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New Jersey 08405

Artificial Turf and Gopher Tortoises at Orlando Sanford International Airport

January 2016

Final Report

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U.S. Department of Transportation
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Ryan King,* Lauren (Vitagliano) Collins,* and John R. Weller**

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*Department of Transportation
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16. Abstract
Under Title 14 Code of Federal Regulations Part 139 (14 CFR 139) Section 309, airports are required to maintain runway safety areas (RSAs) free of “hazardous ruts, humps, depressions or other surface variations.” The safety areas must also be capable of supporting the “occasional passage of aircraft without causing major damage to the aircraft.” A number of airports in the Federal Aviation Administration (FAA) Southern Region have difficulty meeting the regulations under 14 CFR 139 for holes in RSAs caused by burrowing of gopher tortoises. Gopher tortoises are listed as a threatened species in Florida, and mitigation efforts (i.e., tortoise removal or relocation and burrow eliminations) are heavily regulated, expensive, and time-consuming. However, gopher tortoises burrowing in such close proximity to runways are a safety hazard to aircraft that may leave the runway pavement surface.

Artificial turf that meets the specifications in FAA Advisory Circular 150/5370-15B has been identified as a material that can be used to cover large portions of airport property with multiple benefits, such as providing consistent ground cover, as well as reducing maintenance costs and attractive vegetative food sources for hazardous wildlife species. It was determined that research was necessary to assess artificial turf as a potential solution for mitigating the burrowing behavior of gopher tortoises on the airport property.

The FAA Airport Technology Research and Development Branch entered into an agreement with Orlando Sanford International Airport in August 2013 to conduct a study on the applicability of artificial turf in the RSA to mitigate potential hazardous conditions resulting from the presence of burrowing gopher tortoises. The study also investigated the ability of the artificial turf system to withstand exposure to harsh environmental conditions, and the occasional, inadvertent passage of vehicles and aircraft, which was tested by using a specialized vehicle retrofitted with an aircraft nose wheel. An area adjacent to the blast pad at the approach end of Runway 18 was selected as the test site, and construction on the test area commenced in February 2014. Data were collected between May 1, 2014 and April 30, 2015.

The results from over a year of data collections and directed studies demonstrated that artificial turf is compatible with safe airport operations, is durable to passive environmental factors, is not attractive to other hazardous species, resists burrowing by gopher tortoises, and does not exhibit detrimental reduced braking during aircraft or vehicle excursions. It was also determined that the artificial turf performed well during the occasional passage by operational vehicles, including fully loaded aircraft rescue and firefighting vehicles.

17. Key Words
Artificial turf, Runway safety area, Wildlife hazard; Gopher tortoise, Tortoise burrow, Braking availability tester vehicle; Wildlife; Airport design

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	Advisory Circular
ADO	Airport District Office
ARFF	Aircraft rescue and fire fighting
ASBS	Antiskid Braking System
BAT	Braking Availability Tester
CFR	Code of Federal Regulations
FAA	Federal Aviation Administration
Ops	Airport Operations
RSA	Runway safety area
RWY	Runway
SAA	Sanford Airport Authority
SD	Secure digital
SFB	Orlando Sanford International Airport
TWY	Taxiway

EXECUTIVE SUMMARY

Under Title 14 Code of Federal Regulations Part 139 (14 CFR 139) Section 309, airports are required to maintain runway safety areas (RSAs) free of "hazardous ruts, humps, depressions or other surface variations." The safety areas must also be capable of supporting the "occasional passage of aircraft without causing major damage to the aircraft." A number of airports in the Federal Aviation Administration (FAA) Southern Region have difficulty meeting the regulations under 14 CFR 139 for holes in their RSAs caused by the burrowing behavior of gopher tortoises. Gopher tortoises are listed as a threatened species in Florida, and mitigation efforts (i.e., tortoise removal or relocation and burrow eliminations) are heavily regulated, expensive, and time-consuming. However, gopher tortoises burrowing in such close proximity to runways are a safety hazard to aircraft that may leave the runway pavement surface.

Artificial turf that meets the specifications set forth in FAA Advisory Circular 150/5370-15B has been identified as a material that can be used to cover large portions of airport property with multiple benefits, such as providing consistent ground cover, as well as reducing maintenance costs and vegetative food sources that attract hazardous wildlife species. This research assessed artificial turf as a potential solution for mitigating the burrowing behavior of gopher tortoises on the airport property.

The FAA Airport Technology Research and Development Branch conducted a field study at Orlando Sanford International Airport to determine the applicability of artificial turf in the RSA to improve conditions that have been impacted by the burrowing behavior of gopher tortoises. The study also investigated the durability of the artificial turf system located in the harsh operational environment of the runway end.

The results from over a year of data collections and directed studies demonstrated that artificial turf is compatible with safe airport operations, durable to passive environmental factors, suitable for the occasional passage by operational vehicles including fully loaded aircraft rescue and fire fighting vehicles, is not attractive to other hazardous species, resists burrowing by gopher tortoises, and does not exhibit detrimental reduced braking during aircraft (simulated aircraft weights and associated tire pressures) or vehicle excursions.

1. INTRODUCTION.

Under Title 14 Code of Federal Regulations Part 139 (14 CFR 139) Section 309, airports are required to maintain runway safety areas (RSAs) free of “hazardous ruts, humps, depressions or other surface variations” [1]. The safety areas must also be capable of supporting the “occasional passage of aircraft without causing major damage to the aircraft” [1]. A number of airports in the Federal Aviation Administration (FAA) Southern Region have difficulty meeting the regulations under 14 CFR 139 for holes in their RSAs caused by the burrowing behavior of gopher tortoises (see figure 1). Gopher tortoises are listed as a threatened species in Florida, and mitigation efforts (i.e., tortoise removal or relocation and burrow eliminations) are heavily regulated, expensive, and time-consuming. However, having the burrows in such close proximity to runways is a safety hazard to aircraft that may leave the pavement surface.

Figure 1. Gopher Tortoise

1.1 PURPOSE.

Artificial turf was identified as a material that can be used to cover large portions of airport property with multiple benefits, which include providing consistent ground cover while reducing maintenance costs and attractive vegetative food sources for hazardous wildlife species. This report documents research performed that assessed artificial turf as a potential solution for mitigating the burrowing behavior of gopher tortoises on the airport property.

The FAA Airport Technology Research and Development (R&D) Branch conducted a field study at Orlando Sanford International Airport (SFB) to determine the applicability of artificial turf in the RSAs to improve conditions that have been impacted by burrowing gopher tortoises. The study also investigated the durability of the artificial turf system located in the harsh operational environment of the runway end.

1.2 BACKGROUND.

During SFB’s annual 14 CFR 139 inspections, the FAA issued the airport a letter of investigation for the presence of burrows (holes) in the RSA. The Sanford Airport Authority (SAA) began working with the FAA Orlando Airports District Office (ADO) to find a solution to prevent the burrows within the RSAs. Several mitigation strategies were discussed within the ADO and

FAA Office of Airport Safety and Standards. It was determined that a test section of artificial turf installed at SFB could serve two purposes: to investigate how effectively it could mitigate gopher tortoise burrows and to determine its durability within the RSA environment.

1.3 ARTIFICIAL TURF IN THE RSA.

Artificial turf has been used in the airport environment since the year 2000 for a variety of applications: reduced maintenance, erosion control, wildlife and foreign object debris mitigation, and enhanced visibility [2].

Table 1 details the artificial turf installations on U.S. airports. The entries in bold indicate runway (RWY) and taxiway (TWY) locations where artificial turf was installed in an RSA.

Table 1. Artificial Turf Installations [3 and 4]

Date	Airport	Location	Description	Size (sq. ft.)
2000	Chicago Midway International (MDW)	TWY W island	Original test plot	1,000
2002	Chicago Midway International (MDW)	RWY 4R/22L, RWY 31C/13C, and TWY R	Blast test plot and TWY safety area	1,300
2002	**Chicago O'Hare International (ORD)**	**RWY 14L/32R and TWY A17/P3/D3/D7**	**RSA, TWY safety area, and D3 service road**	**1,858**
2002	**Detroit Metropolitan Wayne County (DTW)**	**RWY 9L/27R**	**RSA**	**1,394**
2004	Calhan (5V4)	RWY 17/35	GA turf runway	5,202
2004	**United States Air Force Academy Airfield (AFF)**	**RWY 16R/34L**	**RSA and sail plane staging area**	**26,910**
2006	**Hartsfield-Jackson International (ATL)**	**RWY 10/28**	**RSA**	**2,700**
2007	**Boston Logan International (BOS)**	**RWY 4R/22L, 15R/33L, and TWY F; RWY 4R/22L, 15R/33L, and TWY Q; RWY 4L/22R and TWY K/E/A**	**RSA, TWY safety area, and infield islands**	**165,075**
2007	**John F. Kennedy International (JFK)**	**RWY 22R/4L, RWY 13R/31L, and TWY K**	**RSA of intersection**	**55,015**
2008	**Baltimore/Washington International Thurgood Marshall (BWI)**	**RWY 15R/33L and RWY 10/28**	**RSA of intersection**	**2,867**
2009	**Boston Logan International (BOS)**	**RWY 9/27, RWY 15R/33L, and TWY F**	**RSA of intersection**	**83,000**
2010	**Detroit Metropolitan Wayne County (DTW)**	**RWY 9L/27R, RWY 3L/21R, and TWY V**	**RSA shoulders**	**225,000**
2010	John F. Kennedy International (JFK)	Various TWY shoulders and islands	TWY safety areas	18,565
2010	John F. Kennedy International (JFK)	Various TWY shoulders and islands	TWY safety areas	242,401
2010	John F. Kennedy International (JFK)	Various TWY shoulders and islands	TWY safety areas	46,905
2011	Nashville International (BNA)	TWY K, T4, and T5	TWY safety area	83,958

