 5 | 0.20 | 0.33 | 0.33 | 0.14 | 7 | 1 | 0.33 |
| Operate Throttle, Stick, and Buttons | 3 | 5 | 7 | 9 | 5 | 1 | 5 | 5 | 1 | 0.33 | 3 | 1 |
| Sum Total | 44.787 | 35.733 | 55.333 | 66.000 | 38.533 | 5.283 | 25.429 | 25.429 | 4.330 | 15.695 | 39.676 | 7.724 |

| Function | Conform to MIL standard 1472 | Integrate with Current Lockheed System | Support Multiple Modular Grips | Implement Various Craft Designs | Integrate with components | Filter and Process I/O Data | Input Feedback Signals | Output Signals | Detect Aircraft Control Intent | Detect Signal Activation | Provide Feedback | Operate Throttle, Stick, and Buttons | Weighted Totals | Weighted Totals Percentile | Consistency Vector | Average Consistency | N Value | Random index Value for n = 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Conform to MIL standard 1472 | 0.0223 | 0.1399 | 0.0542 | 0.1061 | 0.0260 | 0.0210 | 0.0056 | 0.0056 | 0.0257 | 0.0091 | 0.2268 | 0.0432 | 0.0571 | 5.71 | 0.7231 | 0.9864 | 12 | 1.54 |
| Integrate with Current Lockheed System | 0.0045 | 0.0280 | 0.0542 | 0.0758 | 0.0260 | 0.0379 | 0.0131 | 0.0131 | 0.0257 | 0.0212 | 0.1260 | 0.0259 | 0.0376 | 3.76 | 0.8545 | | | |
| Support Multiple Modular Grips | 0.0074 | 0.0093 | 0.0181 | 0.0152 | 0.0087 | 0.0270 | 0.0056 | 0.0056 | 0.0257 | 0.0091 | 0.0756 | 0.0185 | 0.0188 | 1.88 | 1.1042 | | | |
| Implement Various Craft Designs | 0.0032 | 0.0056 | 0.0181 | 0.0152 | 0.0052 | 0.0270 | 0.0056 | 0.0056 | 0.0330 | 0.0091 | 0.0084 | 0.0144 | 0.0125 | 1.25 | 1.3337 | Consistency Index | Consistency Ratio | these values are < 0.10 making |
| Integrate with components | 0.0223 | 0.0280 | 0.0542 | 0.0758 | 0.0260 | 0.0379 | 0.0131 | 0.0131 | 0.0257 | 0.0127 | 0.0050 | 0.0259 | 0.0283 | 2.83 | 0.8440 | -1.0012 | -0.6502 | the comparisson consistent |
| Filter and Process I/O Data | 0.2009 | 0.1399 | 0.1265 | 0.1061 | 0.1298 | 0.1893 | 0.2753 | 0.2753 | 0.2309 | 0.0637 | 0.1260 | 0.1295 | 0.1661 | 16.61 | 1.0485 | | | |
| Input Feedback Signals | 0.1563 | 0.0840 | 0.1265 | 0.1061 | 0.0779 | 0.0270 | 0.0393 | 0.0393 | 0.0462 | 0.0127 | 0.0756 | 0.0259 | 0.0681 | 6.81 | 0.6968 | | | |
| Output Signals | 0.1563 | 0.0840 | 0.1265 | 0.1061 | 0.0779 | 0.0270 | 0.0393 | 0.0393 | 0.0462 | 0.0127 | 0.0756 | 0.0259 | 0.0681 | 6.81 | 0.6968 | | | |
| Detect Aircraft Control Intent | 0.2009 | 0.2519 | 0.1627 | 0.1061 | 0.2336 | 0.1893 | 0.1966 | 0.1966 | 0.2309 | 0.3186 | 0.1764 | 0.1295 | 0.1994 | 19.94 | 1.0554 | | | |
| Detect Signal Activation | 0.1563 | 0.0840 | 0.1265 | 0.1061 | 0.1298 | 0.1893 | 0.1966 | 0.1966 | 0.0462 | 0.0637 | 0.0036 | 0.3888 | 0.1406 | 14.06 | 1.0610 | | | |
| Provide Feedback | 0.0025 | 0.0056 | 0.0060 | 0.0455 | 0.1298 | 0.0379 | 0.0131 | 0.0131 | 0.0330 | 0.4460 | 0.0252 | 0.0432 | 0.0667 | 6.67 | 1.3436 | | | |
| Operate Throttle, Stick, and Buttons | 0.0670 | 0.1399 | 0.1265 | 0.1364 | 0.1298 | 0.1893 | 0.1966 | 0.1966 | 0.2309 | 0.0212 | 0.0756 | 0.1295 | 0.1366 | 13.66 | 1.0748 | | | |
| Sum Total | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 100 | | | | |

**Table 1: Customer Needs interactions**

| Questions | Customer Statements | Interpreted need |
|---|---|---|
| How many units are expected to be produced? | If all goes well, ~1,000 units and possibly more. | Design needs to be easily reparable. |
| How will the unit be implemented into your system? | It'll be mounted on a desktop and used in software training for a variety of military vehicles | Design needs to fit variety of military vehicle handles. |
| What is considered Low Cost? | Current models are around $8,000 | Final Design needs to be under $4,000 |
| Are we taking an existing design to modify or completely making a new design? | Building from the ground up | Create an original design |
| Are we making our own grips or using grips from existing aircraft? | Creating your own grip | Grip can be any design as long as its functional |
| Should we make a base, or will it be connected to an existing simulator? | You will need to make a base | HOTAS will be used on a desktop simulator |
| How many buttons and switches etc., what kind of functionality and accuracy is intended? | Reference current models. Design will be used for low fidelity training. | HOTAS needs to have the same functionality as most current models |
| What kind of software will be used? | Prepar3d is software used. | Needs to be able to integrate with software. |
| What are the expectations for the feedback? | Device should provide resistance dependent on relative speed. | HOTAS needs to provide resistance proportional to the simulated speed of the military vehicle |