LOG OF MEETING
DIRECTORATE FOR ENGINEERING SCIENCES

SUBJECT: All-terrain vehicles (ATVs) – Meeting requested by the U.S. Consumer Product Safety Commission (CPSC) staff to demonstrate and discuss static and dynamic testing of ATVs.

DATE OF MEETING: September 13, 2016

PLACE OF MEETING: SEA Corporate Office, Columbus, OH

LOG ENTRY SOURCE: Caroleene Paul, ESME

COMMISSION ATTENDEES: See attached attendance list

NON-COMMISSION ATTENDEES: See attached attendance list

SUMMARY OF MEETING:

Representatives of the Specialty Vehicle Institute of America (SVIA) met with CPSC staff and SEA Limited (SEA) staff to discuss static and dynamic testing of all-terrain vehicles (ATVs).

CPSC staff opened the meeting by reviewing the scope and ground rules for the public meeting:

- The purpose of the meeting was to discuss and allow observation of the methodologies for testing conducted by SEA.
- Discussions would be limited to how the tests were performed and how the data was processed.
- The preliminary data would be presented for discussion purposes only. A full report on the test results will be made available to the public at a later date.

Dr. Gary Heydinger of SEA presented an overview of the tests that were conducted on 12 model year 2014-2015 ATVs to characterize the vehicles. Dr. Heydinger then presented an overview of tests that were conducted to study the effects of rider active behavior and 2-person riding on a single-person ATV.

SEA staff demonstrated VIMF, tilt table, and dynamic testing of ATVs at SEA's indoor and outdoor test facilities; and the meeting participants were given the opportunity to inspect instrumented vehicles and ask questions.

The meeting agenda and presentations are attached.

MEETING ATTENDANCE RECORD
SVIA/ CPSC Staff – September 13, 2016

COMMISSION ATTENDEES:

NAME	**ORGANIZATION**	**PHONE**	**E-MAIL**
Hope Nesteruk	CPSC	301-987-2579	hnesteruk@cpsc.gov
Caroleene Paul	CPSC	301-987-2225	cpaul@cpsc.gov
Anthony Teems	CPSC	301-987-2329	ateems@cpsc.gov

MEETING ATTENDANCE RECORD
SVIA/ CPSC Staff – September 13, 2016

NON-COMMISSION ATTENDEES:

Name		Organization	Phone	Email
Scott	Blanford	Honda	937-309-4889	sblandford@oh.hra.com
Louis	Brady	Polaris	651-408-7546	louis.brady@polaris.com
Lindsey	Burden	Textron	706-294-2854	lburden01@textron.com
Ken	Bush	Suzuki	714-996-7040	kbush@suz.com
Jon	Coyle	SEA	800-782-6851	jcoyle@sealimited.com
Annamarie	Daley	Jones Day	612-270-4598	adaley@jonesday.com
Drey	Dircks	Honda	937-309-4883	ddircks@oh.hra.com
Jeff	Eyres	Polaris	612-916-9943	jeff.eyes@polaris.com
Brad	Franklin	Yamaha	714-761-7842	brad_franklin@yamaha-motor.com
Tyler	Furman	Kawasaki	402-476-6600	tfurman@lcn.kmmfg.com
Brian	Gabel	Yamaha	714-761-7798	brian_gabel@yamaha-motor.com
Gary	Heydinger	SEA	800-782-6851	gheydinger@sealimited.com
Debbie	Jacklitch-Kuiken	Arctic Cat	218-681-9799	dkuiken@articcat.com
Hank	Jebode	SEA	800-782-6851	hjebode@sealimited.com
Daniel	Leclerc	BRP	450-532-5100	daniel.leclerc@brp.com
Michael	McKeen	Arctic Cat	612-350-1787	mmckeen@articcat.com
Jim	Nowjack	SEA	800-782-6851	jnowjack@sealimited.com
Stephen	Oesch		301-229-4692	stephen.oesch@gmail.com
Brandon	Ricketts	Honda	937-309-2243	bricketts@oh.hra.com
Donna	Rudge	Honda	937-309-8591	drudge@oh.hra.com
John	Rupp	Textron	401-457-3674	jrupp@textron.com
Anmol	Sidhu	SEA	800-782-6851	asidhu@sealimited.com
Marie-Claude	Simard	BRP	819-620-5155	marie-claude.simard@brp.com
Joe	Yapp	SEA	800-782-6851	jyapp@sealimited.com
Scott	Zagorski	SEA	800-782-6851	szagorski@sealimited.com

CPSC Public Meeting
Discussion and Demonstration of Static and Dynamic Testing of ATVs
September 13, 2016
SEA, Ltd. – Columbus, Ohio

Agenda

9:00 AM	Welcome and Introductions	Tony Teems CPSC
9:10 AM	CPSC Comments on ATV Evaluations	Tony Teems CPSC
9:20 AM	Presentation on 2015 Vehicle Characterization Study	Gary Heydinger SEA
10:00 AM	Presentation on 2016 Rider-Active and 2-Rider Studies	Gary Heydinger SEA
10:40 AM	Demonstration of VIMF and Tilt Table Testing	Scott Zagorski & SEA Staff
11:45 AM	Lunch	
12:15 PM	Demonstrations of Dynamic Testing	Anmol Sidhu & SEA Staff
1:30 PM	Q&A Session	
2:30 PM	Optional Tour of SEA Facility	

CPSC Public Meeting
Discussion and Demonstration of Static and Dynamic Testing of ATVs
September 13, 2016
SEA, Ltd. – Columbus, Ohio

List of Planned Dynamic Test Demonstrations

Demonstrations of 2015 Vehicle Characterization Study (Human Driver) Tests

- 20 mph Dropped Throttle J-Turn Tests
  Tests Use ATV ASC
  Right Turns in One Heading Direction (NW)
  Tests to the Point of 2-Wheel Lift (2WL)

- Constant Steer (Yaw Rate Ratio) Tests – Based on 50 ft Starting Radius
  Tests Use ATV ASC
  CW Direction Tests
  Tests to Point of 0.4 g. Lateral Acceleration

- Constant 50 ft Radius (Circle) Tests
  Tests Use Human Driver Steering Inputs
  CW Direction Tests
  Tests to Point of 0.4 g. Lateral Acceleration

Demonstrations of 2016 Rider-Active and 2-Rider Study (Autonomous) Tests

- Constant 50 ft Radius (Circle) Tests
  CCW Direction Tests
  Tests to Point of 0.4 g. Lateral Acceleration

- Constant Steer (Yaw Rate Ratio) Tests – Based on 50 ft Starting Radius
  Tests Use ATV ASC
  CCW Direction Tests
  Tests to Point of 0.4 g. Lateral Acceleration

- 20 mph Dropped Throttle J-Turn Tests
  Left Turns in Two Heading Directions (NW and SE)
  Tests to the Point of 2WL

Vehicle Characteristics Measurements Of All-Terrain Vehicles

Tests on Twelve 2014-2015 Model Year Vehicles

Overview of Testing Conducted by SEA for the Consumer Product Safety Commission (CPSC) under U.S. Department of Health and Human Services Contract HHSP233201400030I

Laboratory and Dynamic Testing Completed in 2015

UNITED STATES OF AMERICA
CONSUMER PRODUCT
SAFETY COMMISSION

S-E-A

Disclaimers

These comments are those of SEA, Ltd. staff, and they have not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.

All data contained in this presentation are preliminary and have not been cleared by CPSC.

Test Vehicles

- Vehicles Selected by CSPC
- Curb Weights Ranged from 395.5 lb to 832.0 lb
- Measured Maximum Speeds Ranged from 45.7 mph to 74.0 mph in a Driver-Only Loading Condition
- In Driver Plus Instrumentation (DPI) Loading Condition, Threshold Ay Values Ranged from 0.38 g. to 0.56 g.
- 9 of the Vehicles have Automatic Transmissions
- 3 of the Vehicles (the 3 Lightest) have Manual Transmissions

Test Vehicles

Table 1: Test Vehicle Information and Tire Specifications		
Vehicle A **Curb Weight: 523.9 lb** **Maximum Speed: 47.0 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Maxxis MU13	Maxxis MU13
Tire Size	AT25X8-12 4 Ply	AT25X10-12 4 Ply
Tire Pressure (psi)	3.6	3.6
Vehicle B **Curb Weight: 432.8 lb** **Maximum Speed: 70.0 mph** **Test Conditions: DPI**	**Manual Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Maxxis M976Y	Maxxis M976Y
Tire Size	AT21X7-10	AT20X10-9
Tire Pressure (psi)	4	4
Vehicle C **Curb Weight: 650.8 lb** **Maximum Speed: 66.0 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Independent Rear Suspension** **2WD, 4WD, or 4WD Lock**	
	Front Tires	Rear Tires
Tire Make	Maxxis MU19A	Maxxis MU19A
Tire Size	AT25X8-12 4 Ply	AT25X10-12 4 Ply
Tire Pressure (psi)	5	4.4
Vehicle D **Curb Weight: 714.0 lb** **Maximum Speed: 45.8 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Independent Rear Suspension** **2WD, 4WD, or 4WD Lock**	
	Front Tires	Rear Tires
Tire Make	Kaden Duro 45J	Kaden Duro 52J
Tire Size	AT25X8-12 6 Ply	AT25X10-12 6 Ply
Tire Pressure (psi)	5	5
Vehicle E **Curb Weight: 734.1 lb** **Maximum Speed: 45.7 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Independent Rear Suspension** **2WD, 4WD, or 4WD Lock**	
	Front Tires	Rear Tires
Tire Make	Kaden Duro 45J	Kaden Duro 52J
Tire Size	AT25X8-12 6 Ply	AT25X10-12 6 Ply
Tire Pressure (psi)	5	5
Vehicle F **Curb Weight: 526.2 lb** **Maximum Speed: 53.5 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Kenda Pathfinder	Kenda Pathfinder
Tire Size	AT22X7-10 4 Ply	AT22X10-10 4 Ply
Tire Pressure (psi)	4	3.5

Table 1 (Continued): Test Vehicle Information and Tire Specifications		
Vehicle G **Curb Weight: 694.0 lb** **Maximum Speed: 69.0 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Independent Rear Suspension** **2WD or 4WD**	
	Front Tires	Rear Tires
Tire Make	Duro DI-K911	Duro DI-K911
Tire Size	AT25X8-12 4 Ply	AT25X10-12 4 Ply
Tire Pressure (psi)	5	5
Vehicle H **Curb Weight: 395.5 lb** **Maximum Speed: 71.5 mph** **Test Conditions: DPI**	**Manual Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Dunlop KT391	Dunlop KT396
Tire Size	AT21X7R10 ☆☆	AT20X10R9 ☆☆
Tire Pressure (psi)	4.4	3.9
Vehicle I **Curb Weight: 408.4 lb** **Maximum Speed: 63.0 mph** **Test Conditions: DPI**	**Manual Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Ohtsu Radial HTRAK M/R101	Ohtsu Radial HTRAK M/R101
Tire Size	AT22X7-10 4 Ply	AT22X10-9 4 Ply
Tire Pressure (psi)	4	4
Vehicle J **Curb Weight: 649.8 lb** **Maximum Speed: 60.5 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Independent Rear Suspension** **2WD or AWD**	
	Front Tires	Rear Tires
Tire Make	Dunlop KT511	Dunlop KT515
Tire Size	AT25X8 R12	AT25X10 R12
Tire Pressure (psi)	4.4	3.6
Vehicle K **Curb Weight: 832.0 lb** **Maximum Speed: 74.0 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Independent Rear Suspension** **2x4, 4x4, or 4x4 Lock**	
	Front Tires	Rear Tires
Tire Make	Carlisle AT489 II	Carlisle AT489 II
Tire Size	AT 26X8-14 6 Ply	AT 26X10-14 6 Ply
Tire Pressure (psi)	7	7
Vehicle L **Curb Weight: 716.4 lb** **Maximum Speed: 52.7 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Independent Rear Suspension** **2x4 or AWD**	
	Front Tires	Rear Tires
Tire Make	Polaris by Wanda NS388	Polaris by Wanda NS388
Tire Size	AT24X8-12 6 Ply	AT24X10-12 6 Ply
Tire Pressure (psi)	5	5

Vehicle Loading Conditions

- Driver
  - Used Only for Laboratory Tests
  - Hybrid II Test Dummy Ballasted to 213 lb

- Driver Plus Instrumentation (DPI)
  - Used for Laboratory and Dynamic Tests
  - Hybrid II or Human Test Driver – Nominally 172 lb
  - Measurement Transducers
  - SEA's ATV Automated Steering Controller (ATV ASC)
  - Safety Outriggers
  - 24V Battery
  - Nominally 235 lb over Curb Weight

- Gross Vehicle Weight (GWV)
  - Used for Laboratory and Dynamic Tests
  - DPI Loading Plus Front and Rear Rack Ballast
  - Nominally Loaded to Manufacturers' GVW
  - No GVW Testing on 3 Lightest Vehicles

DPI Loading Condition

Table 2: Driver Plus Instrumentation (DPI) Loading	
Component	**Weight (lb)**
ATV ASC: Base Plate, Motor, National Instruments (NI) cRIO, Electronics and Enclosures	29.0
RT3002 GPS/IMU and Steering Column Encoder	6.7
Auxiliary 24V Battery	2.7
ATV Outriggers	24.5
Test Driver, Helmet and Safety Gear	172.1
Total Nominal DPI Weight	**235.0**

GVW Loading Conditions

Table 3: Gross Vehicle Weight (GVW) Loading									
Vehicle	Manufacturer Specifications				Total Rack Weight Needed To Reach GVW (lb)	Amount Rack Weight Exceeded (lb)	Front Ballast Used (lb)	Rear Ballast Used (lb)	Total Ballast Used (lb)
	Total Added Weight for GVW (lb)	Front Rack Weight (lb)	Rear Rack Weight (lb)	Total Rack Weight (lb)					
A	463	88	176	264	228	0	75	155	230
B	220	NA	NA	NA	NA	NA	NA	NA	NA
C	485	99	187	286	250	0	85	165	250
D	515	100	200	300	280	0	95	185	280
E	515	100	200	300	280	0	95	185	280
F	400	50	100	150	165	15	55	110	165
G	474	88	176	264	239	0	80	160	240
H	250	NA	NA	NA	NA	NA	NA	NA	NA
I	243	NA	NA	NA	NA	NA	NA	NA	NA
J	485	66	133	199	250	51	85	165	250
K	575	120	240	360	340	0	115	225	340
L	485	90	180	270	250	0	85	165	250

Laboratory Tests

- Vehicle Inertia Measurement Facility (VIMF) Tests
  - Weight
  - Track Width and Wheelbase
  - Longitudinal, Lateral and Vertical (Height) CG Location
  - Roll, Pitch and Yaw Inertia
  - Static Stability Factor (SSF)
  - Lateral Stability Coefficient (KST)

- Tilt Table Tests
  - Tilt Table Angle (TTA) and Tilt Table Ratio (TTR)
  - TTA and TTR Determined at Point of High-Side, Two-Wheel Lift
    - Lateral, Right Side Leading Tilts – No Trip Rail
    - Lateral, Left Side Leading Tilts – No Trip Rail
    - Longitudinal, Forward Leading Tilts – 2″ High Trip Rail
    - Longitudinal, Rearward Leading Tilts – 2″ High Trip Rail

