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Analysis of Small Unmanned Ground Vehicle Mobility Performance Algorithms

Paul Richmond, Jason Pusey, George Mason and Barry Coutermarsh

U.S. Army Engineer Research and Development Center and U.S. Army Materiel Systems Analysis Agency

75th MORS 2007
Presented to Working Group 10 and 11

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Presentation Overview

- Project Overview
- ERDC SUGV testing data analysis
- Algorithm Analysis
- Terrain EDM Analysis
- Performance Comparisons
- Future Work
- Summary

Project Overview

Objectives
- Investigate small vehicle terrain interaction for on-road, off-road, and building material (curbs, stairs, carpet) surfaces and develop associated algorithms if required

- Enhance/verify use of the Standard Mobility API algorithms for estimating mobility performance of unmanned vehicles (10-5000 lbs)

Technical Approach and Goals

- Review of existing algorithms and available small vehicle data
- Identify terrain surfaces and conditions for which data is needed
- Identify and develop an approach for modeling electric powered vehicles in a trafficability/mobility model
- Develop approach for estimating effect of remote and autonomous operation on ground vehicle performance

Literature Review

- Searched several databases with these key words:

  unmanned ground vehicle, sugv, ugv, speed, mobility, robot, remote, autonomous, scale model

- Identified over 80 documents which contained data or other information which might be useful in the development of SUGV mobility performance algorithms

- However no comprehensive mobility performance study was found, principally found proof of concept, exploratory or reports of demonstrations
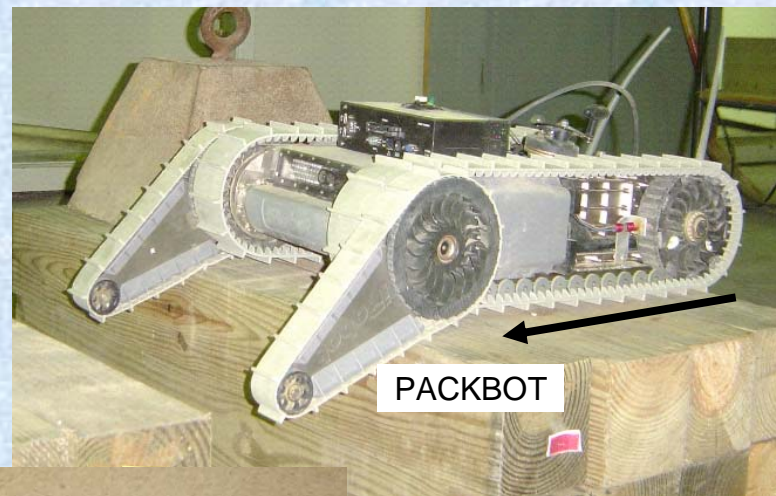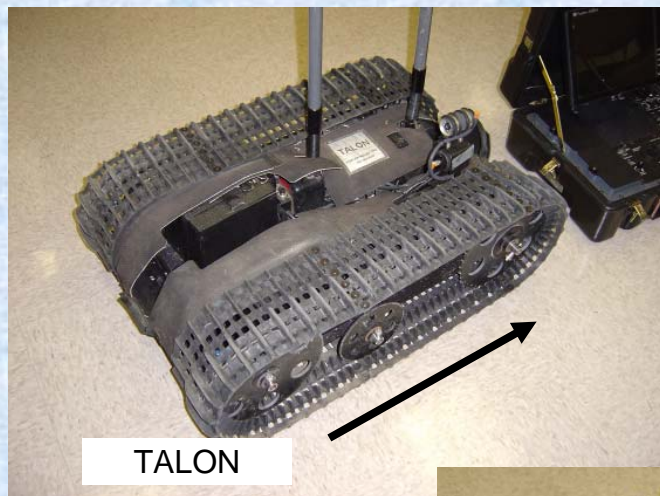
SUGV Test Data Analysis