Table 1. Artificial Turf Installations [3 and 4] (Continued)

Date	Airport	Location	Description	Size (sq. ft.)
2012	San Diego International (SAN)			110,955
2012	John F. Kennedy International (JFK)	TWY Q and P	TWY safety area	51,020
2012	**Boston Logan International (BOS)**	**RWY 4R/22L, RWY 15R/33L, and TWY F**	**RSA of intersection**	**16,145**
2013	Columbia Metropolitan (CAE)	Run-up pads at RWY 29 entrance	Delineation of TWYs	5,716
2014	**Orlando Sanford International (SFB)**	**RWY 18 blast pad**	**RSA**	**68,400**
2015	Honolulu International (HNL)	TWY G	Infield islands	63,000
2015	**John F. Kennedy International (JFK)**	**RWY 4L/22R and RWY 13L/31R**	**RSA of intersection**	**311,822**

1.4 OBJECTIVES.

The objectives of this study were

- to assess the effectiveness of artificial turf to protect the RSA area from damage caused by burrowing gopher tortoises.
- to further assess the durability of the artificial turf in the immediate vicinity of a runway end exposed to jet blast forces caused by departing aircraft; general environmental factors, such as wind, rain, ultraviolet (UV) exposure, etc.; and the occasional traffic from airport vehicles.
- to ascertain whether wet artificial turf located in the RSA poses a safety hazard to aircraft by reducing braking action through decreased levels of interfacial friction between tires and the plastic turf material.

2. ARTIFICIAL TURF INSTALLATION AT ORLANDO SANFORD INTERNATIONAL AIRPORT.

This section introduces the gopher tortoise species and its presence at SFB, along with a summary of a wildlife survey that was conducted prior to project initiation. A review of the processes involved in establishing the test site, including site selection, gopher tortoise removal, and construction is also included.

2.1 GOPHER TORTOISE BACKGROUND.

The gopher tortoise (Gopherus polyphemus) is a species of the Gopherus genus, which is native to the southeastern United States. Gopher tortoises typically grow to be up to 15 inches long and weigh from 8 to 15 pounds. Their burrows, such as the one shown in figure 2, can vary from 3 feet to 52 feet in length and up to 23 feet deep. They are most active in the warmer months but spend most of their lives in their burrows. Each tortoise can dig and use several burrows within their home range throughout the active season. The number of burrows used by an individual varies geographically, seasonally, with the age and sex of the individual, and with habitat type, quality, and size.

Figure 2. Typical Gopher Tortoise Burrow

Gopher tortoises feed primarily on broadleaf grasses, wiregrass, grass-like asters, legumes, and fruits, but they are known to eat over 400 species of plants. Gopher tortoise densities and movements are affected by the amount of herbaceous ground cover. Generally, feeding activity is confined to within 50 meters (164 feet) of the burrow, but a tortoise may travel over 100 meters (328 feet) from its burrow for specific forage requirements [5 and 6].

Gopher tortoises are currently protected by federal law under the Endangered Species Act (ESA) in the Alabama counties west of the Mobile and Tombigbee Rivers and in Mississippi and Louisiana. The eastern portion of the gopher tortoise's range includes Alabama (east of the Mobile and Tombigbee Rivers), Florida, Georgia, and southern South Carolina. In these areas, the gopher tortoise is now a candidate species for possible listing under the ESA. It is also considered a keystone species, because its burrows provide shelter for about 350 other animal species throughout its range [5 and 6].

Several airports in the FAA Southern Region have gopher tortoises on their airfield. When they occur in high densities, such as on the airfield at SFB, effective mitigation is often temporary without a permanent exclusion technique (e.g., perimeter fence with digging barrier). Airports must consider long-term preventative measures to alleviate or reduce gopher tortoise movements onto an airfield and reactive measures to capture and relocate the tortoises accompanied by the elimination of their burrows, particularly when located inside the RSA.

Between December 2008 and April 2014, SFB excavated over 875 burrows and removed 345 gopher tortoises from the RSAs, costing just under $400,000. The mitigation of gopher tortoises in the RSA is a very expensive and continuous issue.

2.2 WILDLIFE SURVEY AND SITE SELECTION.

Before the study began, SFB was surveyed by an FAA National Wildlife Biologist who specifically evaluated hazards presented by gopher tortoises in the airport environment [7].

Data were collected in the field at SFB from June 10 through 12, 2013. Field investigations were performed during day and night (using night vision and infrared equipment) and consisted of gopher tortoise observations and capture, burrow counts within the RSA and throughout the airfield, fence patrols, and tracking. The total number of burrows and tortoises on the airfield was estimated using systematic field analysis, satellite imagery, and conversations with airport personnel. [7]

A count of the burrows specifically in the RSA determined that there were a minimum 400 burrows within 250 ft of each runway centerline (175 ft from the runway edge). RWY 9L-27R is 11,000 feet long and 150 feet wide, and RWY 18-36 is 6002 feet long and 150 feet wide. At the time of the survey, there was an estimated 1200 burrow entrances within the airfield's perimeter fence. Estimating population density proved difficult because of the small size and concealment of young gopher tortoise burrows in the airfield vegetation. [7]

Burrow distribution was heavily concentrated in the northwest region of the airport. The predominant concentration of gopher tortoise burrows was north of RWY 9L-27R and north and west of the approach end of RWY 18. This area comprised portions of land both on and off airport property, as depicted in red in figure 3. Discussions with airport personnel indicated that although airfield gopher tortoise distribution was highest in the northwest region, gopher tortoises have been documented using other areas. [7]

Figure 3. Aerial Photograph of SFB Showing Location of Highest Gopher Tortoise Densities on and off Airport Property

Four gopher tortoises were captured during the related investigation to determine an optimal location for an artificial turf test plot within the RSA. An additional gopher tortoise was captured earlier the same day by airport personnel. All five gopher tortoises were relocated, in accordance with the Florida Fish and Wildlife Conservation Commission permit to capture, remove, and relocate gopher tortoises at the airport. [7]

Patrolling the perimeter fence on foot and by truck indicated multiple dig-out locations on the airport's northern and western boundaries where gopher tortoises accessed the airfield. One adult gopher tortoise was found dead, stuck halfway under the inner perimeter fence within three feet of a burrow inside the airfield. On another occasion, a gopher tortoise was observed following the northern inner perimeter fence from the airfield side until it located a dig-out location to crawl under and out of the airfield. This observation was made while standing outside of the outer perimeter fence; however, a visual of the gopher tortoise was eventually lost due to heavy vegetation outside of the outer fence. [7]

Field observations of the proposed artificial turf test plot at the north end of RWY 18 identified a minimum of 60 gopher tortoise burrows in only a few minutes. Airport personnel remarked that the higher elevations of the airport's northern and western boundaries provide preferred habitat for burrow construction. Also, the lower elevations found in the eastern and southern quadrants of the airport are likely less desirable due to the proximity of the water table and location of the main terminal, hangars, and hard surfaces. [7]

Using the field reconnaissance information acquired during the site survey, the final test site was chosen to be an area immediately surrounding the RWY 18 blast pad. An added benefit of this location was that construction activities would be permitted during daytime hours without affecting normal airport operations. [7]

2.3 REMOVAL OF GOPHER TORTOISES.

Preparing the selected site first required removing all gopher tortoises and back filling all burrows within the designated area. Initial designs defined this burrow exclusion area as the area extending 165 feet outward from the edge of the blast pad area, as shown in the red portion of figure 4. Note the white marks on the landscape; these are gopher tortoise burrows.

Figure 4. Burrow Exclusion Zone

Gopher tortoise removal is a comprehensive process, which is outlined in the following steps.

1. Locate the burrow.

2. Inspect the burrow using a borescope. There are many types and brands of borescopes that can be used to inspect wildlife burrows, and borescope costs fluctuate accordingly. Capabilities include video and/or digital imagery; both capabilities are recommended. The boroscope needs to be waterproof, and it must be able to reach a minimum 30 feet into a burrow.

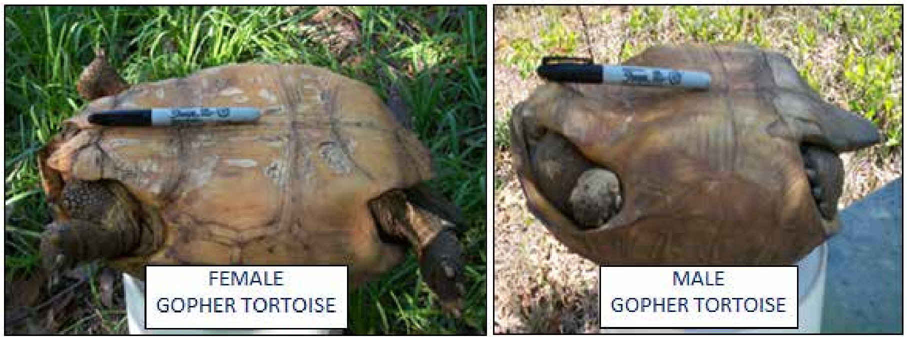
3. Categorize the burrow as active, inactive, or abandoned. Although specific definitions for these terms may be subjective and vary, in general, active burrows are those that are currently being occupied or showing signs of recent occupation (tracks, fresh digging, etc.). Inactive burrows are those not currently being occupied and do not show recent evidence of use. Abandoned burrows show no sign of recent tortoise occupation, appear to be neglected, may be partially collapsed, or may be maintained by other species. Periodic occupation and abandonment of burrows often occurs seasonally.