- Steering Ratio Tests
  - Measured Kinematic Ratio of Steering Column to Roadwheel Angles
  - Measured in Driver Plus Instrumentation (DPI) Loading Condition

VIMF Tests

Live VIMF Demonstration Later Today

Sample VIMF Test Results

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
VIMF Test Number		5765	5766	5842
Total Vehicle Weight (lb)	523.9	737.1	759.6	989.7
Left Front Weight (lb)	151.5	177.3	198.3	232.2
Right Front Weight (lb)	118.4	161.0	176.8	212.1
Left Rear Weight (lb)	132.0	206.1	204.4	293.5
Right Rear Weight (lb)	122.0	192.7	180.1	251.9
Front Track Width (in)	33.20	33.50	33.66	33.93
Rear Track Width (in)	32.25	32.30	32.28	32.35
Average Track Width (in)	32.73	32.90	32.97	33.14
Wheelbase (in)	48.40	48.35	48.30	48.25
CG Longitudinal (in)	23.47	26.16	24.45	26.59
CG Lateral (in)	-1.36	-0.66	-0.99	-1.02
CG Height (in)		23.61	22.65	25.00
Roll Inertia - I_{XX} (ft-lb-s^2)		55	66	86
Pitch Inertia - I_{YY} (ft-lb-s^2)		73	80	141
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		54	63	115
Roll/Yaw - I_{XZ} (ft-lb-s^2)		4	3	8
SSF		0.697	0.728	0.663
KST		0.698	0.728	0.664
Steering Ratio (deg/deg)			1.42	

SEA's Tilt Table – ATV Lateral Tilt Test

Live Tilt Table Demonstration Later Today

SEA's Tilt Table – Lateral Tilt – Close-up of Wheel Lift

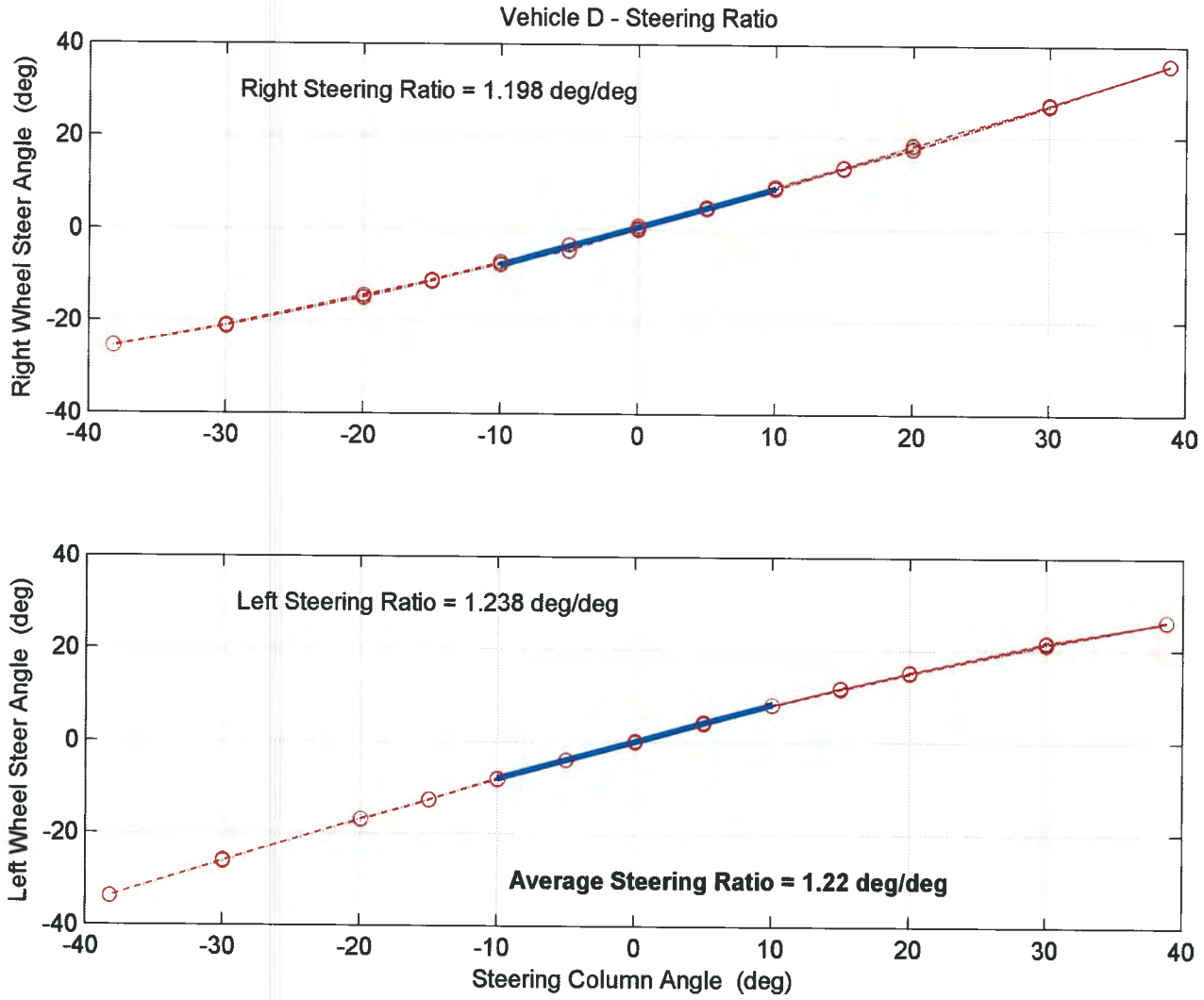
Live Tilt Table Demonstration Later Today

SEA's Tilt Table – Longitudinal Rearward Tilt

Sample Tilt Table Test Results

		Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
Lateral Direction: Right Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	Rear
	Tilt Table Angle (TTA) (deg)	27.4	25.9	21.3
	Tilt Table Ratio (TTR)	0.519	0.486	0.391
Lateral Direction: Left Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	Rear
	Tilt Table Angle (TTA) (deg)	25.8	25.4	20.1
	Tilt Table Ratio (TTR)	0.482	0.474	0.365
	Average Lateral TTA (deg)	**26.6**	**25.6**	**20.7**
	Average Laleral TTR	**0.501**	**0.480**	**0.378**
Longitudinal Direction: Front Tilt	**Tilt Table: First Wheel Lift**	Left	Left	Right
	Forward Tilt Table Angle (FTTA) (deg)	47.5	46.5	44.3
	Forward Tilt Table Ratio (FTTR)	1.091	1.052	0.975
Longitudinal Direction: Rear Tilt	**Tilt Table: First Wheel Lift**	Right	Right	Right
	Rearward Tilt Table Angle (RTTA) (deg)	41.3	45.7	41.4
	Rearward Tilt Table Ratio (RTTR)	0.880	1.024	0.882

Sample Steering Ratio Test Results



Dynamic Tests

- Testing Conducted at NCCAR and TRC
- Dry, Flat Asphalt Test Surfaces
- Suite of Tests, Similar to Tests Conducted on ROVs, to Evaluate Vehicle Handling and Stability
- Test Drivers Attempted to Maintain Upright Posture

List of Dynamic Tests Conducted

- Dynamic Tests in DPI Loading Condition
  - Constant Radius (50 ft) Tests
  - Constant Speed (20 mph) (Slowly Increasing Steer) Tests
  - Constant Steer Tests (Yaw Rate Ratio Tests)
  - 20 mph Dropped Throttle J-Turn (Step Steer) Tests
  - Steering Flick Tests (20 mph)
  - Sinusoidal Sweep Steering (Frequency Response) Tests (15 mph)

- Dynamic Tests in GVW Loading Condition
  - Constant Radius (50 ft) Tests
  - 20 mph Dropped Throttle J-Turn (Step Steer) Tests
  - Steering Flick Tests (20 mph)
  - Sinusoidal Sweep Steering (Frequency Response) Tests (15 mph)

Notes on Dynamic Tests

- For SAE J266 Handling Tests (Circle Tests, Constant Speed Tests, and Constant Steer Tests): Tests and Data Analyses up to 0.4 g. or Point of Near Two-Wheel Lift (Not 0.5 g. that was used for ROV Tests and Analyses)
- Driver "Ay-Warning" Alert Used for Handling Tests
- Circle Tests Conducted on 50 ft Radius Circle (Not 100 ft Radius that was used for ROV Tests)
- Constant Speed Tests Conducted at 20 mph (Not 30 mph that was used for ROV Tests)
- Constant Steer Tests (Yaw Rate Ratio Tests) Followed ROHVA/OPEI Protocols (Except Estimated Ay up to 0.4 g. or Point of Near Two-Wheel Lift)
- Dropped Throttle J-Turn Tests used to Determine Threshold Lateral Acceleration (Threshold Ay) Conducted at 20 mph (Not 30 mph that was used for ROV Tests)
- Steering Flick Tests Conducted at 20 mph (Not 30 mph that was used for ROV Tests)
- Frequency Response Tests Conducted at 15 mph (Not 20 mph that was used for ROV Tests)

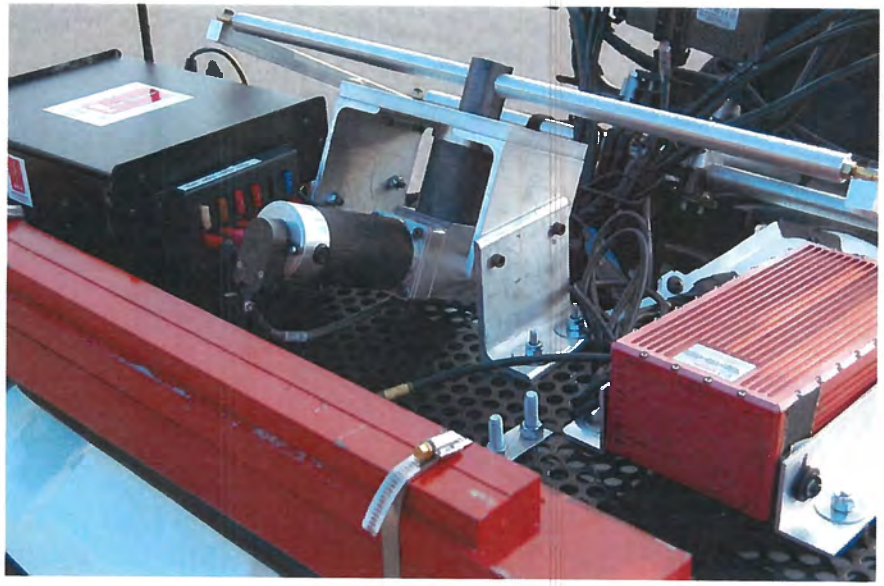
Instrumentation Used During Dynamic Tests

Table 4: Instrumentation Used During Dynamic Testing			
Transducer	**Measurement**	**Range**	**Accuracy**
Oxford Technical Solutions RT3002 Inertial and GPS Navigation System	Longitudinal, Lateral, and Vertical Accelerations	± 100 m/s^2 (± 10 g)	0.01 m/s^2 (0.001 g)
	Roll, Pitch, and Yaw Rates	± 100 deg/s	0.01 deg/s
	Speed	No Limit Specified	0.05 km/h (0.03 mph)
	Roll and Pitch Angles	-180 to +180 deg	0.03 deg
	Vehicle Heading	0 to 360 deg	0.1 deg
Steering Column Encoder	Steering Column Angle (Handlebar Angle)	No Limit Specified	± 0.25 deg

Equipment Used During Dynamic Tests

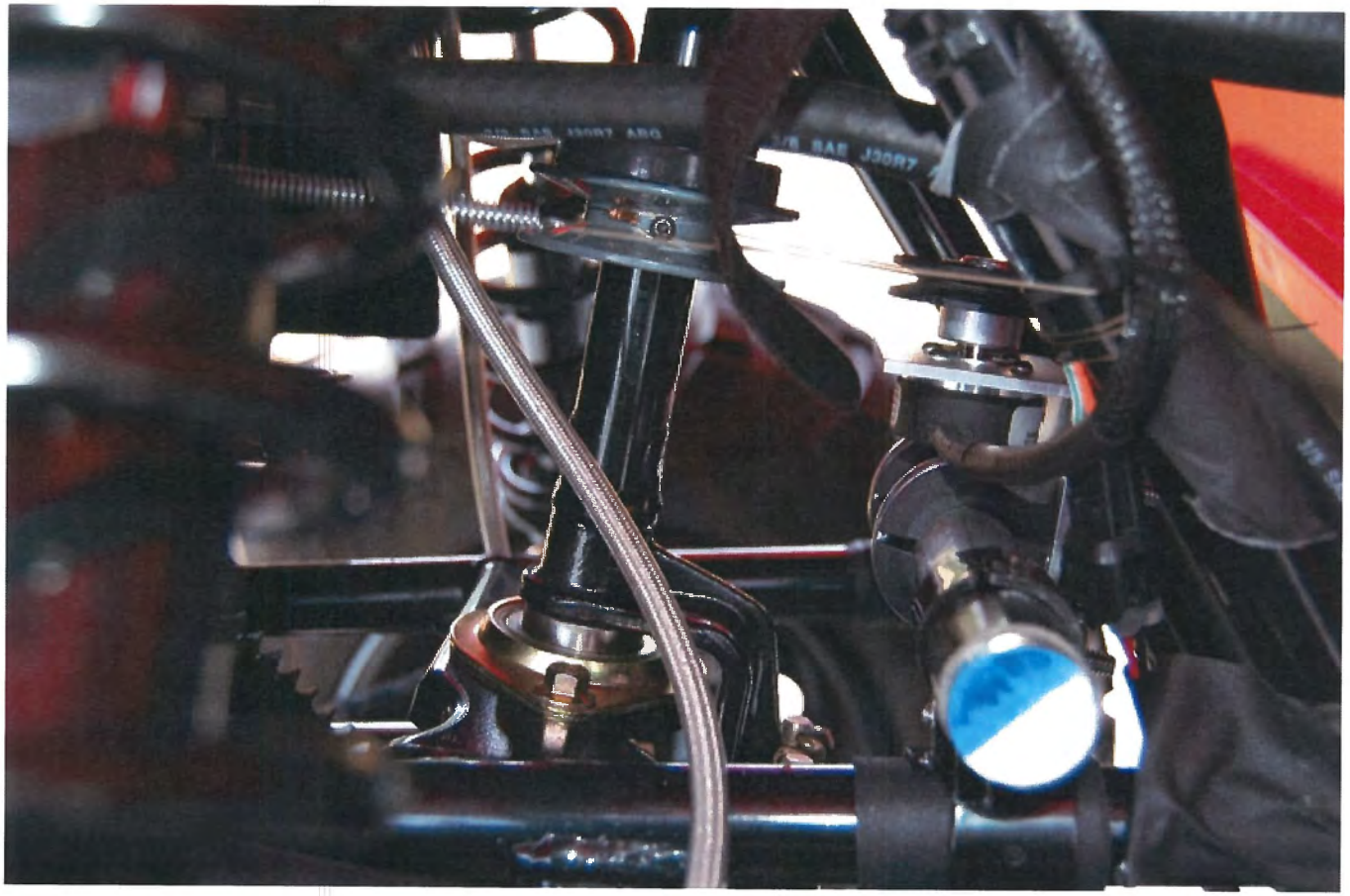
SEA's ATV Instrumentation,
Steering Controller, Ballast, and Safety Outriggers