- ERDC had previously conducted limited mobility performance tests for 3 SUGV

- Analysis of data completed, developed NRMM and STNDMob data files based on these tests

- TO DO: compare model predictions with observed performance
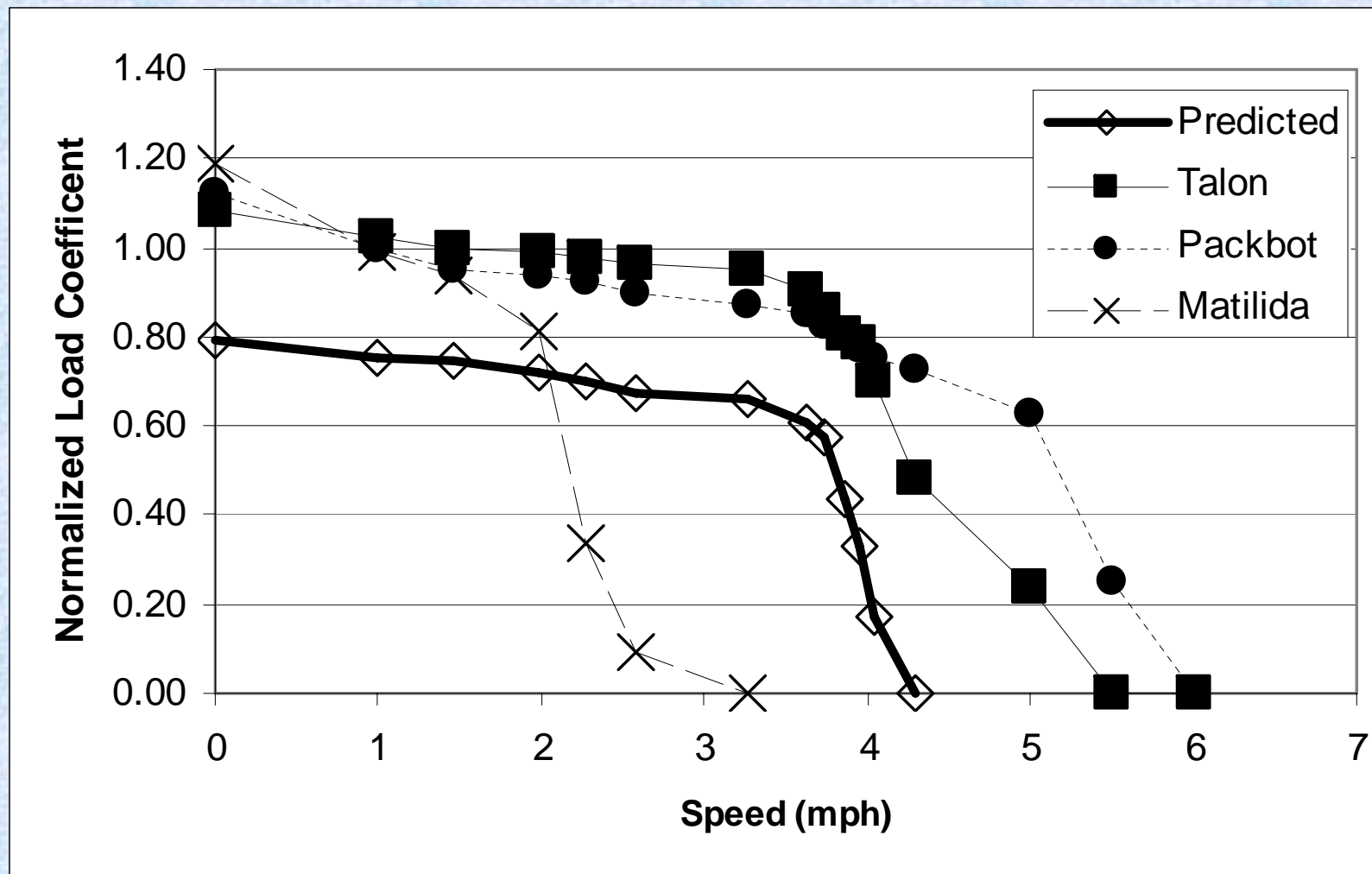
SUGV'S Tested at ERDC