4. Record gopher tortoise's gender and age. As with all tortoises, the underside shells of males are concave, distinguishing them from females, as shown in figure 5. Although a gopher tortoise's age cannot reliably be made visually, it can be estimated based on size. When first hatched, the tortoises are about 1-2 inches long and grow 3/4 inch per year. Adult tortoises are usually at least 10 inches long. The tortoise's length and width can be measured with a tape measure or large caliper.

5. Record the length of the burrow.

6. Record the geographic coordinates of each burrow entrance.

7. Excavate and fill each burrow. At SAA, the gopher tortoises are relocated to outlying airport properties. Gopher tortoises are protected by state law, Chapter 68A-27.003, Florida Administrative Code. If gopher tortoises are located on a property, a Florida Fish and Wildlife Conservation Commission relocation permit is required before disturbing the burrows. A disturbance includes any type of work within 25 feet of a gopher tortoise burrow.



Source: http://www.gophertortoise.org/tortoise/facts.htm

Figure 5. Distinguishing Shell Characteristics Between Male and Female Gopher Tortoises

Initially, a total of 129 burrows were identified within the exclusion zone during the preconstruction process; 85 were active, 16 were inactive, 26 were abandoned, and 2 were not found at the time of removal. A total of 121 gopher tortoises were found; 75 were adults, and 46 were immature [8]. Data recorded for each burrow are included in appendix A. Each burrow's geographic coordinates and video footage of the video borescope inspections remain on file with the Airport Technology R&D Branch and is available upon request. Figure 6 depicts two Google Earth™ images of the test area location, one taken on January 22, 2013 prior to burrow excavation, and the other taken January 17, 2014 after excavation and filling.

Figure 6. Satellite Imagery Before and After Burrow Excavation

The combined length of all the burrows amounted to 1291 linear feet of underground void space in the exclusion zone, with the average individual burrow having a length 10.2 feet. Burrows were predominantly located on the southeast side of the blast pad. Each burrow location was numbered and noted on a diagram, as shown in figure 7.

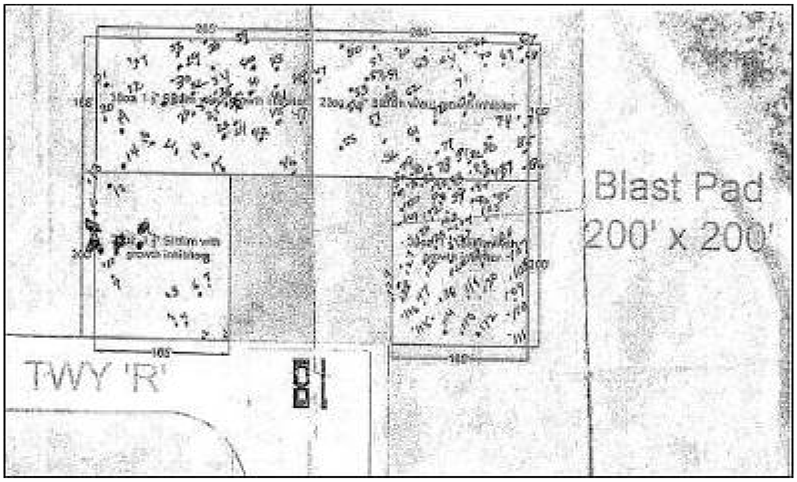


Figure 7. Locations of Numbered Burrows

2.4 ARTIFICIAL TURF CONSTRUCTION.

The artificial turf test section was comprised of four distinct plots of artificial turf, which included combinations of two different densities of synthetic turf fibers, i.e., less dense (22 oz) and more dense (38 oz), as well as treatment of a weed growth inhibitor additive. Figure 8 shows a side-by-side photograph of the two different turf densities. Each plot was adjacent to the blast pad pavement, as shown in figure 9.

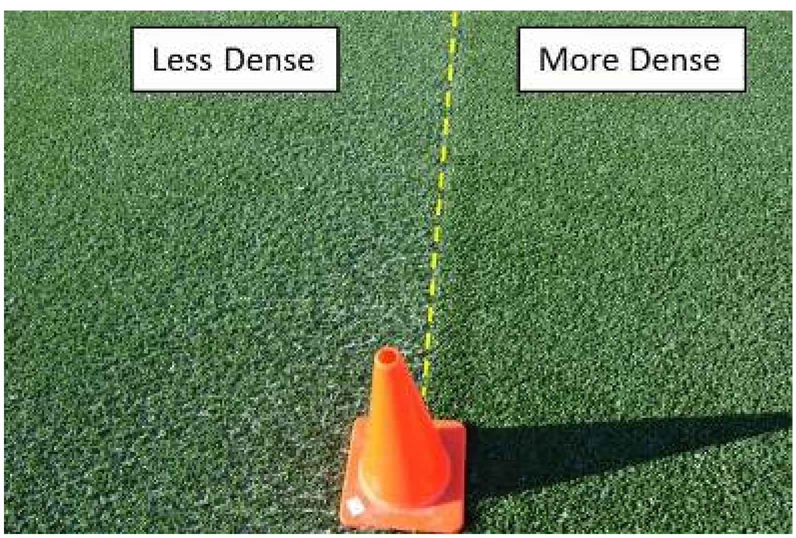
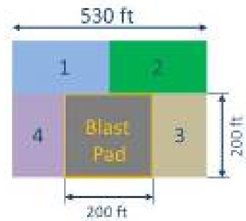


Figure 8. Closeup of the Two Different Turf Densities



Section	Length (ft)	Width (ft)	Total Area (sqft)	Remark
1	265	165	43,725	Heavy gage w/out Growth Inhibiter
2	265	165	43,725	Light gage w/out Growth Inhibiter
3	200	165	33,000	Heavy gage with Growth Inhibiter
4	200	165	33,000	Light gage with Growth Inhibiter

Figure 9. Test Plot Specification Table

The FAA Airport Technology R&D Branch entered into an Other Transaction Agreement (OTA) with the SAA to establish a mechanism for funding. The SAA hosted the artificial turf project and issued a request for proposal based on the FAA's study requirements. A kick-off meeting was held at SFB on September 19, 2013 to review roles and responsibilities of both parties and review bid documents. SAA oversaw the bid, review, and award process, as well as the construction and installation of system components, including site preparations and other necessary infrastructure work. The turf installation work was awarded to Pro Grass, LLC in partnership with AvTurf, LLC in January 2014. Construction began February 2014 and was completed in March 2014. The FAA was present for the final walk-through punch list on March 21, 2014.

An as-built drawing of the test plots is shown in figure 10, which shows plot dimensions, blade density, and whether weed growth inhibitor was applied.

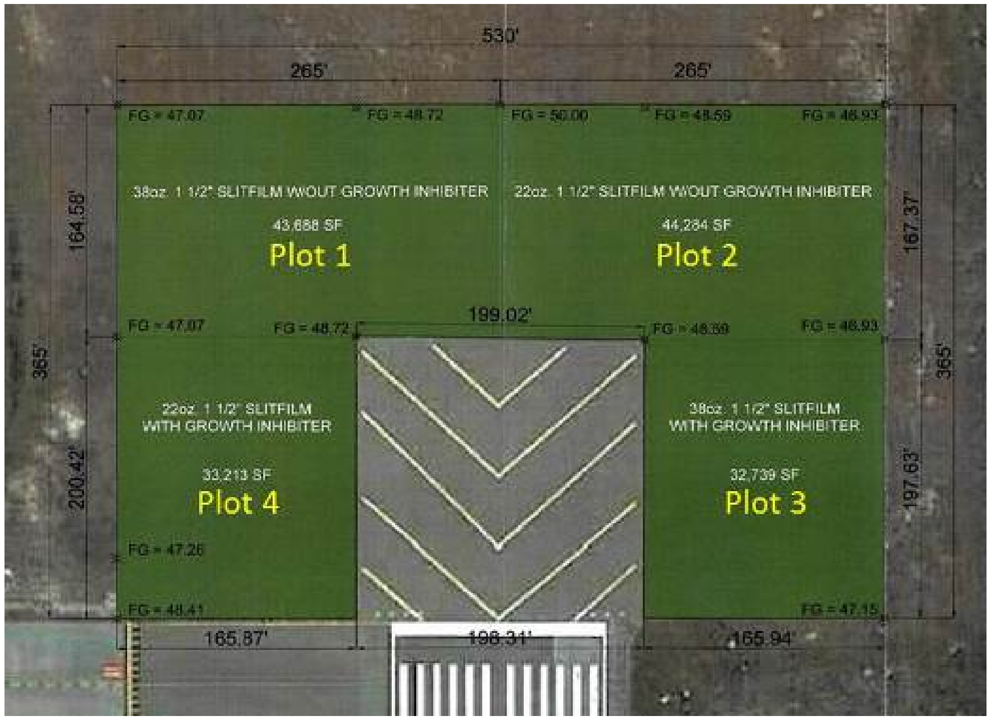


Figure 10. As-Built Drawing of Artificial Turf

Table 2 shows the dimensions and description of the artificial turf plots, which are numbered 1 through 4 clockwise beginning at the top left plot.

Table 2. Dimensions and Descriptions of Artificial Turf Plots

Plot Number	Length (ft)	Width (ft)	Total Area (sq. ft)	Description
1	265.0	164.58	43,688	38 oz slit film, no growth inhibitor
2	265.0	167.37	44,284	22 oz slit film, no growth inhibitor
3	165.94	197.63	32,739	38 oz slit film, with growth inhibitor
4	165.87	200.42	33,213	22 oz slit film, with growth inhibitor

Construction began in February 2014 with preparing the sub-base material, which included filling and grading the test area. After the preparation, the artificial turf system was installed.