Equipment Used During Dynamic Tests



SEA's ATV Automated Steering Controller (ATV ASC)

Equipment Used During Dynamic Tests

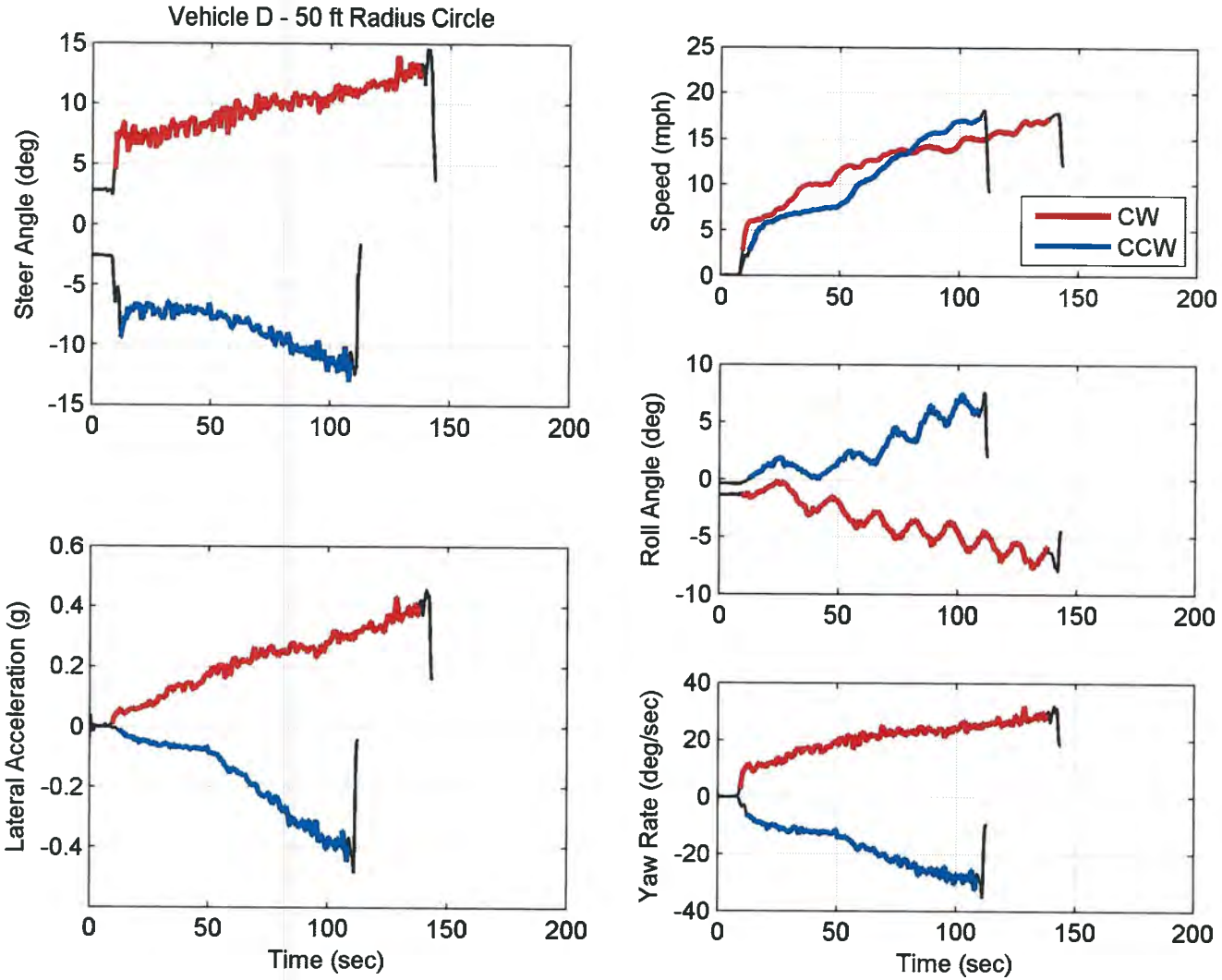


SEA's Vehicle-Specific Steering Column Angle Measurement Transducer

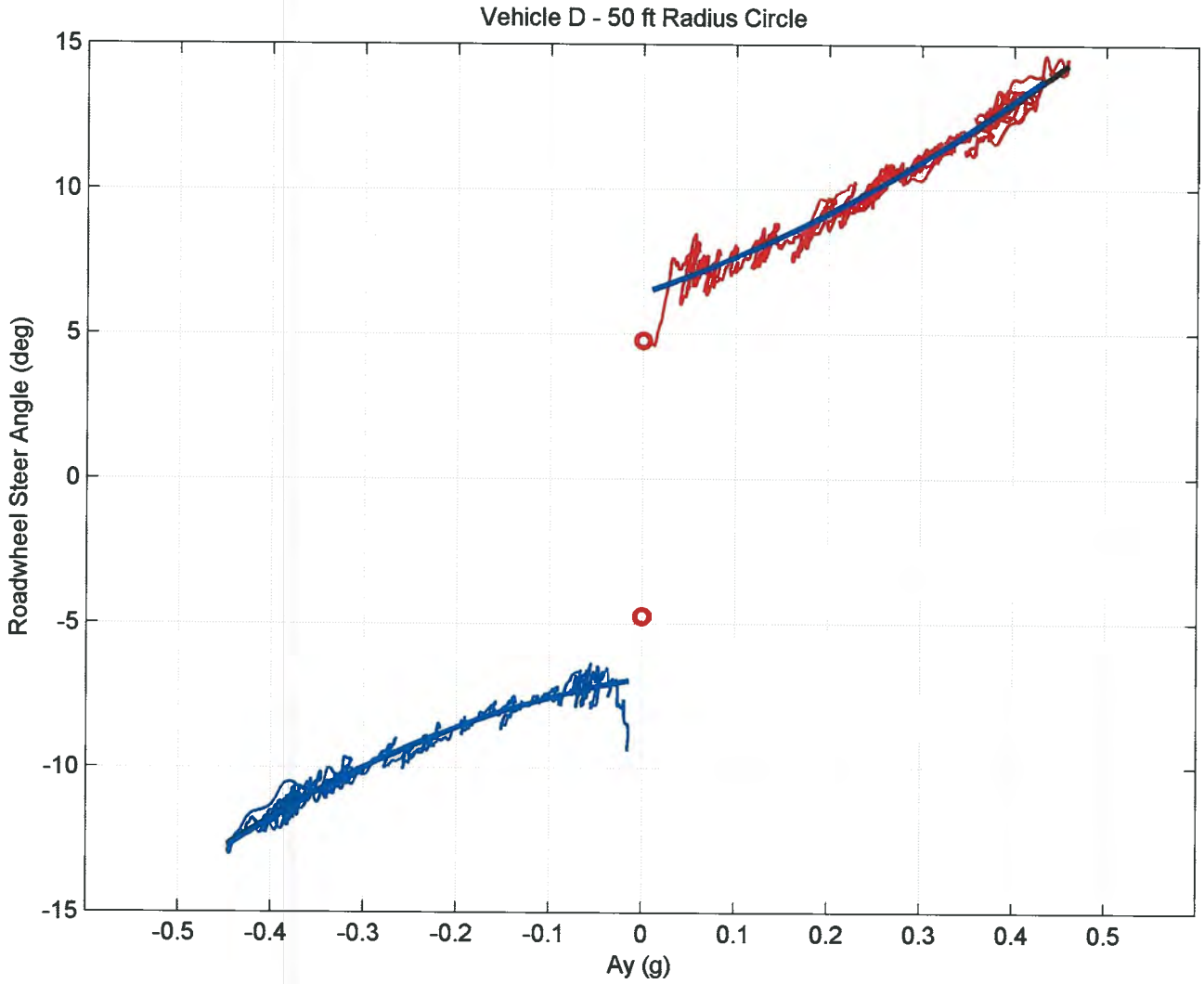
Constant Radius (50 ft) (Circle)Tests

Human Driver Steering Input

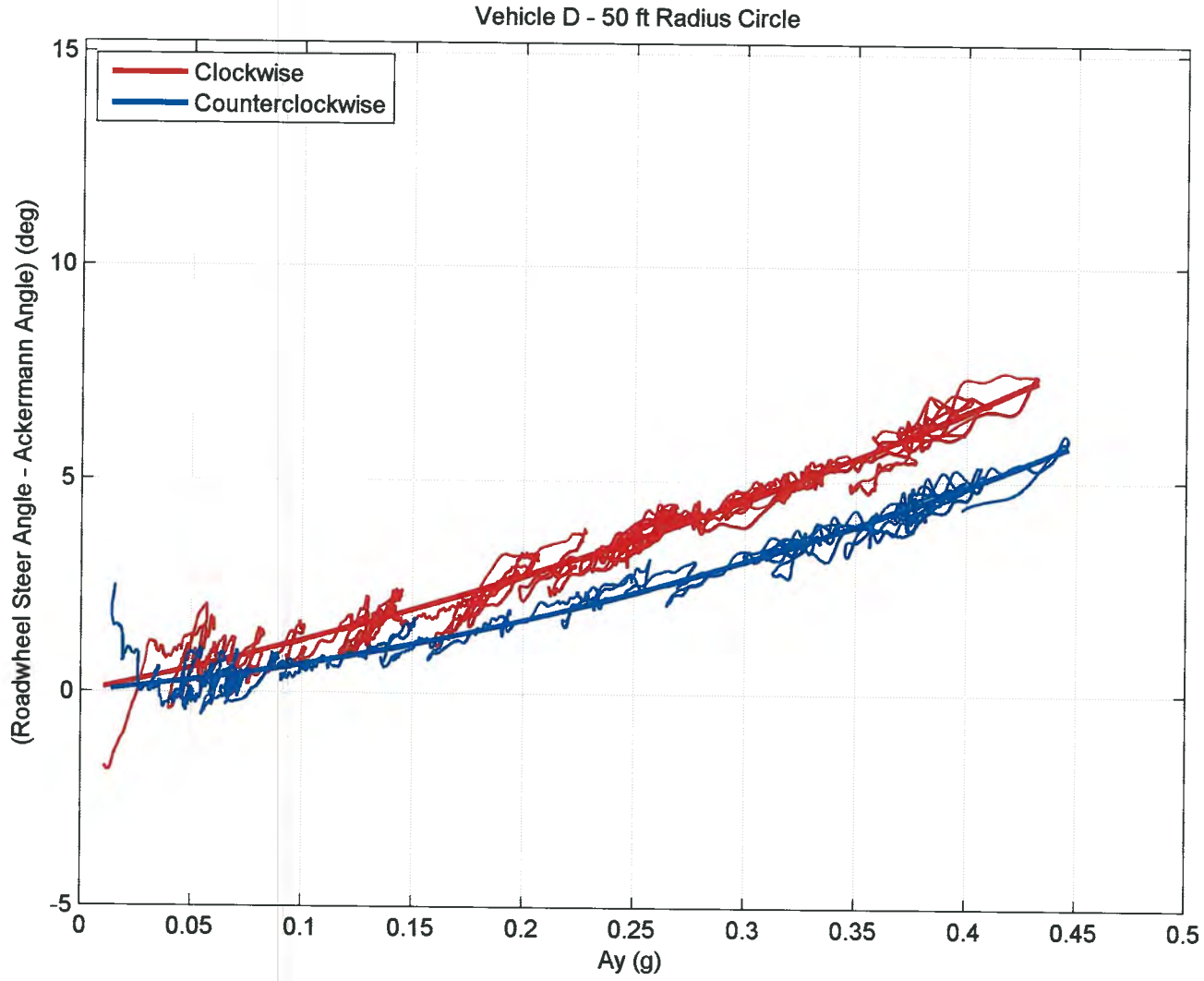
Sample Circle Test Results



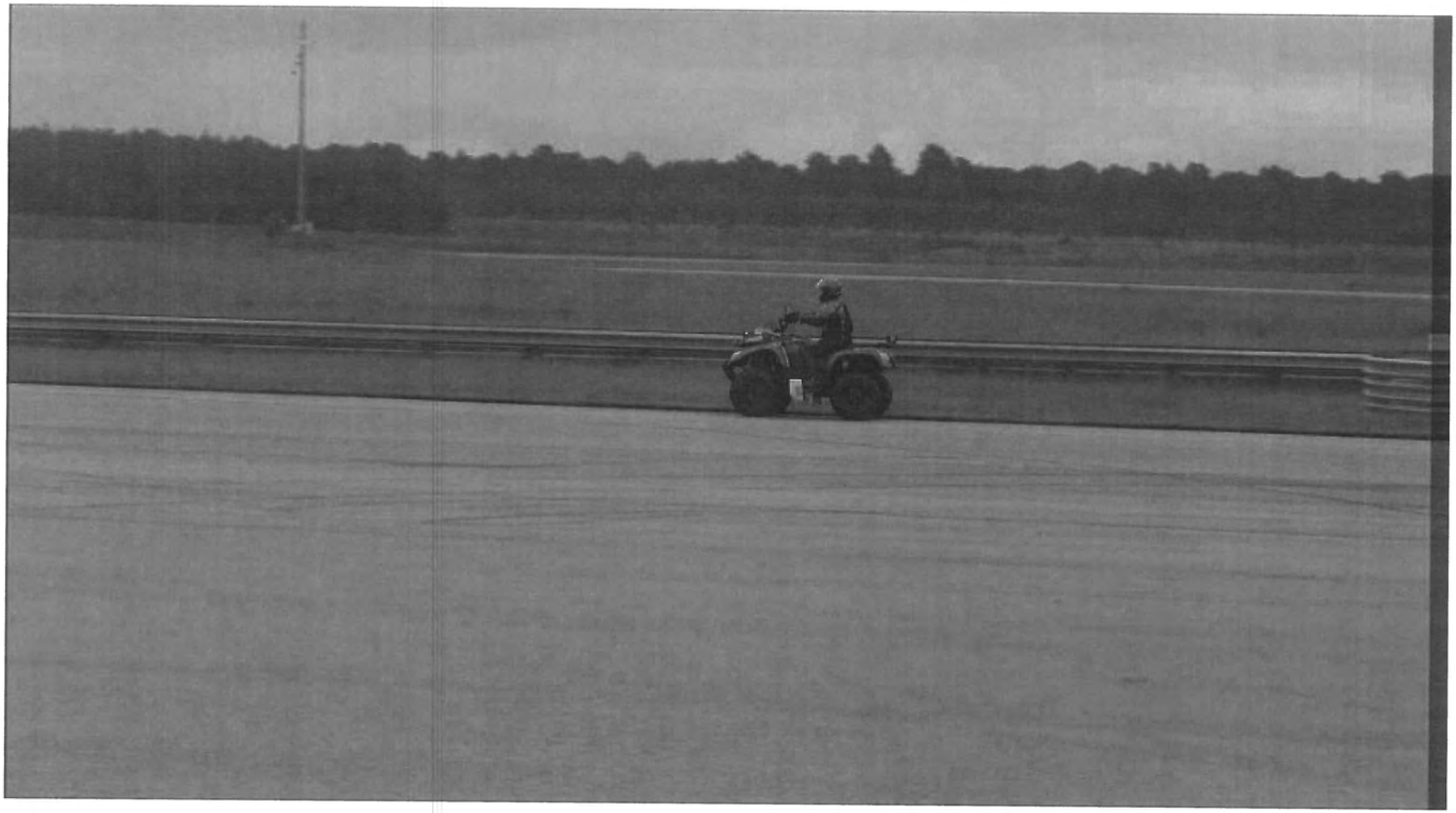