TALON

PACKBOT

MATILDA

SUGV Test Data Analysis

SUGV Test Data Analysis

Stair Climbing

- The TALON was the only vehicle recorded as a no-go.
- Vertical step of 8 inches
- Horizontal step of 5.5 inches

Algorithm Analysis

Based on full sized manned vehicles:

- 19 vehicle performance algorithms identified
- 9 algorithms are based on driver behavior (e.g. ride comfort, reaction time)
- Most significant issue is scaling of obstacles (geometric and vegetation)

Levels of Autonomy

- 10 levels of autonomy defined by ALFUS working group[1]
- Most significant issue is characterizing ANS (Autonomous Navigation Systems) time delay
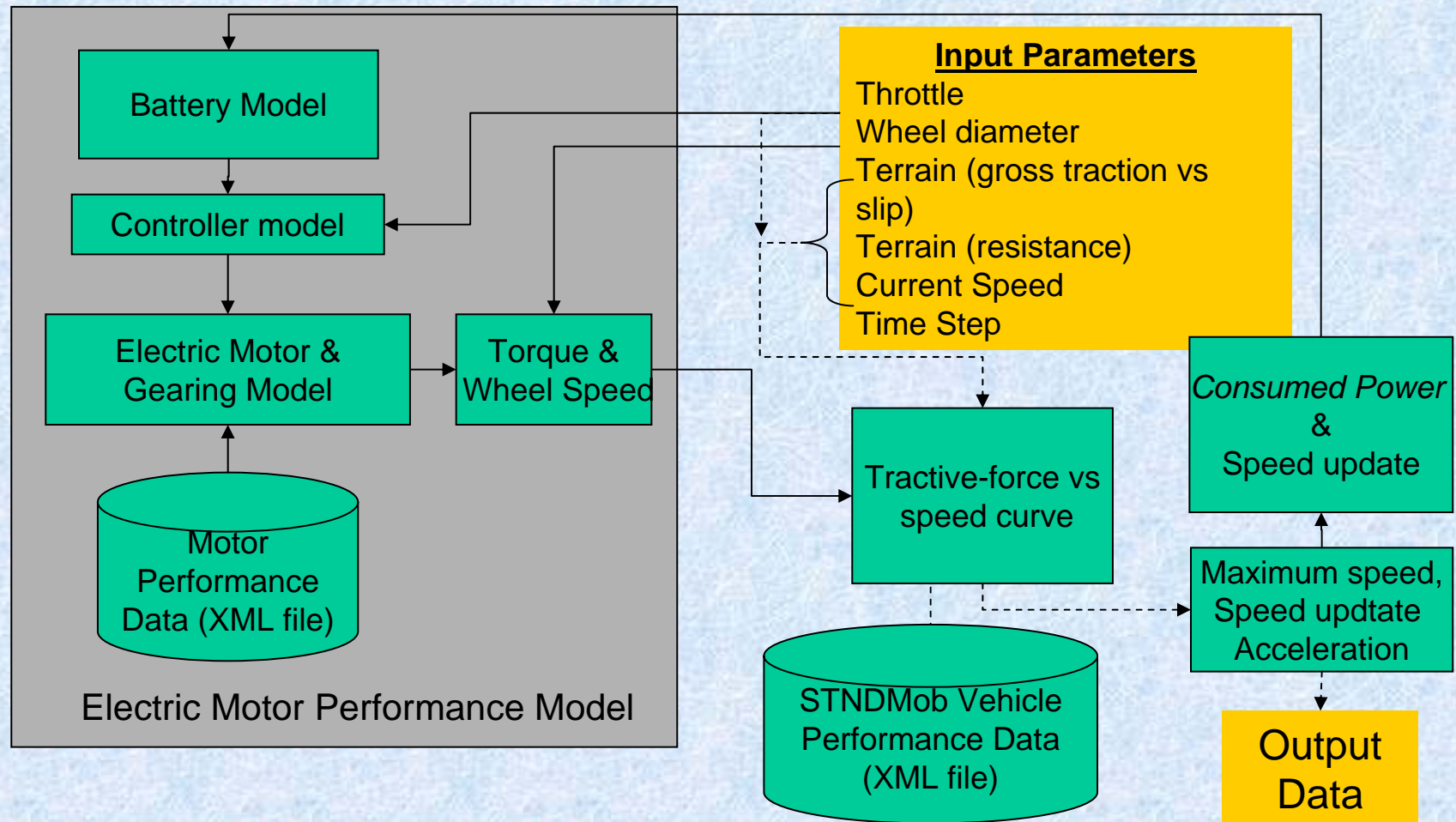
[1] http://www.isd.mel.nist.gov/projects/autonomy_levels/