3. DATA COLLECTION.

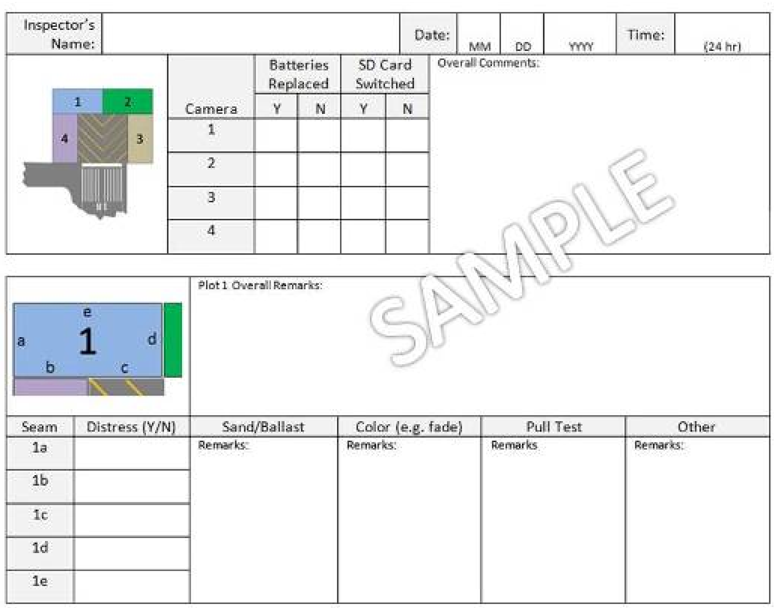
Data collection began on May 1, 2014 and ended on May 31, 2015. During the 1-year period, several objectives were studied on the artificial turf: durability and maneuverability, braking action and friction characteristics, and mitigation of gopher tortoise burrowing. The data collected consisted of reports completed by airport personnel, data from vehicle exposure, braking tests, and still photographs of gopher tortoises and other wildlife activity.

3.1 DURABILITY AND MANEUVERABILITY OF ARTIFICIAL TURF.

Airports are exposed to varying and sometimes harsh weather conditions. SFB, in particular, occasionally experiences average monthly rainfall and high temperatures of 7.24 inches and 91.5°F, respectively, between June and September [9]. Long periods of high humidity, direct sunlight, and occasional periods of torrential rainfall are some factors that can contribute to the detriment of susceptible materials, such as the artificial turf. Other factors may impact the life of artificial turf including jet blast forces from departing aircraft and occasional, and sometimes inadvertent, traversing of the RSA by vehicular traffic from Airport Operations (Ops) vehicles, including aircraft rescue and fire fighting (ARFF) trucks. While this study does not focus on the UV stability of the artificial turf material, the potential for color fading was one of the parameters monitored over the duration of the project.

3.1.1 Turf Condition Reports.

In accordance with the SAA Turf Monitoring Plan, provided in appendix B, airport personnel regularly inspected the turf plots to document the condition of the turf as exposed to normal daily, seasonal, climatic, and operational conditions. Every two weeks, SAA personnel conducted field examinations of the turf plots for signs of wear and/or damage with special attention to seams and perimeter edges where the turf interfaces with pavement. Each plot was inspected individually; several parameters were observed and recorded, including changes in color, distribution and displacement of sand ballast material, lift resistance, and vegetative growth. Additionally, the wildlife cameras were inspected during field examinations; batteries were checked for remaining power levels, and memory cards were replaced if found to be at full capacity. A form was created to make data collection easy and consistent, and the forms were submitted monthly to the FAA. A portion of a sample form is shown in figure 11. The data are summarized in tables 3 through 6.


Inspector's Name: | Date: MM DD YYYY | Time: (24 hr)

Camera	Batteries Replaced Y	Batteries Replaced N	SD Card Switched Y	SD Card Switched N
1				
2				
3				
4				

Overall Comments:

SAMPLE

Plot 1 Overall Remarks:

Seam	Distress (Y/N)	Sand/Ballast	Color (e.g. fade)	Pull Test	Other
1a		Remarks:	Remarks:	Remarks	Remarks:
1b					
1c					
1d					
1e					

Figure 11. Sample Data Form

Table 3. Plot 1 Summary of Inspection Results

Date	Seam Distress (Yes/No)					Ballast Displacement	Color Fade/Change	Lift Test	Vegetative Growth
	a	b	c	d	e				
4-29-2014	N	N	N	N	N	Consistent	No change	No give	Very minor spots
5-13-2014	N	N	N	N	N	Consistent	No change	No give	Minor in spots
5-27-2014	N	N	N	N	N	Consistent	No change	No give	Minor in spots
6-10-2014	N	N	N	N	N	Consistent	No change	No give	Minor, sprouting
6-24-2014	N	N	N	N	N	Consistent	No change	No give	Minor, sprouting
7-8-2014	N	N	N	N	N	Consistent, sand smoothed out from testing.	No change	No give	Minor, sprouting
7-22-2014	N	N	N	N	N	Consistent	No change	No give	More minor growth
8-5-2014	N	N	N	N	N	Consistent	No change	No give	Small patches of grass
8-19-2014	N	N	N	N	N	Consistent	No change	No give	Small patches of grass
9-2-2014	N	N	N	N	N	Consistent	No change	No give	Small patches of grass around edges
9-16-2014	N	N	N	N	N	Consistent	No change	No give	Minor, sprouting
9-30-2014	N	N	N	N	N	Consistent	No change	No give	Growth around edges and pavement
10-14-2014	N	N	N	N	N	Consistent	No change	No give	Growth around edges and pavement
10-28-2014	N	N	N	N	N	Consistent	No change	No give	Growth around edges and pavement
11-11-2014	N	N	N	N	N	Consistent	No change	No give	Growth around edges and pavement
11-25-2014	N	N	N	N	N	Consistent	No change	No give	Growth around edges and pavement
12-9-2014	N	N	N	N	N	Consistent	No change	No give	Minor growth
12-22-2014	N	N	N	N	N	Consistent	No change	No give	Minor growth
1-6-2015	N	N	N	N	N	Consistent	No change	No give	Minor growth
1-20-2015	N	N	N	N	N	Consistent	No change	No give	Edge growth
2-3-2015	N	N	N	N	N	Consistent	No change	No give	Edge growth
2-17-2015	N	N	N	N	N	Consistent	No change	No give	Edge growth
3-3-2015	N	N	N	N	N	Consistent	No change	No give	Edge growth
3-17-2015	N	N	N	N	N	Consistent	No change	No give	Edge growth
4-7-2015	N	N	N	N	N	Consistent	No change	No give	Edge growth
4-21-2015	N	N	N	N	N	Consistent	No change	No give	Minor weeds in seam 1D

Table 4. Plot 2 Summary of Inspection Results

Date	Seam Distress (Yes/No)					Ballast Displacement	Color Fade/Change	Lift Test	Vegetative Growth
	a	b	c	d	e				
4-29-2014	N	N	N	N	N	Consistent	No change	No give	None found
5-13-2014	N	N	N	N	N	Consistent	No change	No give	None found
5-27-2014	N	N	N	N	N	Consistent	No change	No give	None found
6-10-2014	N	N	N	N	N	Consistent	No change	No give	Minor sprouting
6-24-2014	N	N	N	N	N	Consistent	No change	No give	Minor sprouting
7-8-2014	N	N	N	N	N	Consistent	No change	No give	Minor grass along edges
7-22-2014	N	N	N	N	N	Consistent	No change	No give	More minor growth

Table 4. Plot 2 Summary of Inspection Results (Continued)

Date	Seam Distress (Yes/No)					Ballast Displacement	Color Fade/Change	Lift Test	Vegetative Growth
	a	b	c	d	e				
8-5-2014	N	N	N	N	N	Consistent	No change	No give	Small patches of grass
8-19-2014	N	N	N	N	N	Consistent	No change	No give	Small patches of grass near pavement
9-2-2014	N	N	N	N	N	Consistent	No change	No give	Small patches of grass near pavement
9-16-2014	N	N	N	N	N	Consistent	No change	No give	Larger patches around c and d edge
9-30-2014	N	N	N	N	N	Consistent	No change	No give	Larger patches of growth west side
10-14-2014	N	N	N	N	N	Consistent	No change	No give	Larger patches of growth west side
10-28-2014	N	N	N	N	N	Consistent	No change	No give	Edges and throughout
11-11-2014	N	N	N	N	N	Consistent	No change	No give	Edges and more throughout
11-25-2014	N	N	N	N	N	Consistent	No change	No give	Edges and more throughout
12-9-2014	N	N	N	N	N	Consistent	No change	No give	More grass growing up through turf
12-22-2014	N	N	N	N	N	Consistent	No change	No give	New grass growing up through turf
1-6-2015	N	N	N	N	N	Consistent	No change	No give	New grass growing up through turf
1-20-2015	N	N	N	N	N	Consistent	No change	No give	Larger patches of growth west side
2-3-2015	N	N	N	N	N	Consistent	No change	No give	Growth slowed
2-17-2015	N	N	N	N	N	Consistent	No change	No give	Weeds throughout
3-3-2015	N	N	N	N	N	Consistent	No change	No give	More growth throughout
3-17-2015	N	N	N	N	N	Consistent	No change	No give	More growth throughout
4-4-2015	N	N	N	N	N	Consistent	No change	No give	Heavy growth throughout
4-21-2015	N	N	N	N	N	Consistent	No change	No give	Weeds throughout