Sample Circle Test Results



Sample Circle Test Results

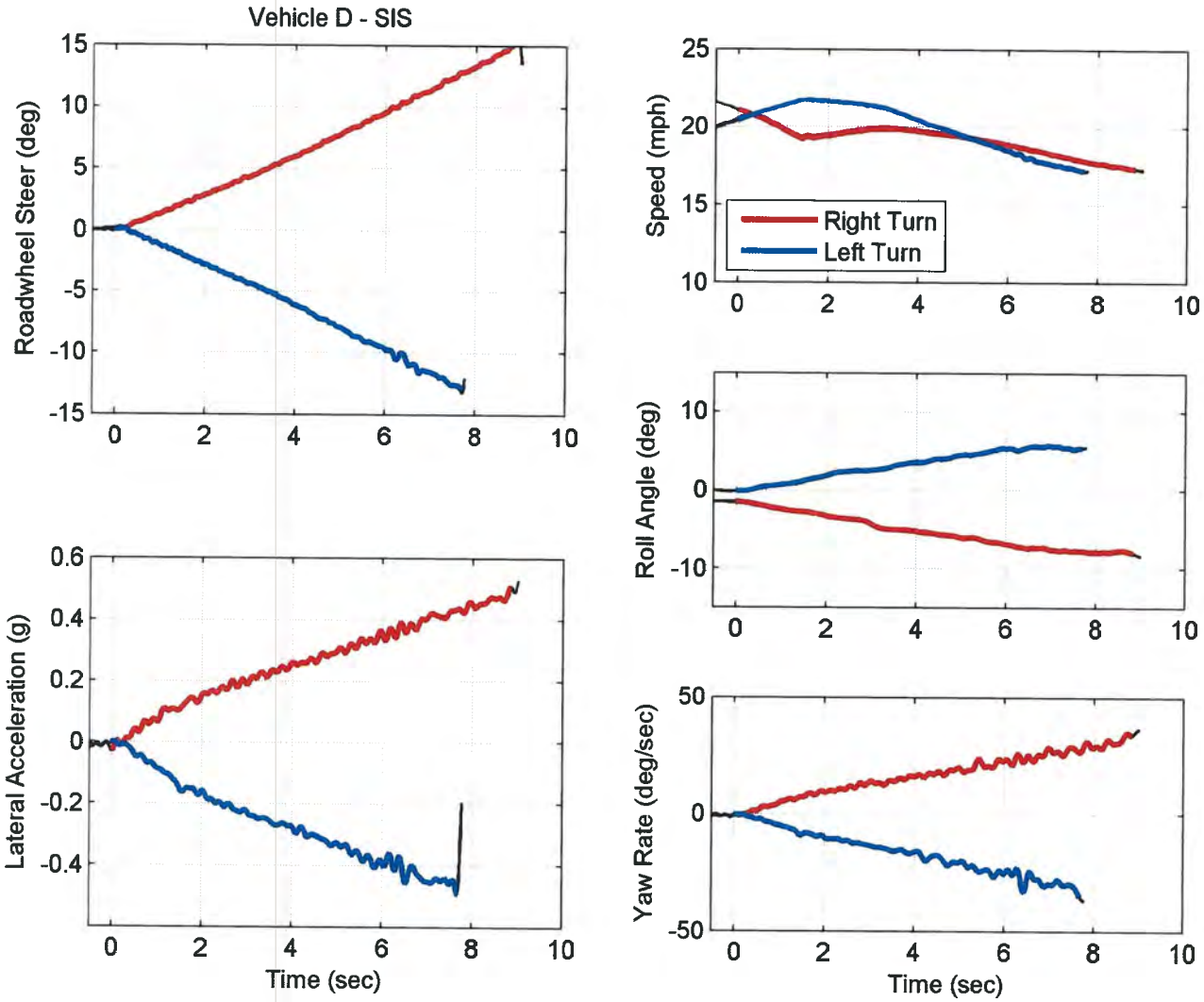


Constant Speed (20 mph) (Slowly Increasing Steer) Test

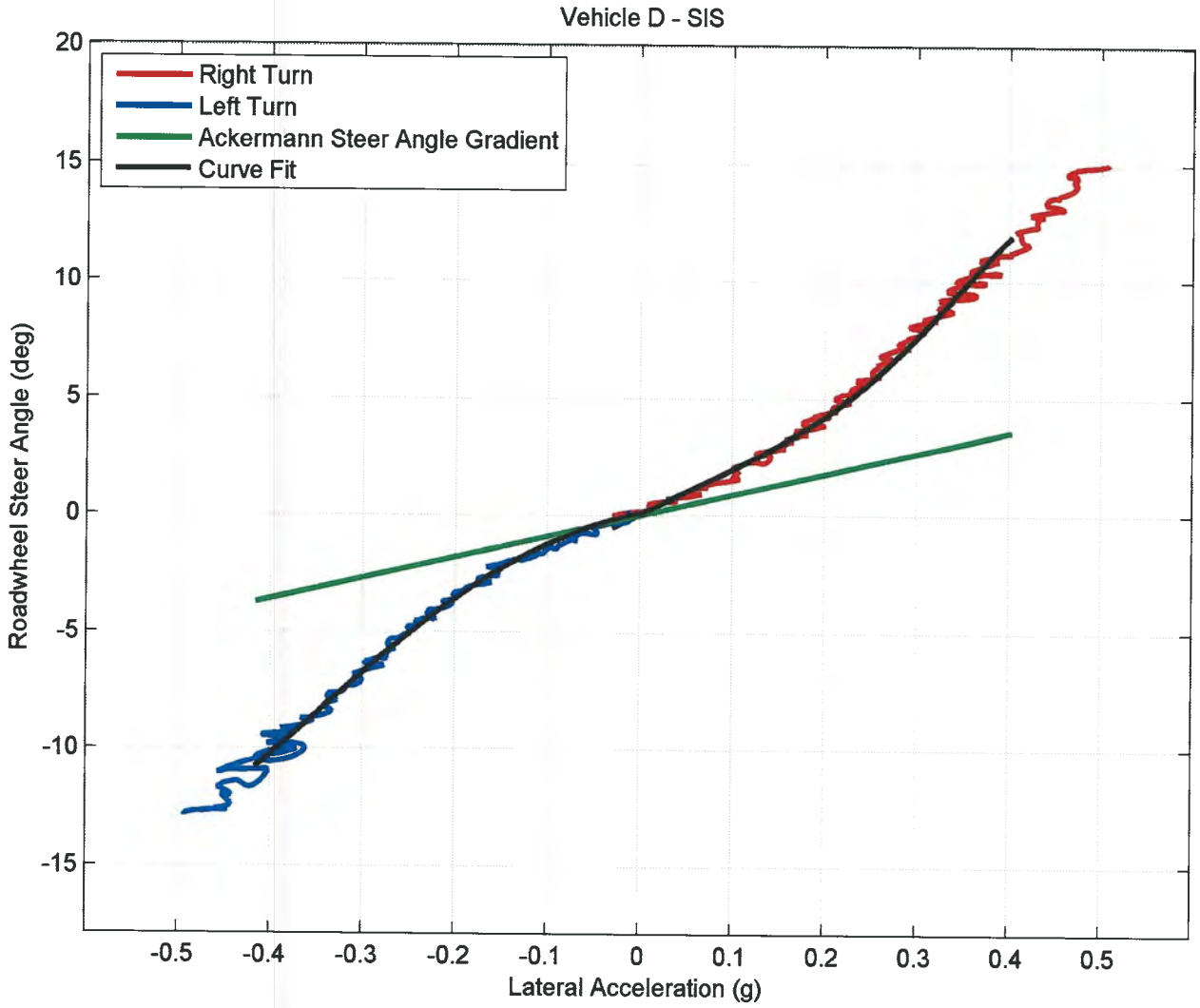


ATV ASC Used for Steering Input

Sample Slowly Increasing Steer Test Results



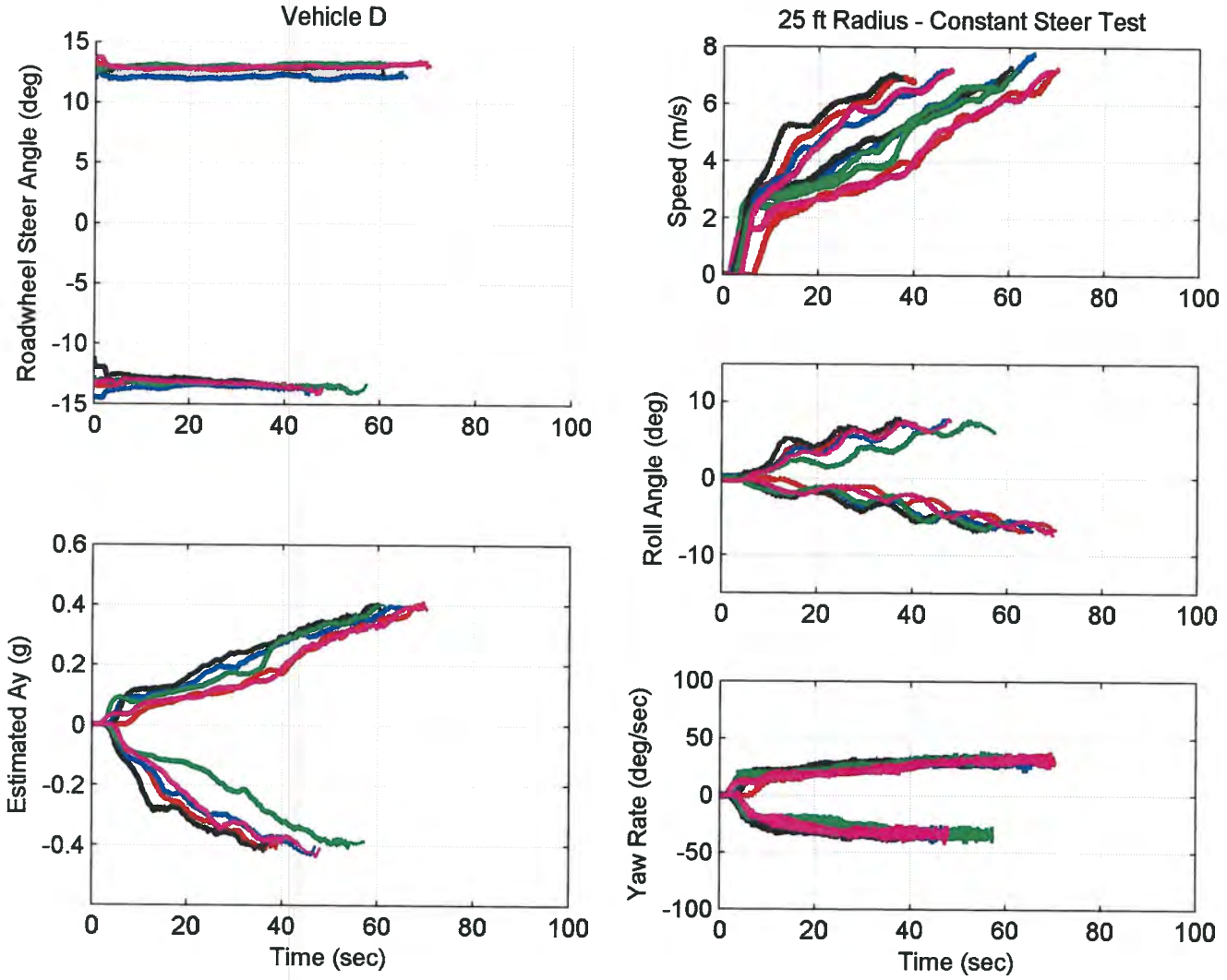
Sample Slowly Increasing Steer Test Results



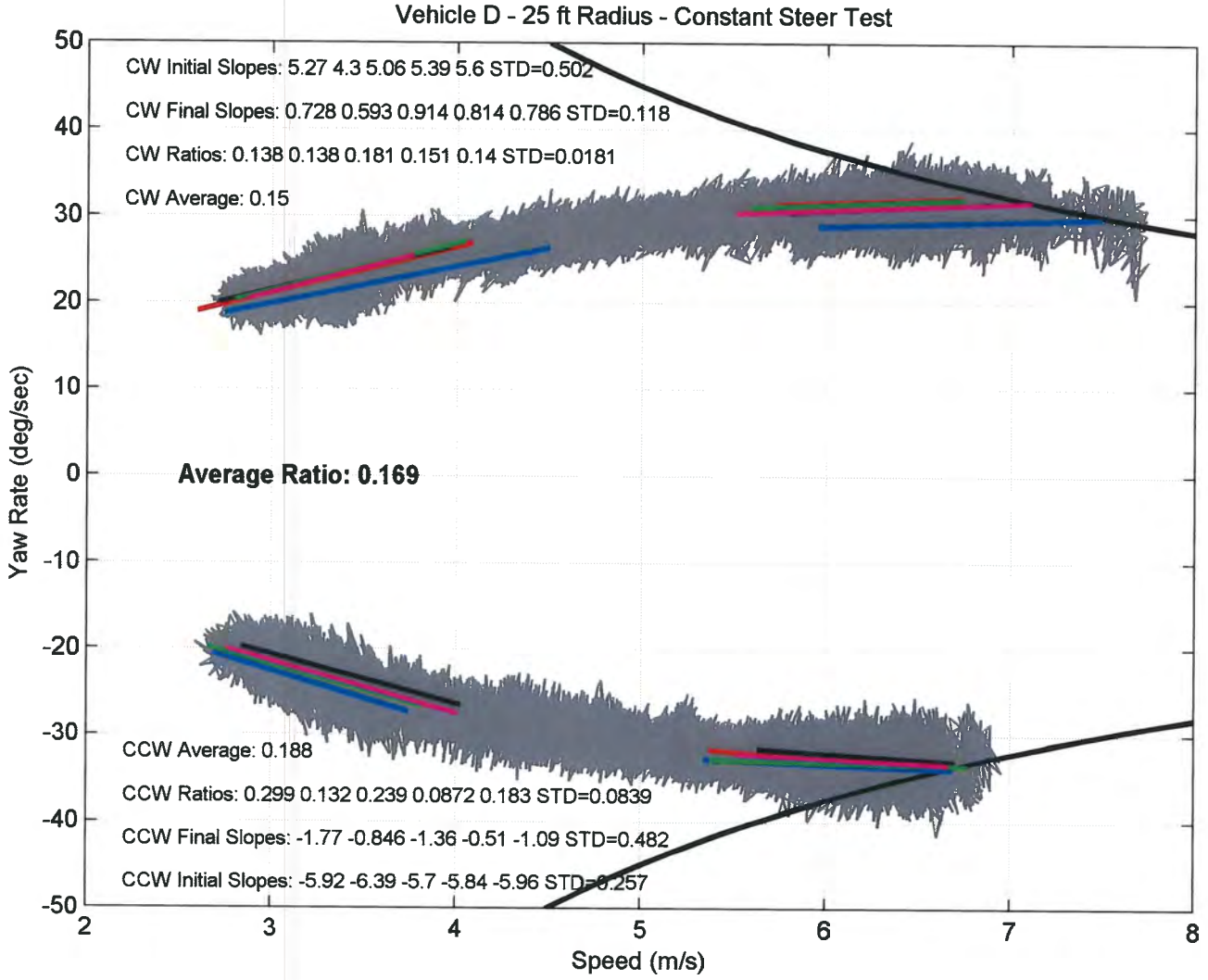
Constant Steer Test (Yaw Rate Ratio Test)