Mobility Performance Algorithms:

- **Tractive-force vs speed equation hyperbolic curve fit**
- **Dry and wet road surface friction coefficients for driving and braking**
- **Soil and road surface resistance (self-propelled or towed), Snow resistance**
- **Obstacle forces**
- **Slope effects (gravity)**
- **Vehicle cornering resistance (Wheeled/Tracked)**
- **Acceleration and deceleration**
- **Speed limited by sliding or tipping on curves**
- **Vegetation limited speed**
- **Visibility limited speed**
- **Ride (roughness, shock) limited speed**
- **Tire limited speed**

Conceptual Electric Vehicle Trafficability Model

Input Parameters
Throttle
Wheel diameter
Terrain (gross traction vs slip)
Terrain (resistance)
Current Speed
Time Step

Battery Model

Controller model

Electric Motor & Gearing Model

Torque & Wheel Speed

Motor Performance Data (XML file)

Electric Motor Performance Model

Tractive-force vs speed curve

STNDMob Vehicle Performance Data (XML file)

Consumed Power & Speed update

Maximum speed, Speed updtate Acceleration

Output Data

(dashed lines show current STNDMob API for full sized vehicles)

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Terrain Environmental Data Model (EDM) Analysis

- STNDMOB based on OneSAF EDM (Terrain)
- SUGV also need to be able to move over building materials, as described by the OneSAF Ultra High Resolution Building EDM
- 4 building components identified:
  - Floor construction type
  - Stair construction type
  - Roof assembly type
  - Ventilation duct material type
- Modify STNDMob to recognize these materials, modify vehicle data file to contain performance data for these materials