Table 5. Plot 3 Summary of Inspection Results

Date	Seam Distress (Yes/No)					Ballast Displacement	Color Fade/Change	Lift Test	Vegetative Growth
	a	b	c	d	e				
4-29-2014	N	N	N	N	N	Consistent	No change	No give	None found
5-13-2014	N	N	N	N	N	Consistent	No change	No give	None found
5-27-2014	N	N	N	N	N	Consistent	No change	No give	None found
6-10-2014	N	N	N	N	N	Consistent	No change	No give	None found
6-24-2014	N	N	N	N	N	Consistent	No change	No give	None found
7-8-2014	N	N	N	N	N	Consistent	No change	No give	Along edges
7-22-2014	N	N	N	N	N	Consistent	No change	No give	Along edges
8-5-2014	N	N	N	N	N	Consistent	No change	No give	None found (cut by airport maintenance)
8-19-2014	N	N	N	N	N	Consistent	No change	No give	Along edges
9-2-2014	N	N	N	N	N	Consistent	No change	No give	None found

Table 5. Plot 3 Summary of Inspection Results (Continued)

Date	Seam Distress (Yes/No)					Ballast Displacement	Color Fade/Change	Lift Test	Vegetative Growth
	a	b	c	d	e				
9-16-2014	N	N	N	N	N	Consistent	No change	No give	None found
9-30-2014	N	N	N	N	N	Consistent	No change	No give	Minor growth around edges
10-14-2014	N	N	N	N	N	Consistent	No change	No give	None found
10-28-2014	N	N	N	N	N	Consistent	No change	No give	Along edges
11-11-2014	N	N	N	N	N	Consistent	No change	No give	Along edges onto turf
11-25-2014	N	N	N	N	N	Consistent	No change	No give	Along edges onto turf
12-9-2014	N	N	N	N	N	Consistent	No change	No give	Along edges onto turf
12-22-2014	N	N	N	N	N	Very minor waves in turf	No change	No give	Along edges onto turf
1-6-2015	N	N	N	N	N	Very minor waves in turf	No change	No give	Along edges onto turf
1-20-2015	N	N	N	N	N	Consistent	No change	No give	Along edges onto turf
2-3-2015	N	N	N	N	N	Consistent	No change	No give	Along edges onto turf
2-17-2015	N	N	N	N	N	Consistent	No change	No give	Along edges onto turf
3-3-2015	N	N	N	N	N	Consistent	No change	No give	Along edges onto turf
3-17-2015	N	N	N	N	N	Consistent	No change	No give	Along edges onto turf
4-7-2015	N	N	N	N	N	Consistent	No change	No give	Along edges onto turf
4-21-2015	N	N	N	N	N	Consistent	No change	No give	Along edges onto turf

Table 6. Plot 4 Summary of Inspection Results

Date	Seam Distress (Yes/No)					Ballast Displacement	Color Fade/Change	Lift Test	Vegetative Growth
	a	b	c	d	e				
4-29-2014	N	N	N	N	N	Consistent	No change	No give	None found
5-13-2014	N	N	N	N	N	Consistent	No change	No give	None found
5-27-2014	N	N	N	N	N	Consistent	No change	No give	Minor
6-10-2014	N	N	N	N	N	Consistent	No change	No give	None found
6-24-2014	N	N	N	N	N	Minor sand build-up due to water ponding and draining off in area	No change	No give	None found
7-8-2014	N	N	N	N	N	Consistent	No change	No give	None found
7-22-2014	N	N	N	N	N	Consistent	No change	No give	Along edges
8-5-2014	N	N	N	N	N	Minor sand build-up due to water ponding and draining off in area	No change	No give	Along edges
8-19-2014	N	N	N	N	N	Washout filled in	No change	No give	None found
9-2-2014	N	N	N	N	N	Consistent	No change	No give	None found
9-16-2014	N	N	N	N	N	Consistent	No change	No give	None found
9-30-2014	N	N	N	N	N	Consistent	No change	No give	Growth around edges
10-14-2014	N	N	N	N	N	Minor build-up of sand around sign	No change	No give	Growth around edges
10-28-2014	N	N	N	N	N	Minor build-up of sand around sign	No change	No give	Growth around edges
11-11-2014	N	N	N	N	N	Small amount of sand around sign pads	No change	No give	Growth around edges

Table 6. Plot 4 Summary of Inspection Results (Continued)

Date	Seam Distress (Yes/No) a	b	c	d	e	Ballast Displacement	Color Fade/Change	Lift Test	Vegetative Growth
11-25-2014	N	N	N	N	N	Consistent	No change	No give	Growth around edges
12-9-2014	N	N	N	N	N	Minor sand ponding	No change	No give	Growth around edges
12-22-2014	N	N	N	N	N	Minor sand ponding	No change	No give	Growth around edges
1-6-2015	N	N	N	N	N	Minor sand ponding	No change	No give	Growth around edges
1-20-2015	N	N	N	N	N	Minor sand ponding	No change	No give	Growth around edges
2-3-2015	N	N	N	N	N	Sand smoothed out on its own	No change	No give	Growth around edges
2-17-2015	N	N	N	N	N	Minor sand/ballast ponding around lights and signs	No change	No give	Growth around edges
3-3-2015	N	N	N	N	N	Sand seems smoother around light and signs	No change	No give	Growth around edges
3-17-2015	N	N	N	N	N	Consistent	No change	No give	Growth around edges
4-7-2015	N	N	N	N	N	Minor sand ponding	No change	No give	Growth around edges
4-21-2015	N	N	N	N	N	Minor sand ponding	No change	No give	Growth around edges

The FAA conducted a final site inspection on May 14, 2015. Consistent with the data presented above, vegetation growth was the only difference in appearance since installation. As expected, plots 3 and 4 had significantly less vegetation growth throughout the study period due to the addition of the growth inhibitor. Most of the growth in these plots was around the edges and onto the artificial turf. Plot 2 had more vegetation growth than plot 1, perhaps due to the thinner slit film. SAA performed regular grass cutting maintenance in areas adjacent to the artificial turf installation. None of the seams showed signs of distress. Ballast/sand displacement was consistent in all plots for a majority of the study. One exception was noted in plot 4. It is hypothesized that during periods of heavy rains, water would pond in areas of plot 4 and relocated some of the sand as it drained. The sand also gathered around the sign and light bases located in the plot. Over time, the sand smoothed and redistributed on its own. The color and appearance of the artificial turf did not change over time.

3.1.2 Vehicle Maneuverability Tests.

In July 2014, the FAA research team traveled to SFB for testing. To test the artificial turf's maneuverability, common types of airport vehicles were maneuvered around the artificial turf test area under normal vehicle passage conditions, e.g., normal speeds, turning, and normal braking. An Ops truck (Ford® F-150) and an ARFF vehicle (Oshkosh® Striker® 3000) were used as test vehicles. Both vehicles also performed turns and normal braking to a stop on the turf. No damage was observed during these tests. Figure 12 depicts the Ops and ARFF vehicles during the dry maneuverability tests.

Figure 12. The Ops Truck and ARFF Vehicle in Dry Maneuverability Tests

3.2 BRAKING ACTION AND FRICTION CHARACTERISTICS VEHICLE TEST AND RESULTS.

The second objective in the data collection phase was to assess the turf's braking action and friction characteristics with actual vehicles and aircraft tires. Again, common airport vehicles were used to test vehicle braking action and friction characteristics. The use of an actual aircraft was not feasible, yet a specialized vehicle that met the objectives of the tests was identified to represent certain aircraft weights. Team Eagle, Ltd.'s Braking Availability Tester (BAT) vehicle was identified as having the capability of inducing scalable aircraft loads and representative pressures, as well as aircraft antiskid braking systems (ASBSs) in the form of a standard passenger vehicle. The BAT vehicle was developed to test how an aircraft's ASBS reacts to contaminants on airport surfaces.

The BAT vehicle uses an actual aircraft tire inflated up to 180 psi, which is equivalent to an Airplane Design Group-II Gulfstream G280 nose tire and rated at 4350 psi. The tire is mounted on the underside of a pickup truck and can deliver up to 2700 psi of downward force. According to Team Eagle, Ltd., "During operation, ballast from the BAT chassis is transferred to the BAT aircraft tire to produce a scaled tire patch with equivalent tire/ground contact pressure to a referenced aircraft. The braking forces are then measured in the BAT using embedded sensors and then are extrapolated into the actual braking forces that an aircraft will see if maximum braking is applied by the reference aircraft landing or during an aborted takeoff" [10].

3.2.1 Airport Vehicle Tests.

In this series of tests, the Ops truck began at the RSA boundary line (30 feet left of the runway centerline), accelerated up to a designated speed (20 mph, 30 mph, and 40 mph, respectively), and drove straight through the blast pad onto the turf. The vehicle began braking at 22 feet past the runway threshold and came to a stop prior to exiting the turf at the backside. Next, the ARFF vehicle, weighing approximately 81,700 pounds, followed the same maneuvers as the Ops truck, but at slower speeds. The designated braking area for the ARFF vehicle was 47 feet past the runway threshold. No damage was observed on the artificial turf during these tests except for two small ripples less than 1 inch in height, which surfaced in front of the ARFF vehicle during run 8. The ripples flattened as the ARFF vehicle exited the area. Additionally, as the vehicles passed over the turf during each test run, some sand infill material kicked up behind the tires, as shown in figure 13. The sand accumulated on the surface of the artificial turf in the wheel paths.