ATV ASC Used for Steering Input

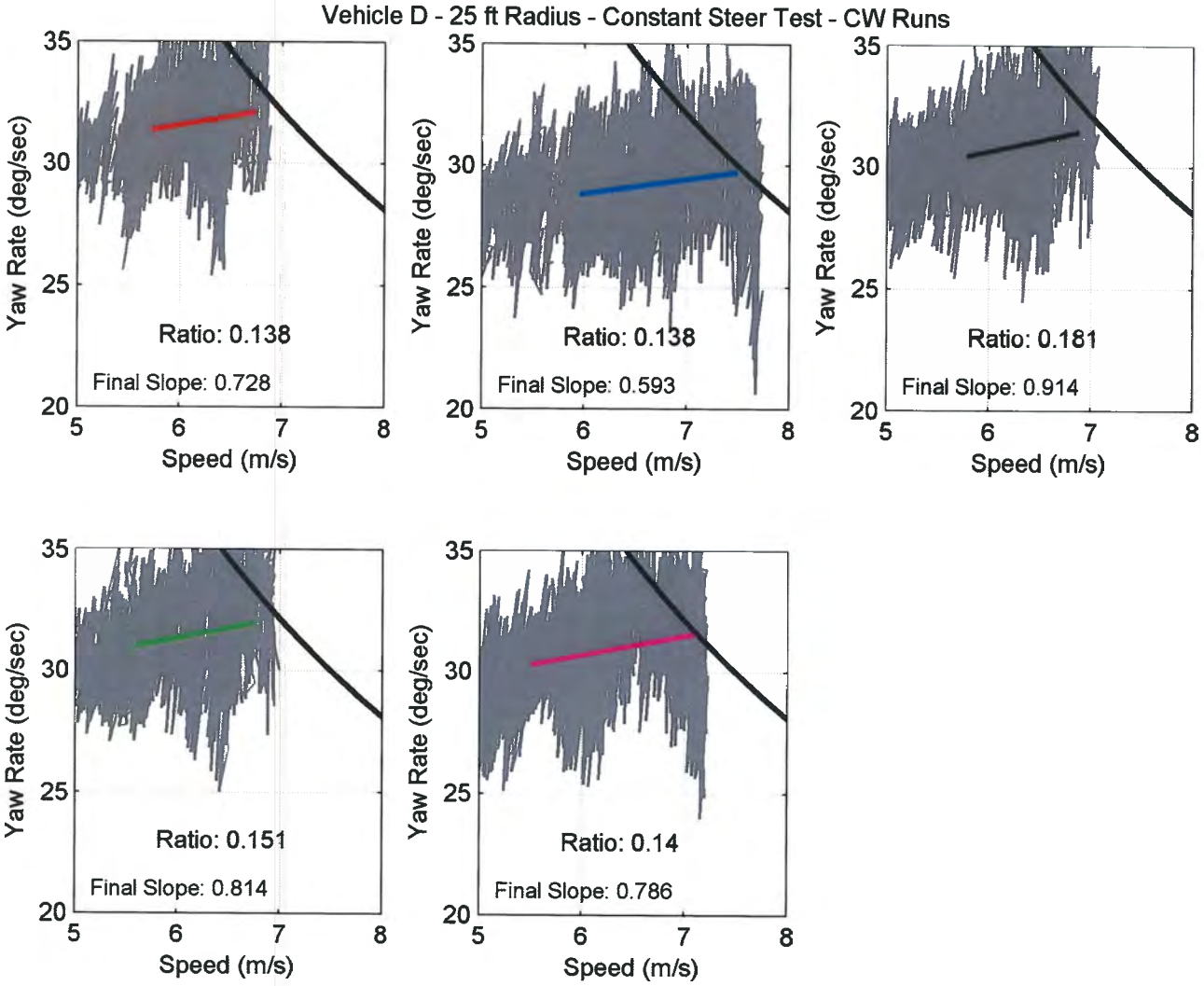
Sample Yaw Rate Ratio Test Results



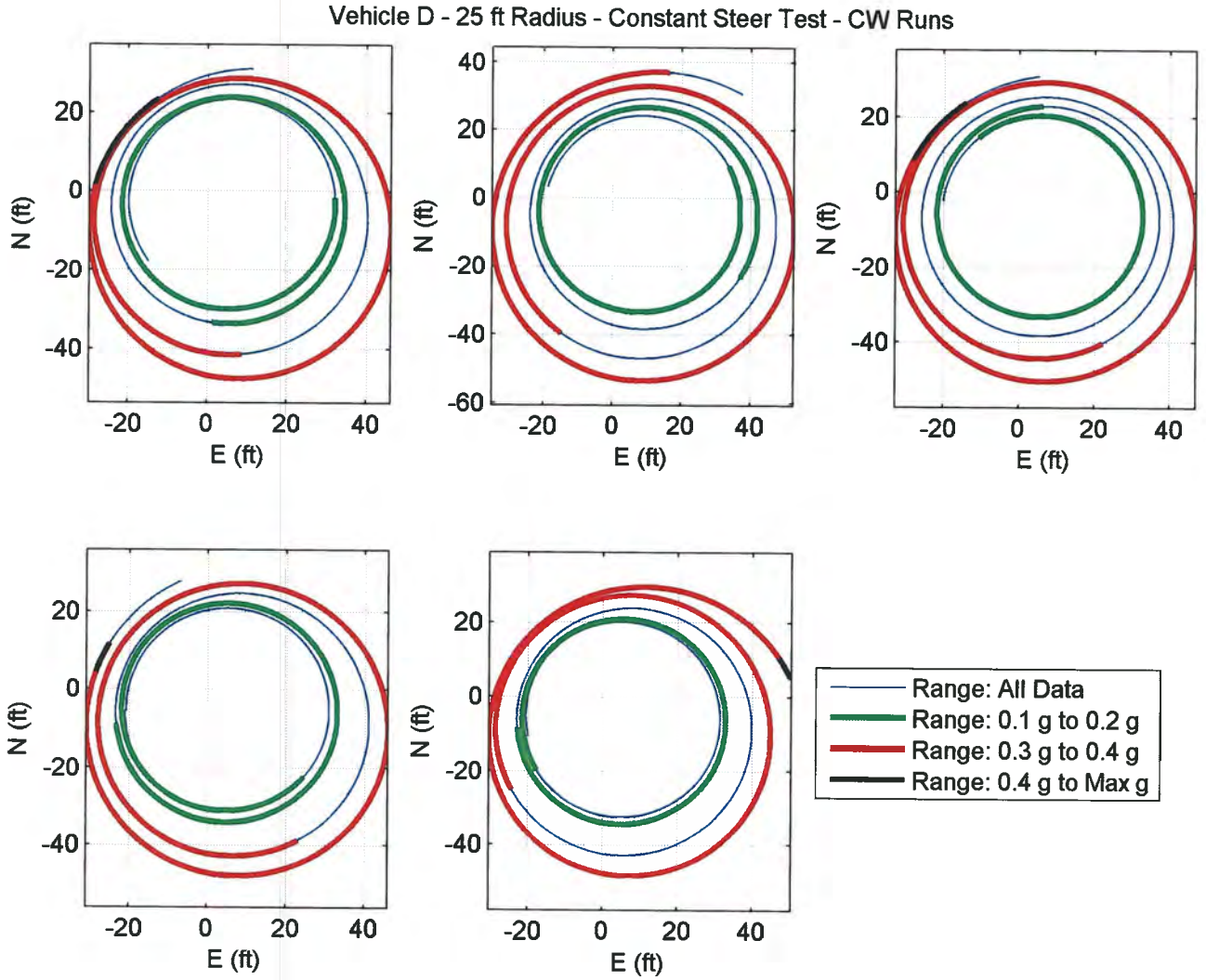
Sample Yaw Rate Ratio Test Results



Sample Yaw Rate Ratio Test Results



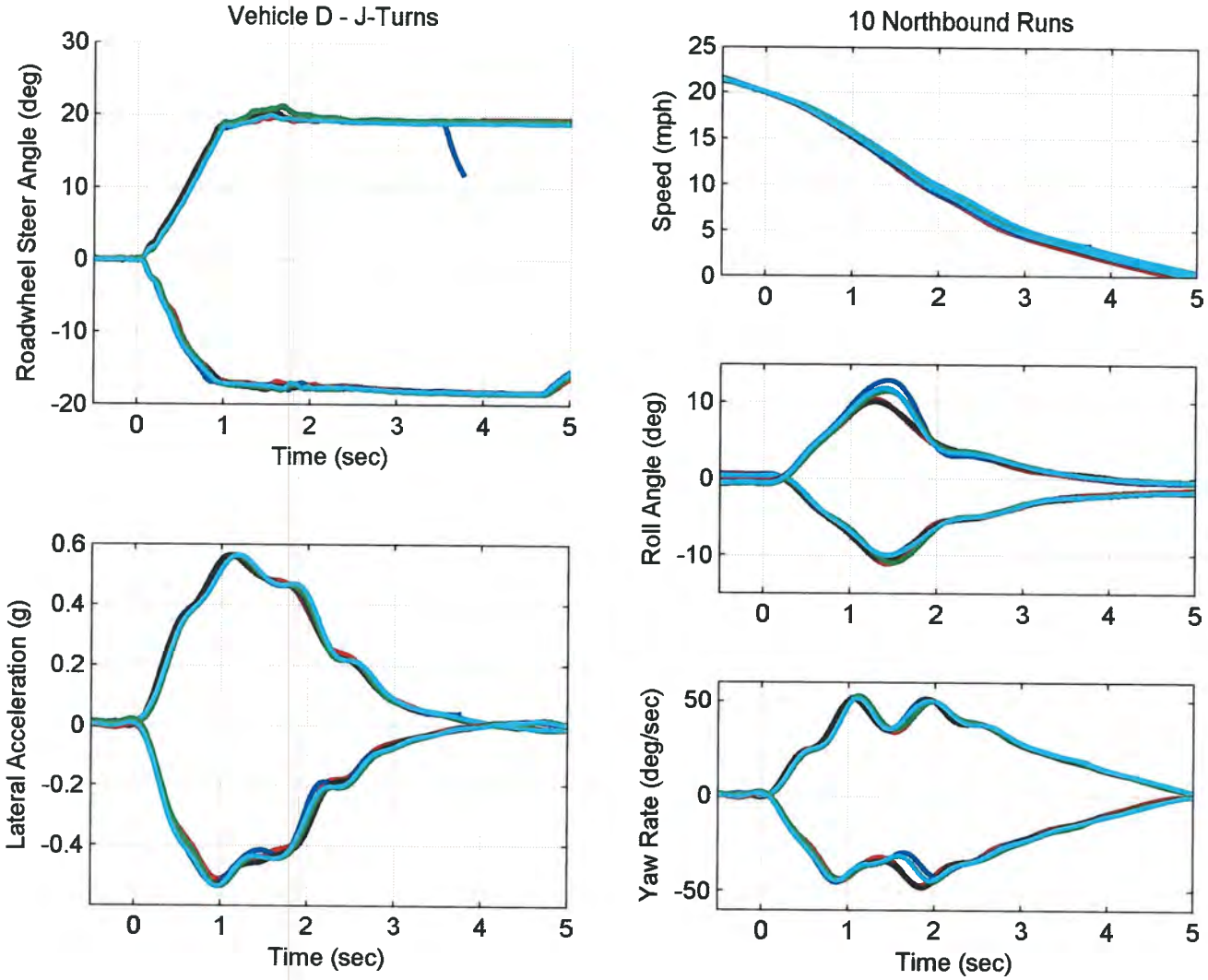
Sample Yaw Rate Ratio Test Results



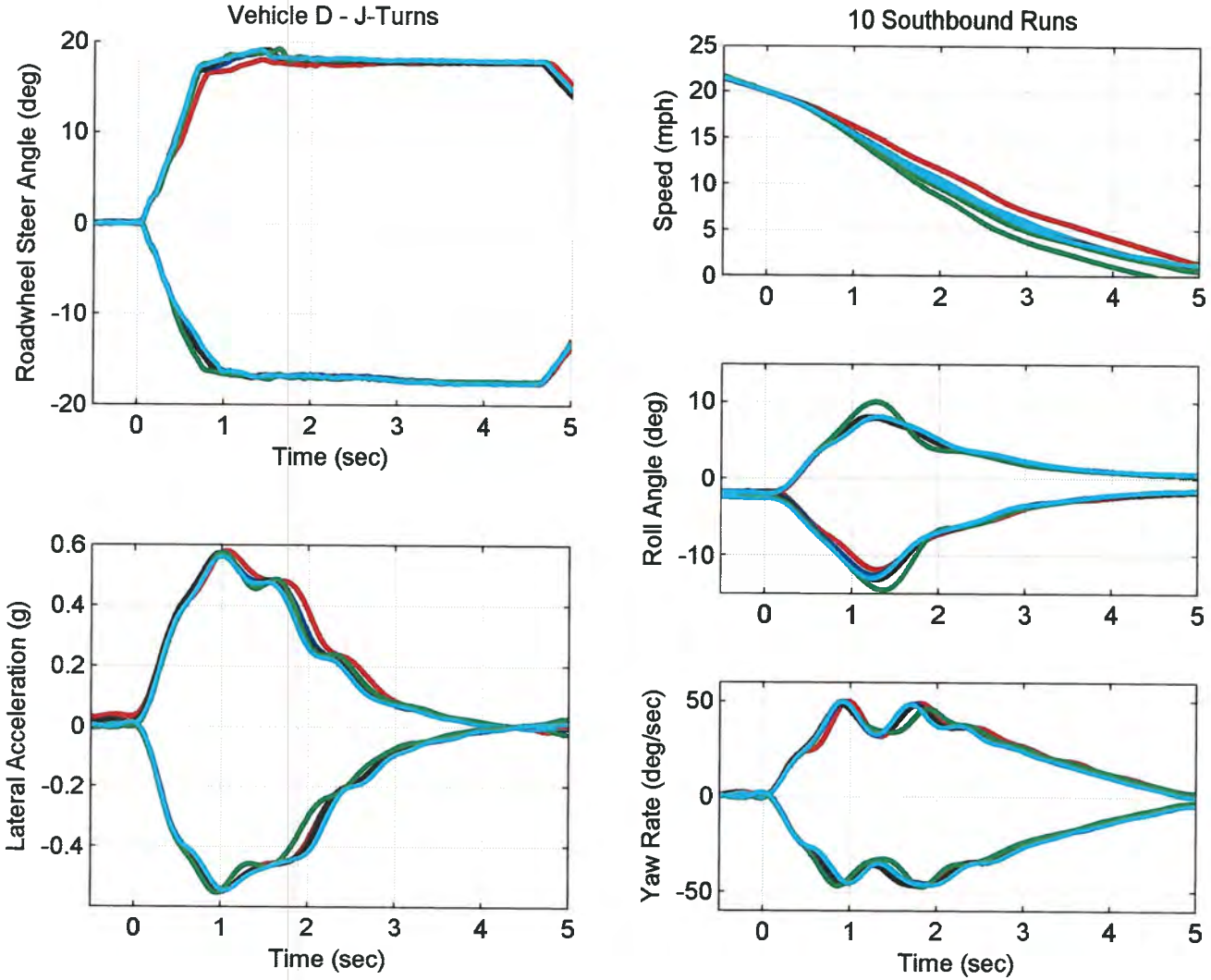
20 mph Dropped Throttle J-Turn (Step Steer) Test