Roofing Material Examples

Raised Expansion Joint

Built-up roof with three different surfaces
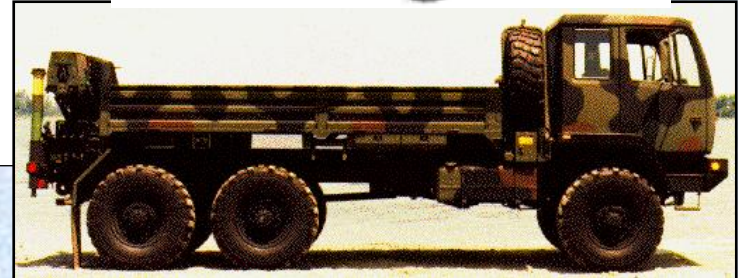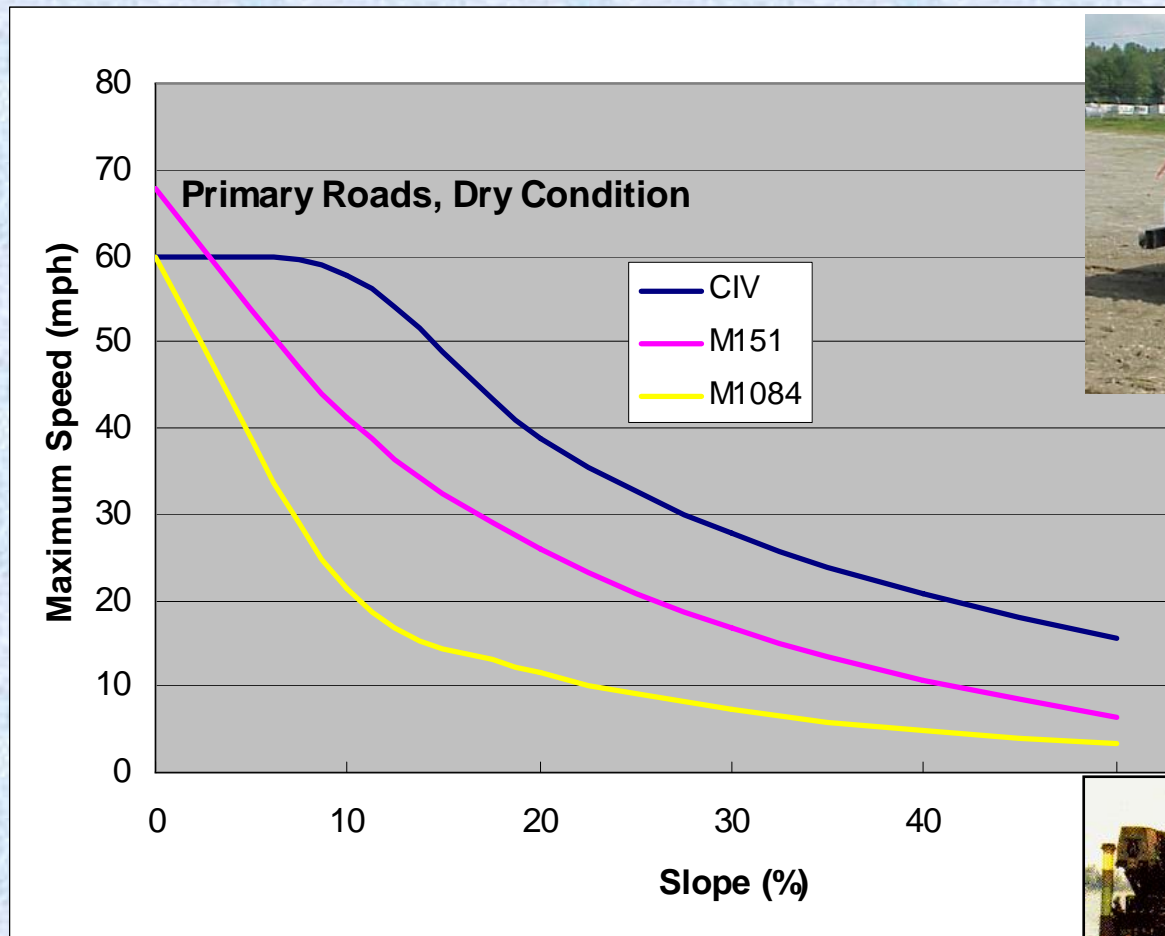
Tile roof with steep slope

Performance Comparisons

Objectives:

- Compare small vehicle test data to model performance
- Compare limited or qualitative data from literature to closest representative vehicle
- Determine if small vehicles can be categorized for force-on-force models
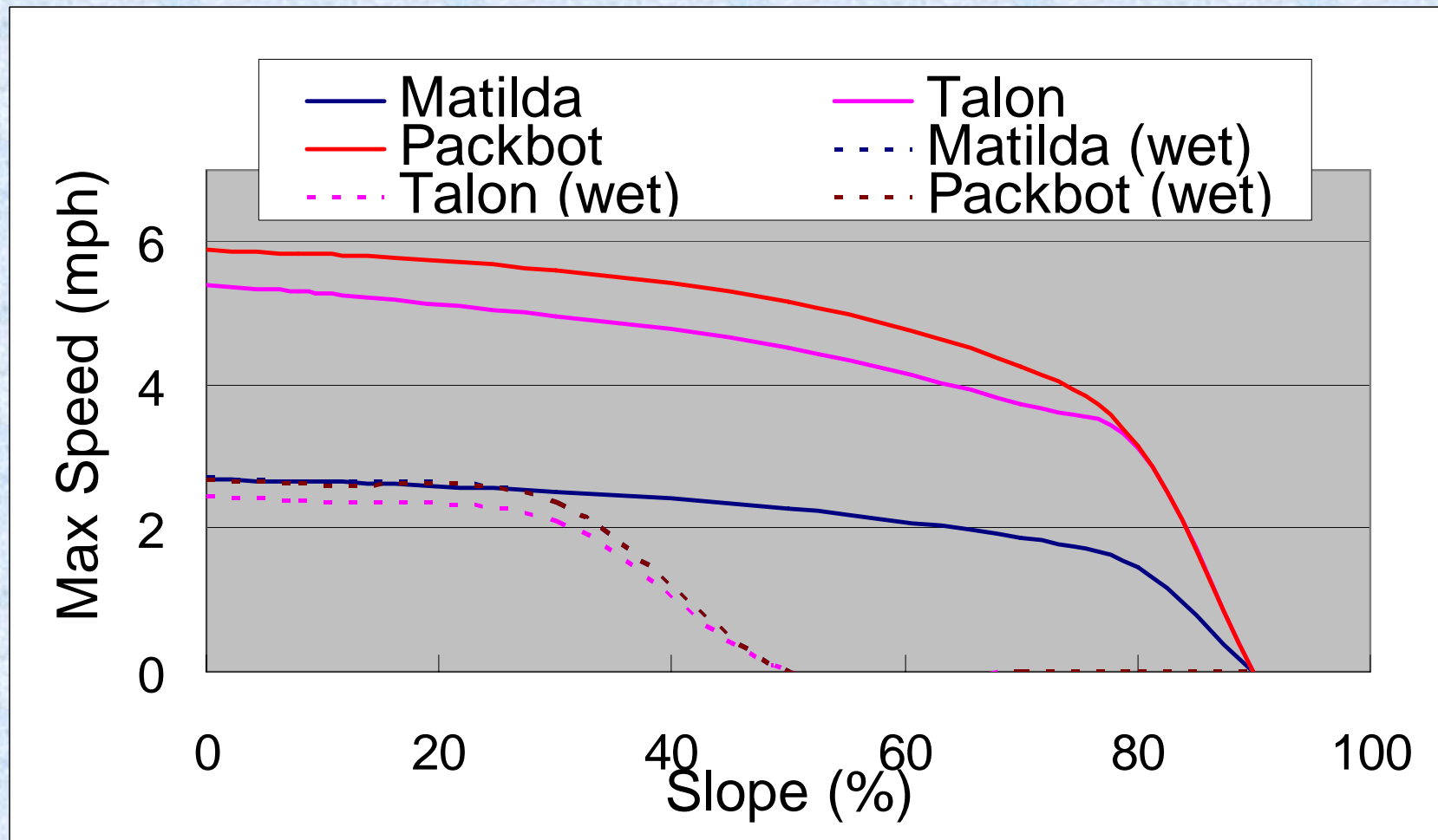
Performance Comparisons

Primary Roads, Dry Condition

Legend:
- CIV
- M151
- M1084

X-axis: Slope (%)
Y-axis: Maximum Speed (mph)

Performance Comparisons

Future

- Continue analysis, and finalize/publish formal report of this work.

- Talon and Packbot will be tested on building material surfaces later this summer.

Summary

- No systematic SUGV mobility testing has been reported
- Small standard vehicles may need there own mobility class for use in STNDMob
- Identified 19 performance algorithms, 9 are related to the driver
- Quantifying time delays due to ANS or robotic control is problematic
- Future work is oriented towards building material surfaces

Questions??