After the dry vehicle braking runs were completed, the tire paths were swept with a push broom to push the sand infill material back into place among the base of the synthetic fiber turf blades.

Figure 13. Sand Infill Material Displacement From Ops Truck Passage

The turf condition, turf density, vehicle speed, run duration, vehicle stopping distance, and damage were recorded for the ten vehicle runs on dry turf, as shown in table 7.

Table 7. Data Collected During Vehicle Braking Action and Friction Characteristics Tests Under Dry Conditions

Run No.	Vehicle	Turf Density	Speed (mph)	Duration (seconds)	Stopping Distance (ft)	Damage
1	Ops truck	Heavy–left side	20	20.26	42	None
2	Ops truck	Heavy–left side	30	11.46	71	None
3	Ops truck	Light–right side	20	19.16	48	None
4	Ops truck	Light–right side	30	12.32	75	None
5	Ops truck	Heavy–left side	40	14.20	101	None
6	Ops truck	Light–right side	40	11.68	109	None
7	ARFF vehicle	Heavy–left side	15	19.71	22	None

Table 7. Data Collected During Vehicle Braking Action and Friction Characteristics Tests Under Dry Conditions (Continued)

Run No.	Vehicle	Turf Density	Speed (mph)	Duration (seconds)	Stopping Distance (ft)	Damage
8	ARFF vehicle	Light–right side	15	17.06	13	Two small ripples (less than 1 in.) in front of front tires. Flattened when exited.
9	ARFF vehicle	Heavy–left side	30	17.96	71	None
10	ARFF vehicle	Light–right side	30	18.56	68	None

The testing area was then prepared for wet braking conditions. An ARFF vehicle used an overhead boom to apply 3000 gallons of water to the artificial turf test sections to create a flooded condition representative of a significant passing rain shower. Figure 14 shows the ARFF vehicle spraying the test area and the flooded condition immediately following.

Figure 14. Water Application to Artificial Turf Test Sections

The Ops truck and the ARFF vehicle repeated the same braking tests on the wet artificial turf as described for the dry braking tests. Table 8 shows the results of the artificial turf test runs under wet conditions for the Ops truck and ARFF vehicle. In one instance, the ARFF vehicle caused small ripples in front of the tires similar to what occurred during the dry tests. During one of the faster runs, small ruts were created in the artificial turf, and significant sand infill was dislodged, as shown in figure 15.

Table 8. Data Collected During Braking Action and Friction Characteristics Tests Under Wet Conditions

Run No.	Vehicle	Turf Density	Speed (mph)	Duration (seconds)	Stopping Distance (ft)	Damage
11	Ops truck	Heavy–left side	20	11:09	45	None
12	Ops truck	Light–right side	20	11:11	54	None
13	Ops truck	Heavy–left side	30	11:13	71	None
14	Ops truck	Light–right side	30	11:15	80	None
15	Ops truck	Heavy–left side	40	11:18	118	None
16	Ops truck	Light–right side	40	11:22	112	None
17	ARFF vehicle	Heavy–left side	15	11:30	18	Ripple in front of left front tire, less rippling on right front tire.
18	ARFF vehicle	Light–right side	15	11:34	11	None
19	ARFF vehicle	Heavy–left side	30	11:37	54	Small ruts from tires, a lot of sand infill dislodged.
20	ARFF vehicle	Light–right side	30	11:41	66	None

Figure 15. The Ops Truck and ARFF Vehicle During Wet Friction Tests

3.2.2 The BAT Vehicle and Aircraft Simulation.

In the third set of tests, the BAT vehicle was used to collect, package, and analyze data to assess artificial turf in a variety of scenarios to simulate aircraft under both dry and wet conditions. The data collected by the BAT vehicle included: vertical load, horizontal load, brake torque, brake pressure, ASBS servo amps, pedal, ASBS antiskid signal, ASBS mode, and wheel speed.

The BAT vehicle test runs were designed so the vehicle would traverse both densities of turf in a single run. The test lane configuration is shown in figure 16. Two test lanes, right and left, were established. Each test lane included acceleration zones (shaded blue in figure 16) that enabled the BAT vehicle to achieve the target entrance speeds. For the right test lane, the BAT vehicle accelerated from a stopped position at the southeast corner of the RSA boundary line and drove diagonally to the southwest corner of the turf at the RWY 18 threshold. The vehicle then stopped accelerating and maintained speed throughout the purple portion of the lane. An orange traffic cone was placed at the end of the purple zone to designate the beginning of the braking zone. Braking was conducted within the orange braking zone until the BAT vehicle came to a complete stop. Figure 17 shows the aircraft wheel chassis mounted under the truck during braking (circled in red).

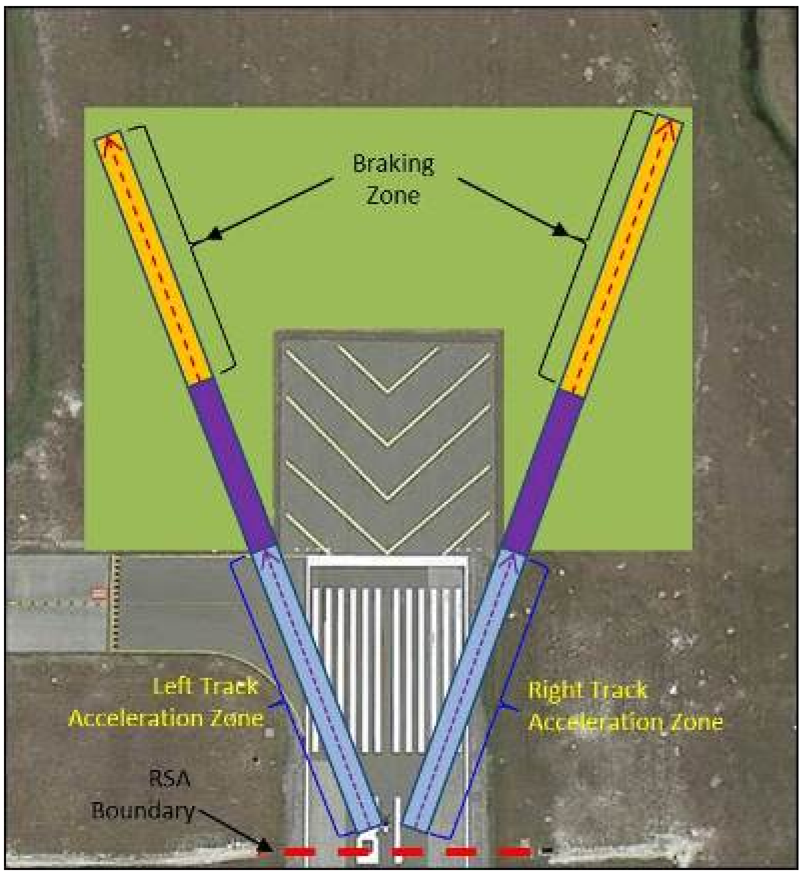


Figure 16. The BAT Vehicle Braking Action and Friction Characteristics Test Lane Configurations

Figure 17. The BAT Vehicle Aircraft Wheel Chassis During Testing

Several variables were introduced: vertical load of 1900 lb and 2600 lb, speed, with and without aircraft wheel braking, and wet and dry conditions. The nose gear tire was inflated to 185 psi. Figure 18 depicts the BAT vehicle during dry braking action and friction characteristics test, and figure 19 shows the BAT vehicle during wet braking action and friction characteristics tests. For each run, stopping distance was recorded and no damage was observed. The results are listed in table 9.

Figure 18. The BAT Vehicle During Dry Braking Action and Friction Characteristics Tests

Figure 19. The BAT Vehicle During Wet Braking Action and Friction Characteristics Tests

Table 9. Data Collected During BAT Vehicle Braking Action and Friction Characteristics Tests Under Dry and Wet Conditions

Run No.	Vehicle	Conditions	Turf Starting Point	Speed (mph)	Braking (aircraft wheel)	Vertical Load (lb)	Stopping Distance (ft)	Damage
21	BAT	Dry	Left side	30	No	2600	169	None
22	BAT	Dry	Left side	30	Yes	2600	152	None
23	BAT	Dry	Left side	40	Yes	2600	135	None
24	BAT	Dry	Left side	50	Yes	2600	90	None
25	BAT	Dry	Right side	30	No	2600	143	None
26	BAT	Dry	Right side	30	Yes	2600	128	None
27	BAT	Dry	Right side	40	Yes	2600	98	None
28	BAT	Dry	Right side	50	Yes	2600	131	None
29	BAT	Dry	Left side	30	No	1900	107	None
30	BAT	Dry	Left side	30	Yes	1900	83	None
31	BAT	Dry	Left side	40	Yes	1900	100	None
32	BAT	Dry	Left side	50	Yes	1900	117	None
33	BAT	Dry	Right side	30	No	1900	108	None
34	BAT	Dry	Right side	30	Yes	1900	96	None
35	BAT	Dry	Right side	40	Yes	1900	90	None
36	BAT	Dry	Right side	50	Yes	1900	136	None
37	BAT	Wet	Right side	40	Yes	2600	161	None
38	BAT	Wet	Right side	40	Yes	2600	136	None

The results of the BAT vehicle testing were provided by Team Eagle, Ltd. The results of each individual run can be found in appendix C. A summary of Team Eagle, Ltd.'s analysis was delivered in a letter to the FAA on September 24, 2014, and indicates the following.

"1. Typically 3 seconds of constant speed braking of the BAT wheel was possible before the truck needed to slow to avoid running off the turf.