ATV ASC Used for Steering Input

Sample J-Turn Test Results



Sample J-Turn Test Results



Sample J-Turn Test Results

Vehicle D

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.5635	-0.5129
2	0.5615	-0.5264
3	0.5638	-0.5294
4	0.5631	-0.5353
5	0.5639	-0.5361
Mean Value of 5 Runs	0.5631	-0.5280
Standard Deviation of 5 Runs	0.001	0.009

Average of 10 Northbound Runs

0.5456

Run Number	Southbound Right Turns	Southbound Left Turns
1	0.5798	-0.5449
2	0.5689	-0.5479
3	0.5741	-0.5494
4	0.5757	-0.5531
5	0.5630	-0.5462
Mean Value of 5 Runs	0.5723	-0.5483
Standard Deviation of 5 Runs	0.007	0.003

Average of 10 Southbound Runs

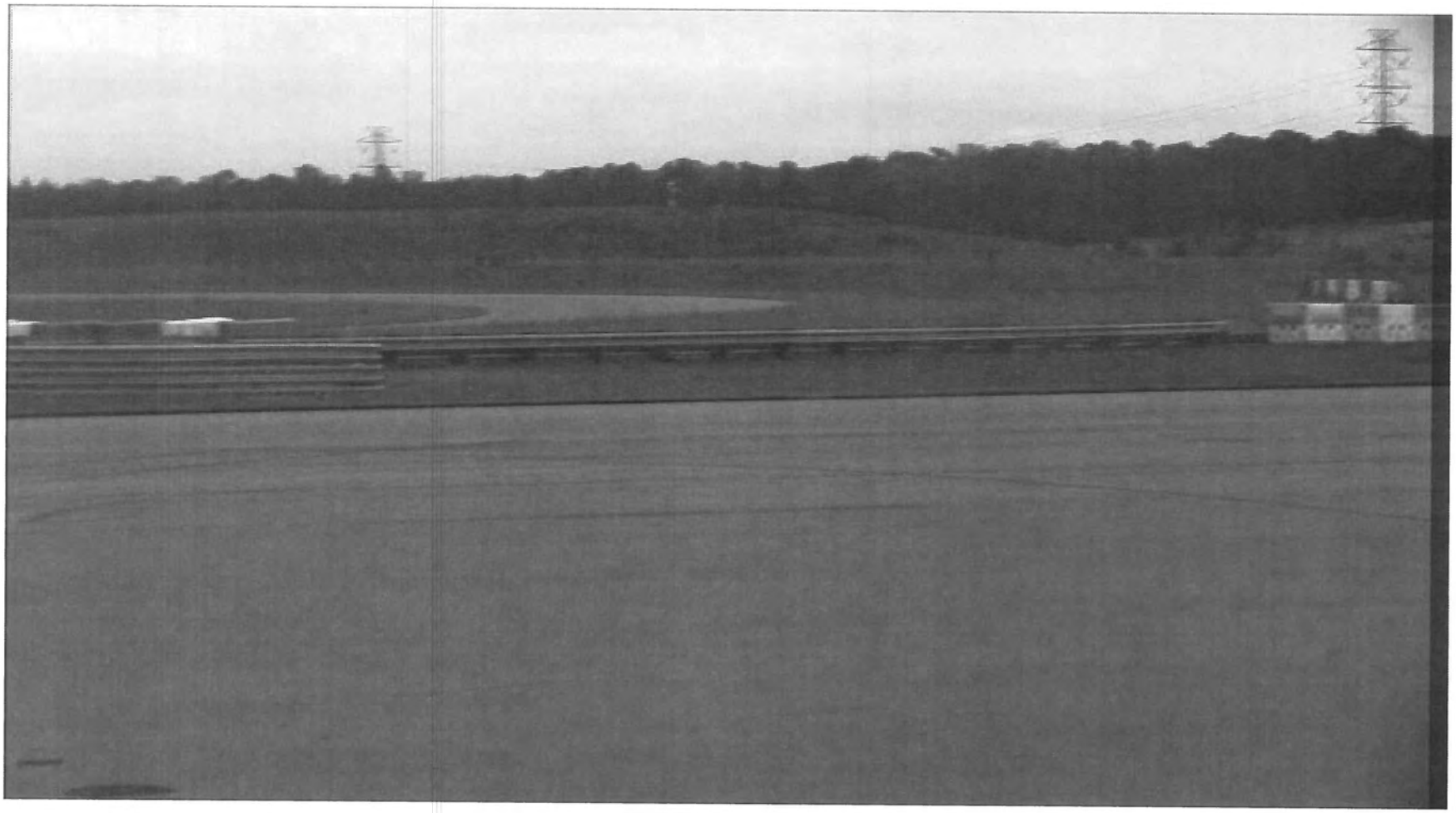
0.5603

Average of All 20 Runs

0.553

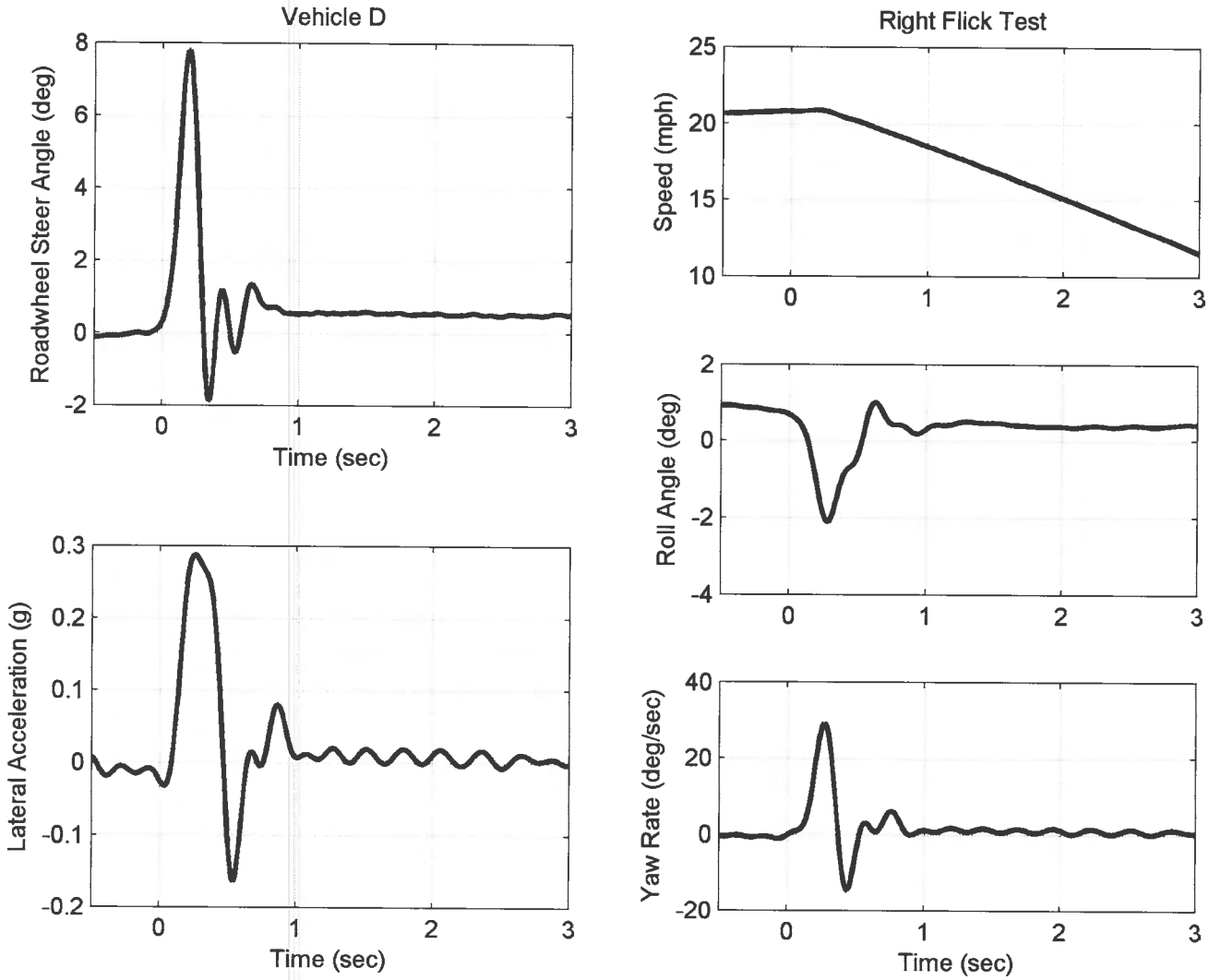
Threshold Ay

Steering Flick Test (20 mph)

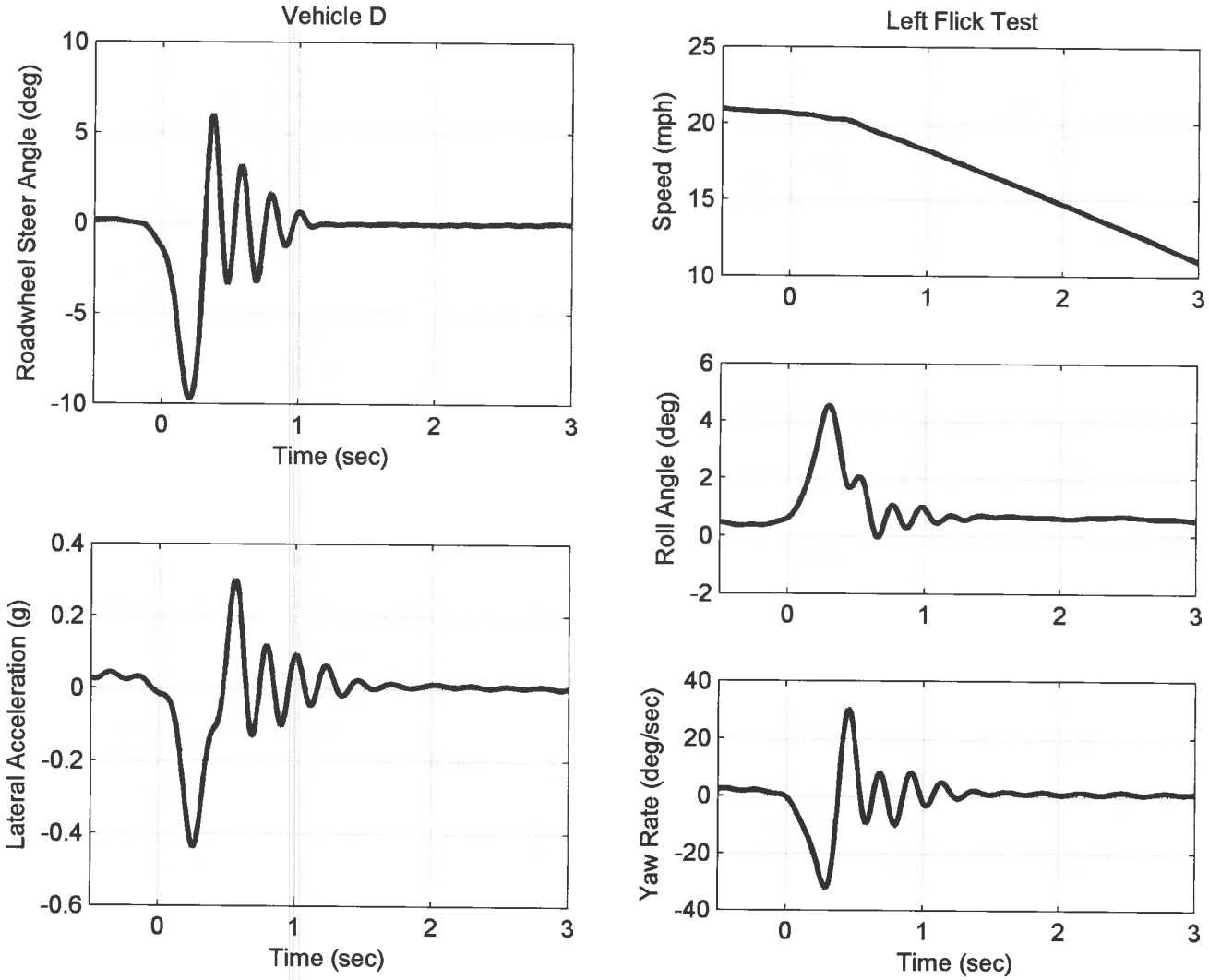


Human Driver Steering Input

Sample Steering Flick Test Results



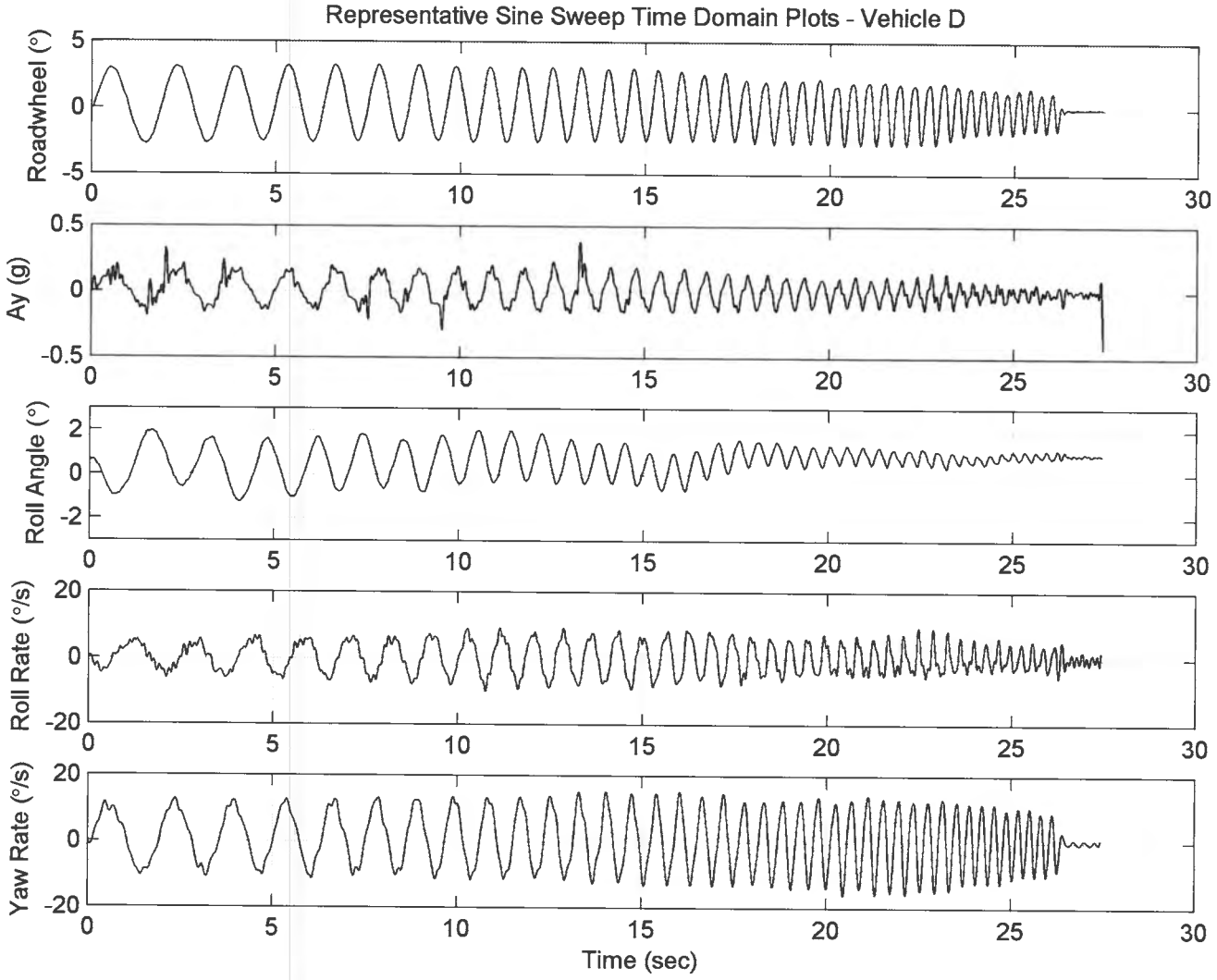
Sample Steering Flick Test Results



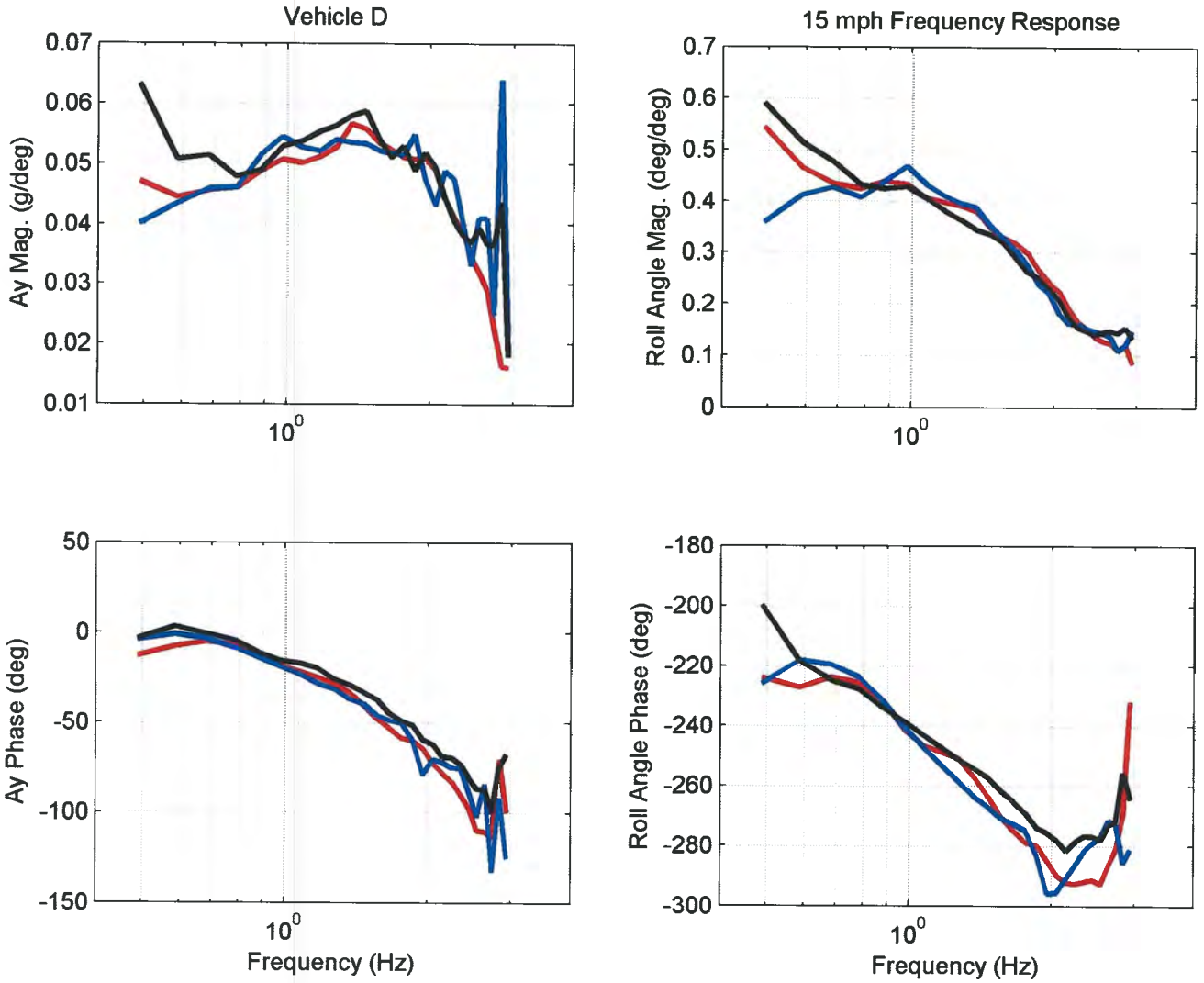
Sinusoidal Sweep Steering Test (15 mph)

ATV ASC Used for Steering Input

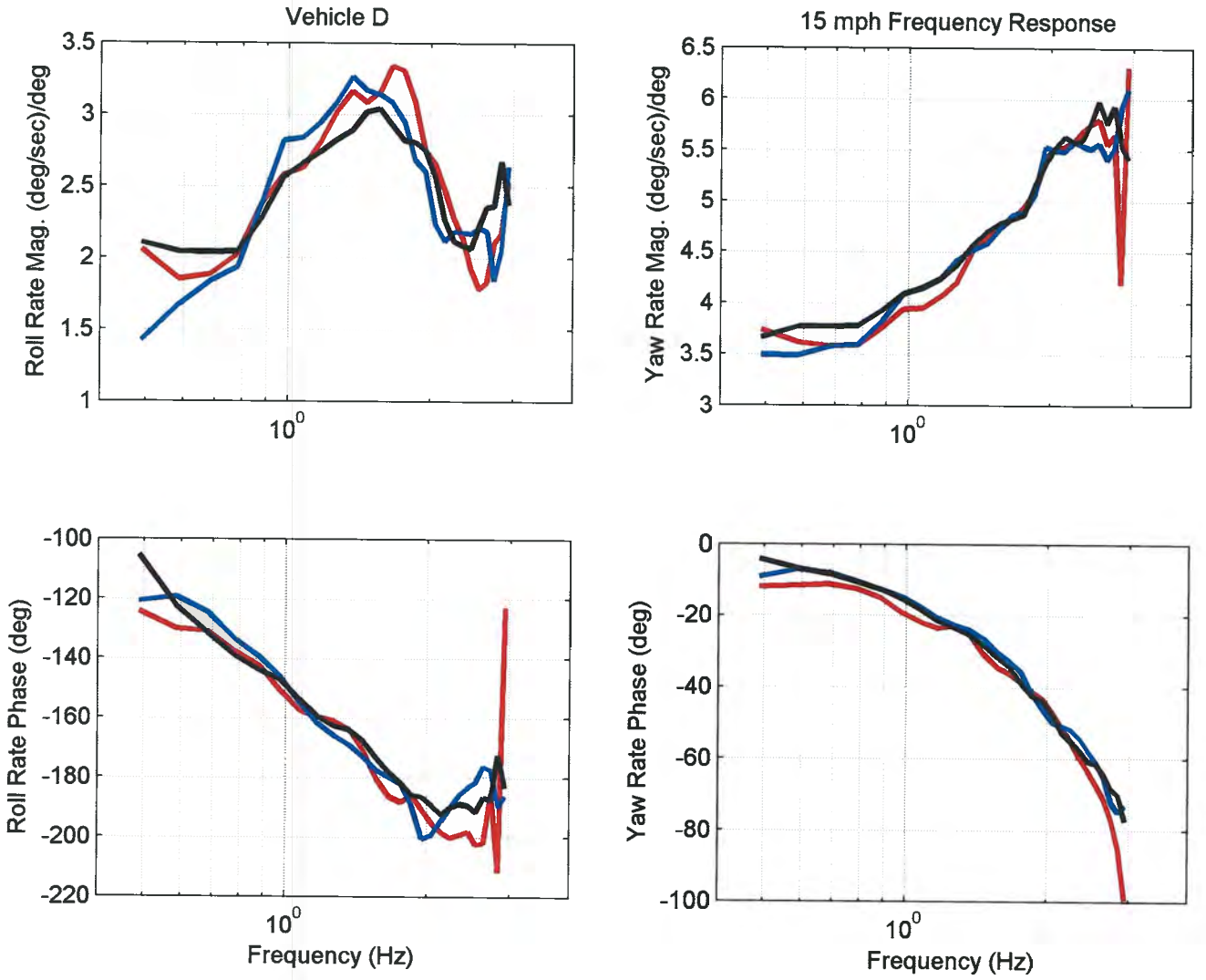
Sample Sinusoidal Sweep Test Results



Sample Sinusoidal Sweep Test Results



Sample Sinusoidal Sweep Test Results



ATV and ROV Testing at NCCAR
At the End of a Long Week in September 2015

Rider-Active and 2-Rider Studies On All-Terrain Vehicles

Tests on Twelve 2014-2015 Model Year Vehicles

Overview of Testing Conducted by SEA for the Consumer Product Safety Commission (CPSC) under U.S. Department of Health and Human Services Contract HHSP233201400030I

Dynamic Testing Started in 2016

UNITED STATES OF AMERICA
CONSUMER PRODUCT
SAFETY COMMISSION

S-E-A

Disclaimers

These comments are those of SEA, Ltd. staff, and they have not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.

All data contained in this presentation are preliminary and have not been cleared by CPSC.

Overview of Testing

- Same Vehicles as 2015 Vehicle Characterization Measurement Study
- No Laboratory Tests Conducted
- All Dynamic Tests Conducted Autonomously Using SEA's ATV Automated Driver (ATV AD)
- "Driver and Rider Weight Frame" Used To Ballast Vehicles to Desired Test Weight

Live Demonstrations Later Today

Vehicle Loading Conditions

- Rider-Active Loading Condition
  - Representative Driver-Only Loading – (213-215 lb Driver)
  - Measurement Transducers
  - SEA's ATV Automated Driver (ATV AD)
  - Safety Outriggers
  - 24V Battery
  - Nominally 213-215 lb over Curb Weight

- 2-Rider Loading Condition
  - Representative 2-Rider Loading – (213-215 lb Driver & Passenger)
  - Measurement Transducers
  - SEA's ATV Automated Driver (ATV AD)
  - Safety Outriggers
  - 24V Battery
  - Nominally 426-430 lb over Curb Weight

Sample Test Weights

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	ATV ATD and Ballast to Driver Loading	ATV ATD and Ballast to 2 Riders
VIMF Test Number		5765	5766	5842		
Total Vehicle Weight (lb)	523.9	737.1	759.6	989.7	741.1	954.4
Left Front Weight (lb)	151.5	177.3	198.3	232.2	168.4	187.6
Right Front Weight (lb)	118.4	161.0	176.8	212.1	160.4	176.3
Left Rear Weight (lb)	132.0	206.1	204.4	293.5	211.6	300.2
Right Rear Weight (lb)	122.0	192.7	180.1	251.9	200.7	290.3
Front Track Width (in)	33.20	33.50	33.66	33.93	33.50	33.93
Rear Track Width (in)	32.25	32.30	32.28	32.35	32.30	32.35
Average Track Width (in)	32.73	32.90	32.97	33.14	32.90	33.14
Wheelbase (in)	48.40	48.35	48.30	48.25	48.35	48.25
CG Longitudinal (in)	23.47	26.16	24.45	26.59	26.90	29.85
CG Lateral (in)	-1.36	-0.66	-0.99	-1.02	-0.42	-0.37
CG Height (in)		23.61	22.65	25.00		
Roll Inertia - I_{XX} (ft-lb-s^2)		55	66	86		
Pitch Inertia - I_{YY} (ft-lb-s^2)		73	80	141		
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		54	63	115		
Roll/Yaw - I_{XZ} (ft-lb-s^2)		4	3	8		
SSF		0.697	0.728	0.663		
KST		0.698	0.728	0.664		
Steering Ratio (deg/deg)			1.42			

Justification for Selection of Driver Lean Angles Used for Rider-Active Study

- Conducted Circle Tests Using Two Different Drivers and Two Different Vehicles, One Light Vehicle and One Heavy Vehicle
- Test Drivers (Torsos) Leaned on Average 8° on the Heavy Vehicle and 12° on the Light Vehicle During Drives When They Attempted to Remain Upright
- Test Drivers (Torsos) Leaned on Average 22° on the Heavy Vehicle and 27° on the Light Vehicle During Drives When They Attempted to Drive With Generous Lean
- Two Simulated Driver (Torso) Lean Angles – 20° and 40° – Were Used for the Rider-Active Study
- Based on Evaluation of Upper Body Component Weights of 215 lb, 95th Percentile Male; Rider-Active Moments of 625 in-lb and 1,250 in-lb were used for the Simulated 20° and 40° Rider-Active Leans, Respectively

Sample Images Used For Selection of Driver Lean Angles Used for Rider-Active Study

Driver 1
Heavy Vehicle
"Upright"

Driver 1
Heavy Vehicle
"Generous Lean"