2. After initial application of the BAT brake, the ASBS system takes approximately 1 second to stabilize.

3. In all runs (braking and non-braking), there are spikes of horizontal load occurring at approximately 10 Hz, that seem to begin on entering the turf.

4. These horizontal load spikes may be related to simultaneous noise and spikes of a similar frequency in the wheel speed traces.

5. The above-mentioned spikes may be caused by the BAT wheel running over the soft substrate (sand) found under the turf.

6. The ASBS of the BAT is actively acting to modify braking, as evidenced by the changing servo amps and brake pressure.

7. There seems to be some correlation between vertical load (high vs. low) and the horizontal loads and brake pressures measured.

8. The characteristic "saw-tooth" pattern of anti-skid limited braking seen in winter testing does not appear in these data sets.

9. As per #8 above, we did not experience any low/no braking situations with the artificial turf. In fact, the turf appeared to provide reasonable braking capability." [11]

3.3 MITIGATION OF GOPHER TORTOISE BURROWING.

The following sections focus on the assessment of artificial turf as a method for protecting the RSA from damage caused by burrowing turtles. The information was gathered through the installation of cameras and analysis of the still photographs collected.

3.3.1 Camera Installation.

Four wildlife cameras were installed at locations along the perimeter of the artificial turf adjacent to the blast pad, which provided perspectives from the northwest, north, northeast, and southeast. Figure 20 shows the locations of each camera represented by red dots and lightly shaded overlays to show the field of view of each camera with respect to the artificial turf plots.

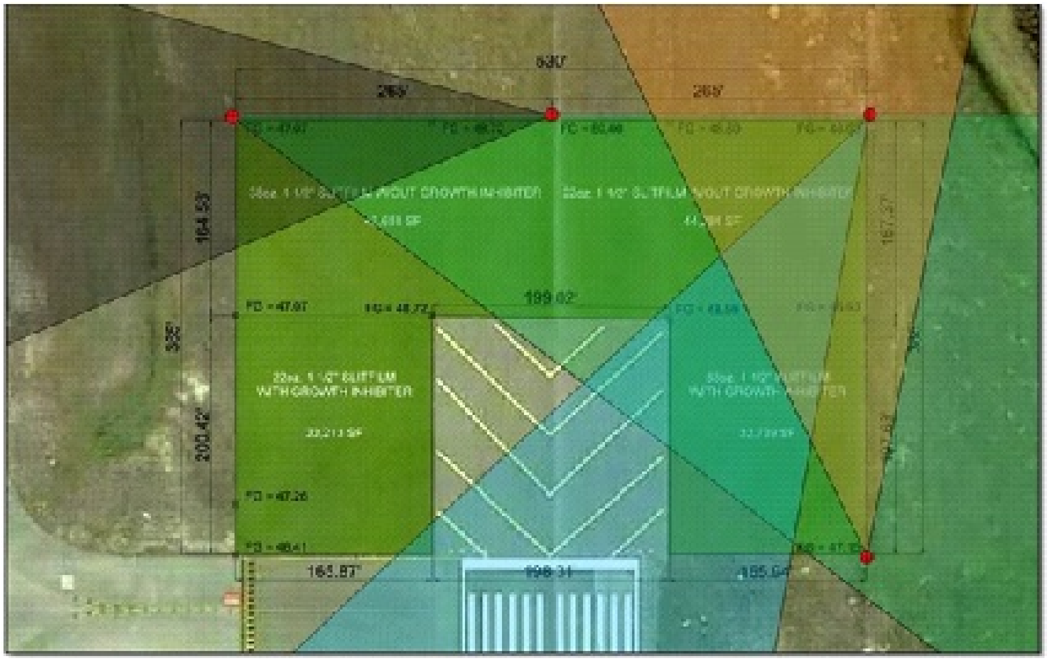


Figure 20. Location of Wildlife Cameras Surrounding Artificial Turf Plots

The cameras ran continuously on rechargeable batteries and recorded photographs of movement, including the intended gopher tortoise targets. Analyses of the photo database were limited to the scope and objectives of this project, i.e., a focus on gopher tortoise activity to assess the mitigating effect artificial turf may have on gopher tortoise burrowing activity.

Each camera recorded still images onto SanDisk® secure digital (SD) card removable media according to the configuration of the cameras. During this project, the cameras were configured to take two pictures of any movement that triggered the motion sensor on the camera. The time interval between pictures was set at 3 seconds. After two photos were recorded, a pause setting was configured that reduced the number of photos captured and stored of the same activity.

On biweekly basis during the study, personnel from SAA checked the storage capacity of each SD card and replaced it with a blank SD card when necessary. The files from each SD card were then downloaded to a server via file transfer protocol (FTP). SAA then notified the FAA via email that the files were updated on the server, and FAA personnel used FileZilla® file management software to download the files to a local drive.

3.3.2 Camera Data Analysis.

Each image file was visually inspected for activity. Activity types included presence of animals, vehicles, and humans. Images with such activity were saved to a folder named Keepers and organized by type.

Subsequently, the images in the Keeper folder were compiled into a Microsoft® Excel® spreadsheet for further analysis. The spreadsheet comprised separate tabs for each camera as well as a separate corresponding tab that contained the non-animal images. The images were grouped according to the species identified in the picture. For all non-gopher tortoise species that were captured, only the total number of species was computed for example, if an image showed seven cattle egrets, it was only counted as one photo of cattle egret as opposed to a photo of seven cattle egrets. Individual animals in the pictures were not tallied, although the dataset would accommodate that analysis in the future.

The breakdown of species and number of images captured by each picture is presented in table 10. Figures 21 and 22 show some of the images captured by the wildlife cameras, including both non-gopher tortoise species and gopher tortoise.

Table 10. Number of Images per Camera Listed by Species

Species	NECAMS2	NOCAMS1	NWCAMS1	SECAMS3	Total
Blackbirds	0	0	0	2	2
Caracara	7	5	0	7	19
Cattle Egret	11	18	9	11	49
Coyote	31	17	61	9	118
Fish Crow	4	0	0	0	4
Gopher Tortoise	184	25	47	15	271
Great Blue Heron	2	0	0	0	2
Hawk	3	0	0	0	3
Opossum	4	0	0	0	4
Sandhill Crane	0	6	4	2	12
Caracara and Gopher Tortoise	2	0	0	0	2
Totals	248	71	121	46	486

Figure 21. Non-Gopher Tortoise Camera Image Samples

Figure 22. Gopher Tortoise Camera Image Samples

Identifying individual gopher tortoises was difficult because ensuring that a particular gopher tortoise was not double counted was not possible; the same gopher tortoise may have been captured simultaneously by separate cameras. Therefore, for gopher tortoise activity, the number of images was totaled as well as best estimates of how many actual separate events took place. An event was defined as a close series of images that, based on timestamp and the image itself, clearly show that the images depict the same activity. So although two or more images may exist, they would only represent a single event if the timestamp and images were consistent with a single event.

Analysis of the gopher tortoise activity yielded a breakdown of the individual photos of gopher tortoises and a best estimate of the number of events that those photos captured. Table 11 shows that breakdown.

Table 11. Number of Photos of Gopher Tortoises With Corresponding Number of Events

Wildlife Camera Name	Number of Photos	Number of Events
NECAMS2	184	47
NOCAMS1	25	14
NWCAMS1	47	16
SECAMS3	15	9
Total	271	86

4. CONCLUSIONS.

This study was intended to determine the applicability of artificial turf in the runway safety areas (RSAs) to improve conditions that have been impacted by burrowing gopher tortoises. The study also investigated the durability of the artificial turf system located in the harsh operational environment of the runway end. The results of over a year of data collection indicate that the implementation of artificial turf that meets the specifications set forth in Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5370-15B is a viable safety improvement alternative to RSAs that have potentially unsafe conditions due to gopher tortoise burrowing. In consideration of each of the project objectives, the conclusions are presented below.

The first objective was to assess the effectiveness of artificial turf to protect the RSA area from damage caused by burrowing gopher tortoises. Wildlife cameras were placed on the perimeter of the artificial turf test sections and recorded 271 images of gopher tortoises walking on the artificial turf; additionally, 215 images of activity from 9 other species were captured. Despite the pre-installation levels of gopher tortoise activity recorded on camera near the blast pad, inspections of the artificial turf condition throughout the course of the study showed no indication that the tortoises attempted, or were successful in reestablishing burrows within the areas. Based on those findings, it can be concluded that artificial turf provides a suitable level of exclusion against gopher tortoise burrowing, specifically within the RSA. Additionally, analysis of the total level of activity by all species indicates that artificial turf does not constitute an attractant to hazardous wildlife species. Finally, it was determined that the artificial turf did not allow gopher tortoises to breach the surface to create new burrows, did not provide an attractant to hazardous species, and did not prohibit gopher tortoises from accessing runways and other movement surfaces. Artificial turf may provide a deterrent to burrowing animals in an RSA, but additional/improved exclusion controls must be considered to reduce access to the airfield or movement areas.

The second objective was to assess the environmental durability of the artificial turf including exposure to jet blast forces and general environmental factors such as wind, rain, ultraviolet exposure, etc., as well as the occasional traffic from airport vehicles. This objective was achieved by regular, periodic, visual and tactile inspections of the artificial turf condition. The results support the conclusion that, over the course of 14 months, the artificial turf material did not exhibit any indications of deterioration due to the passive environmental forces exerted upon it. As for durability under the forces exerted by the passage of operational vehicles, including aircraft rescue and fire fighting (ARFF) vehicles, one test resulted in the fully loaded ARFF vehicle tires pushing the artificial turf to a minimal extent, which recovered to pretest condition immediately after removing the load. The artificial turf proved to be ultimately resilient.