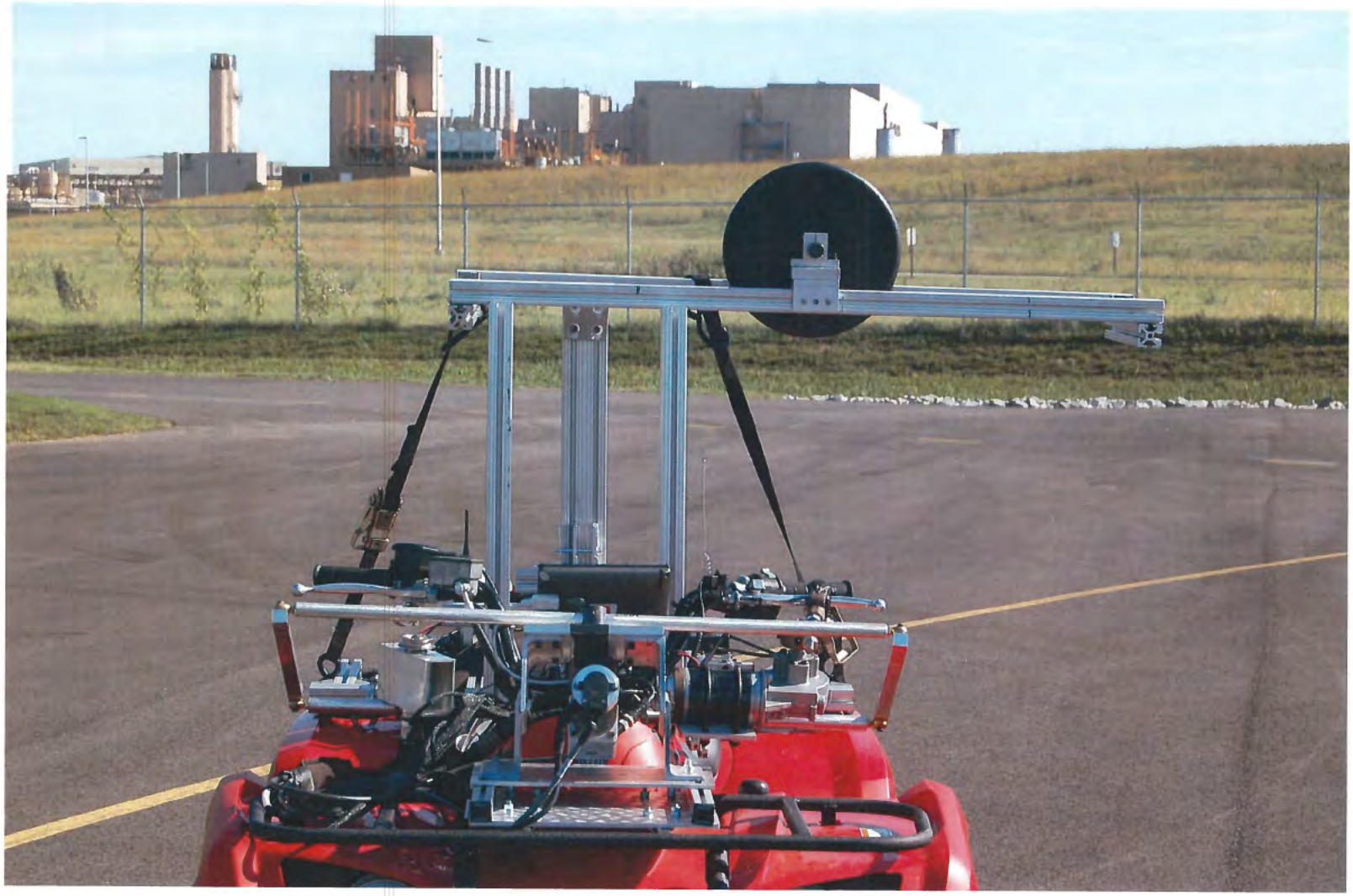
Sample Images Used For Selection of Driver Lean Angles Used for Rider-Active Study

Driver 2
Light Vehicle
"Upright"

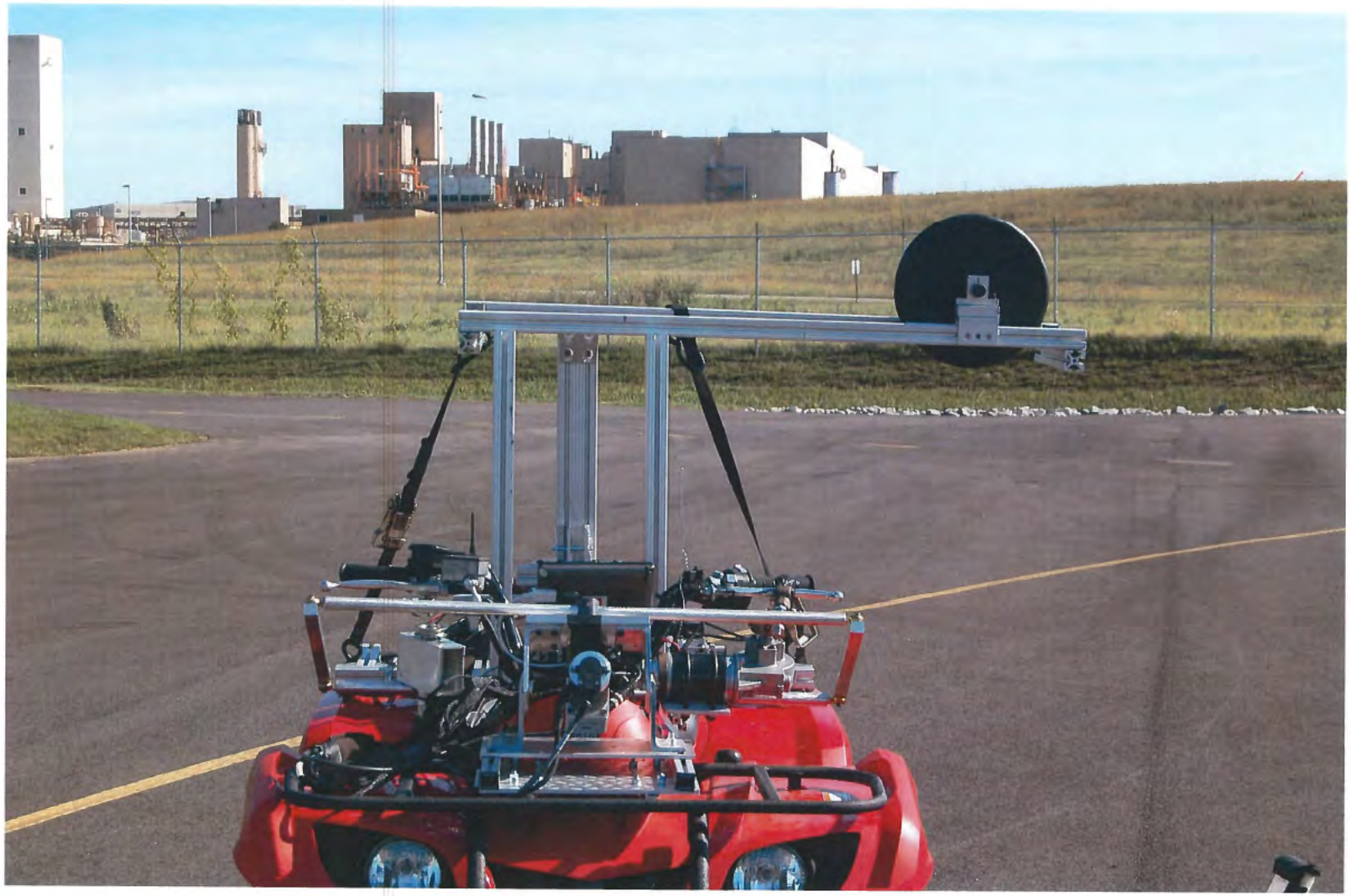
Driver 2
Light Vehicle
"Generous Lean"

Rider-Active Study – No Driver Lean

Rider-Active Study – 20° Driver Lean



Rider-Active Study – 40° Driver Lean



2-Rider Study – Side View

2-Rider Study – Front View

Spreadsheet for Rider-Active Study Ballast

Component	Weight (lb)	Component CG to Top of Outrigger	Distance (in)	Moment	Moment (in-lb)
W_{95}	213	z_{95}	33.1	$W_{95} \times z_{95}$	7056

Component	Weight (lb)	Component CG to Top of Outrigger	Distance (in)	Moment	Moment (in-lb)
W_F	35	z_F	30.0	$W_F \times z_F$	1050
W_R	56.4	z_R	26.2	$W_R \times z_R$	1477
W_{OR}	29.5	z_{OR}	0.0	$W_{OR} \times z_{OR}$	0
W_B	**92.1**	z_B	**49.2**	$W_B \times z_B$	4529
	213	Confirmation of Total Weight & Moment			7056

Weight of Moving Mass	**45.0**	lb	
Lateral Movement for 20 deg Lean	**13.9**	in	**Rider-Active Moment**
Lateral Movement for 40 deg Lean	**27.8**	in	**625 in-lb**
			1250 in-lb

Spreadsheet for Ballast Confirmation

Vehicle Curb Weight 650.8 lb

	Instrumentation Only	Autonomous Driver Only	Autonomous 2-Rider
	(lb)	**(lb)**	**(lb)**
LF	**184.7**	**195.0**	**212.7**
RF	**183.8**	**194.0**	**210.3**
LR	**195.5**	**236.7**	**324.6**
RR	**203.4**	**238.3**	**332.6**
	767.4	**864.0**	**1080.2**
Check of Vehicle & Instr. Weight	771.7		
Check of "Autonomous Driver" Weight		213.2	
Check of 2-Rider Weight			429.4

Dynamic Tests

- Testing Conducted at SEA
- Dry, Flat Asphalt Test Surface
- Dynamic Tests for Rider-Active Study
  - Counterclockwise (CCW) Constant Radius (50 ft) Tests
  - Constant Steer Tests (Yaw Rate Ratio Tests) – Left Turns Only
  - 20 mph Dropped Throttle J-Turn Tests – Left Turns Only
  - All Tests Conducted with No Driver Lean, 20° Driver Lean and 40° Driver Lean
- Dynamic Tests for 2-Rider Study
  - Constant Radius (50 ft) Tests
  - Constant Steer Tests (Yaw Rate Ratio Tests)
  - 20 mph Dropped Throttle J-Turn Tests

Instrumentation Used During Dynamic Tests

Table 4: Instrumentation Used During Dynamic Testing			
Transducer	**Measurement**	**Range**	**Accuracy**
Oxford Technical Solutions RT3002 Inertial and GPS Navigation System	Longitudinal, Lateral, and Vertical Accelerations	± 100 m/s^2 (± 10 g)	0.01 m/s^2 (0.001 g)
	Roll, Pitch, and Yaw Rates	± 100 deg/s	0.01 deg/s
	Speed	No Limit Specified	0.05 km/h (0.03 mph)
	Roll and Pitch Angles	-180 to +180 deg	0.03 deg
	Vehicle Heading	0 to 360 deg	0.1 deg
Steering Column Encoder	Steering Column Angle (Handlebar Angle)	No Limit Specified	± 0.25 deg

Equipment Used During Dynamic Tests

ATV AD, Weight Frame Ballast, and Safety Outriggers

Features of ATV AD

- Wireless, Off-Board Control and Monitoring
- Path-Following Algorithms (GPS Base Station Used)
- Speed-Following Algorithms
- Open-Loop Control Features for Steering, Throttle, and Brake Control
- Versatile Maneuver Type and Severity Selection
- Safety Features
  - Program and Manual Kill Circuits
  - "Ay Limit" to End Maneuvers
  - Speed Limits
  - Location Limits

Components of ATV AD

ATV ASC, Throttle Controller, Brake Motor, GPS/IMU

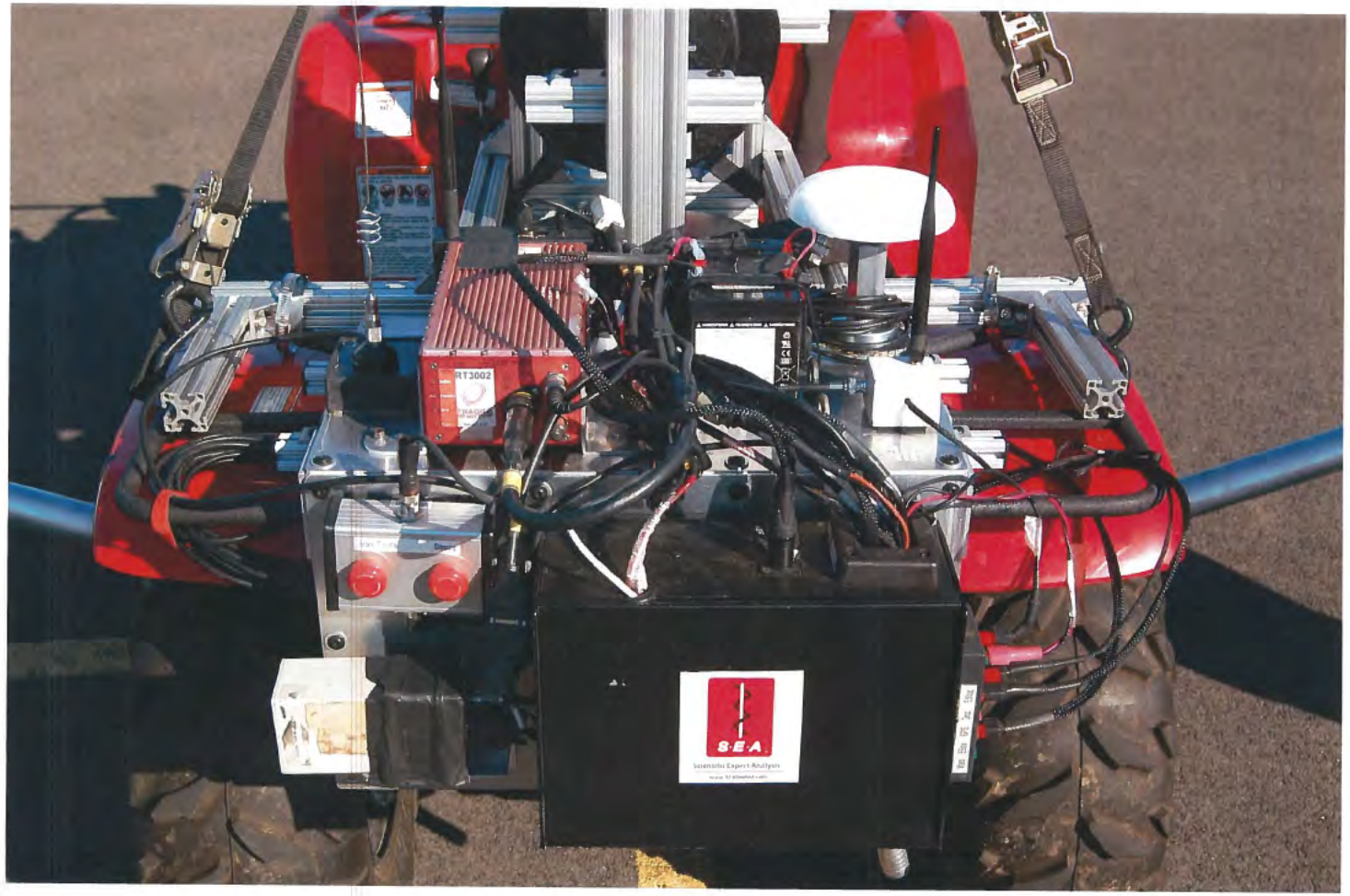
Components of ATV AD

Throttle Controller

Components of ATV AD

Brake Motor

Components of ATV AD



GPS/IMU, 24V Battery, Electronics Box and Antennas

Components of ATV AD Vehicles with Manual Transmissions

Gear Shift Actuator
(Not Shown – Motor Used to Actuate Clutch)