The final objective addressed operational safety concerns with respect to potential hazards that an artificial turf surface could present to vehicles and aircraft that travel across it, whether purposefully or inadvertently, in an emergency. Specifically, would wet artificial turf located in the RSA pose a safety hazard to aircraft or vehicles by reducing braking action through decreased levels of interfacial friction for the tires. The results of tests using vehicles and the specialized antiskid aircraft braking system on the Team Eagle, Ltd. Braking Availability Tester (BAT) vehicle were conclusive for the given weights and tire pressures. Under both wet and dry conditions, the artificial turf did not present any low-braking nor no-braking conditions, such as would be experienced during braking on runways contaminated with significant winter contaminants. During all test runs, the BAT vehicle achieved target entrance speeds and was able to fully decelerate to a stop within the artificial turf test sections.

Given the results and conclusions of these studies, artificial turf that meets the specifications set forth in FAA AC 150/5370-15B is a viable mitigating solution to unsafe conditions that could be present from active burrowing of gopher tortoises. Implementation of artificial turf within the RSA has been demonstrated under test conditions to be compatible with the safe operation of the airport, including exposure to inadvertent excursions of aircraft and operational vehicles.

5. REFERENCES.

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6. Florida Fish and Wildlife Conservation Commission, http://myfwc.com/media/1329739/GopherTortoise_LivingWithBrochure.pdf, (date last visited 05/16/13).

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APPENDIX A—BURROW DATA BEFORE ARTIFICIAL TURF INSTALLATION

Table A-1 shows the gopher tortoise burrow data collected at Orlando Sanford International Airport before artificial turf installation.

Table A-1. Burrow Data Before Artificial Turf Installation

Count	Length (feet)	Status	Age	Notes
1	8	Abandoned		
2	13	Active	Adult	
3	5	Abandoned		
4	5	Active	Immature	
5	12	Active	Immature	
6	0	Abandoned		
7	12	Active	Adult	
8	0	Abandoned	Immature	
9	7	Active	Immature	
10	8	Active	Immature	
11	9	Active	Immature	
12	16	Active	Adult	
13	8	Active	Adult	
14	5	Active	Immature	
15	0	Abandoned		
16	13	Active	Adult	
17	11	Active	Immature	
18	11	Active	Immature	
19	9	Active	Immature	
20	8	Inactive	Adult	
21	12	Active	Adult	
22	4	Inactive	Immature	
23	10	Inactive	Adult	
24	15	Active	Adult	
25	8	Inactive	Adult	
26	10	Inactive	Adult	
27	12	Inactive	Adult	
28	11	Inactive	Adult	
29	12	Active	Adult	
30	7	Inactive	Adult	
31	14	Inactive	Adult	
32	11	Inactive	Adult	
33	7	Active	Immature	

Table A-1. Burrow Data Before Artificial Turf Installation (Continued)

Count	Length (feet)	Status	Age	Notes
34	13	Active	Adult	
35	12	Active	Immature	
36	13	Active	Adult	
37	12	Active	Adult	
38	8	Active	Adult	
39	17	Active	Adult	
40	22	Active	Adult	
41	17	Active	Adult	
42	4	Inactive	Adult	
43	21	Active	Adult	
44	15	Active	Adult	
45	15	Active	Adult	
46	17	Active	Adult	
47	18	Inactive	Adult	
48	12	Active	Immature	
49	21	Active	Adult	
50	13	Active	Adult	
51	12	Active	Adult	
52	18	Active	Adult	
53	6	Abandoned	Adult	
54	3	Inactive	Immature	
55	14	Active	Adult	
56		None		
57	17	Active	Adult	
58	11	Active	Immature	
59	8	Active	Immature	
60	12	Active	Adult	
61	13	Active	Immature	
62	12	Active	Adult	
63	7	Inactive	Immature	
64	9	Active	Immature	
65	12	Active	Immature	
66	15	Active	Adult	
67	8	Inactive	Adult	
68	18	Active	Adult	
69	6	Abandoned	Immature	
70	13	Inactive	Adult	
71	6	Abandoned	Adult	
72	18	Active	Adult	

Table A-1. Burrow Data Before Artificial Turf Installation (Continued)

Count	Length (feet)	Status	Age	Notes
73	16	Active	Adult	
74	5	Abandoned	Adult	
75	16	Active	Adult	
76	18	Active	Adult	
77	5	Active	Immature	
78	16	Active	Adult	
79	5	Active	Immature	
80	18	Inactive	Adult	
81	6	Active	Immature	
82	14	Active	Adult	
83	13	Active	Immature	
84	16	Active	Adult	
85	11	Inactive	Adult	
86	0	Abandoned	Adult	
87	12	Active	Adult	
88	5	Inactive	Adult	
89	6	Active	Immature	
90	9	Active	Immature	
91	6	Inactive	Immature	
92	5	Inactive	Immature	
93	16	Active	Adult	
94	8	Active	Immature	
95	4	Abandoned	Immature	
96	10	Active	Immature	
97	0	Abandoned	Immature	
98	4	Active		Snake
99	19	Active	Adult	
100	15	Active	Adult	
101	6	Inactive	Adult	
102	4	Active	Immature	
103	8	Inactive	Immature	
104	6	Abandoned	Adult	
105	0	Abandoned	Adult	
106	6	Inactive	Immature	
107	13	Active	Adult	
108	8	Active	Immature	
109	6	Active		Multiple, no scope
110	10	Active	Adult	
111	9	Active	Immature	

Table A-1. Burrow Data Before Artificial Turf Installation (Continued)

Count	Length (feet)	Status	Age	Notes
112		None		
113	8	Active	Adult	
114	13	Active	Adult	
115	10	Active	Adult	
116	6	Inactive	Adult	
117	12	Active	Adult	
118	10	Active	Immature	
119	6	Active	Immature	
120	12	Inactive	Adult	
121	10	Abandoned	Adult	
122	0	Abandoned	Adult	
123	11	Active	Immature	
124	6	Active	Immature	
125	9	Active	Immature	
126	12	Active	Adult	
127	12	Active	Immature	
128	15	Active	Adult	
129	4	Active	Immature	

APPENDIX B—ORLANDO SANFORD INTERNATIONAL AIRPORT AUTHORITY TURF-MONITORING PLAN

The Federal Aviation Administration (FAA) Airport Technology Research and Development (R&D) Branch requirements for Orlando Sanford International Airport's gopher tortoise and artificial turf project are listed in figure B-1.

Orlando Sanford International Airport

FAA Airport Safety R & D Section Project Requirements

Monitoring Gopher Tortoise Activity in and around Artificial Turf Installed on Runway 18 Approach

The following numbered descriptions will correspond to the numbers on the attached calendar.

1. Gopher Tortoise activity monitoring – on Tuesday of each week, observe the artificial turf and a 50-foot area surrounding the artificial turf and record your observations on the Biweekly Monitoring Data Sheet
2. Artificial Turf condition monitoring – on Tuesday of each week, conduct visual observations of the Artificial Turf and record your observations on the Biweekly Monitoring Data Sheet – photographs of any issues discovered should be taken and kept with that days report
3. Photographs – on the first Tuesday of each month take photos of the turf as indicated in the Test Plan provided by the FAA R & D Section
4. Field Camera Battery Checks – check and log the condition of the Field Camera batteries each Tuesday
5. Field Camera SD Card Checks – check the remaining pictures available of each SD card in each Field Camera each Tuesday – change as necessary and upload to the FTP site
6. Field Camera Battery Replacement – Beginning with April 29^{th}, 2014, replace the batteries in the field cameras every third Tuesday. If this needs to be accomplished more often, please notify George Speake so that the calendars can be adjusted.
7. Anytime that any Operations personnel are in the vicinity of the turf installation and can make an observation of wildlife activity, please do so to ensure we get as much data as possible. All observations should be noted in the Airport Wildlife Database.

Figure B-1. The FAA R&D Requirements for Orlando Sanford International Airport's Gopher Tortoise and Artificial Turf Project

APPENDIX C—TEAM EAGLE, LTD. DATA FOR INDIVIDUAL RUNS

The results of the Braking Availability Tester (BAT) vehicle tests were provided by Team Eagle, Ltd. The following figures show the results of each individual run.

Tire pressure: 175 psi

RUN	Side of turf	Target Speed (mph)	Vertical Load (lb)	BAT Brake (Y/N)	WET / DRY	Time
1	left	30	High	N	DRY	11:32 AM
2	left	30	High	Y	DRY	11:30 AM
3	left	40	High	Y	DRY	11:40 AM
4	left	50	High	Y	DRY	11:45 AM
5	right	30	High	N	DRY	11:50 AM
6	right	30	High	Y	DRY	11:55 AM
7	right	40	High	Y	DRY	11:57 AM
8	right	50	High	Y	DRY	12:00 PM
9	left	30	Low	N	DRY	12:22 PM
10	left	30	Low	Y	DRY	12:27 PM
11	left	40	Low	Y	DRY	12:29 PM
12	left	50	Low	Y	DRY	12:33 PM
13	right	30	Low	N	DRY	12:06 PM
14	right	30	Low	Y	DRY	12:10 PM
15	right	40	Low	Y	DRY	12:14 PM
16	right	50	Low	Y	DRY	12:18 PM
17	right	40?	Low	Y	WET	12:45 PM
18	right	40?	Low	Y	WET	12:48PM

Figure C-1. Data for BAT Vehicle Runs

Side	left
Target Speed (fps)	44.1
Vertical load (lb)	High
Brake (Y/N)	N
Wet/Dry	Dry

1

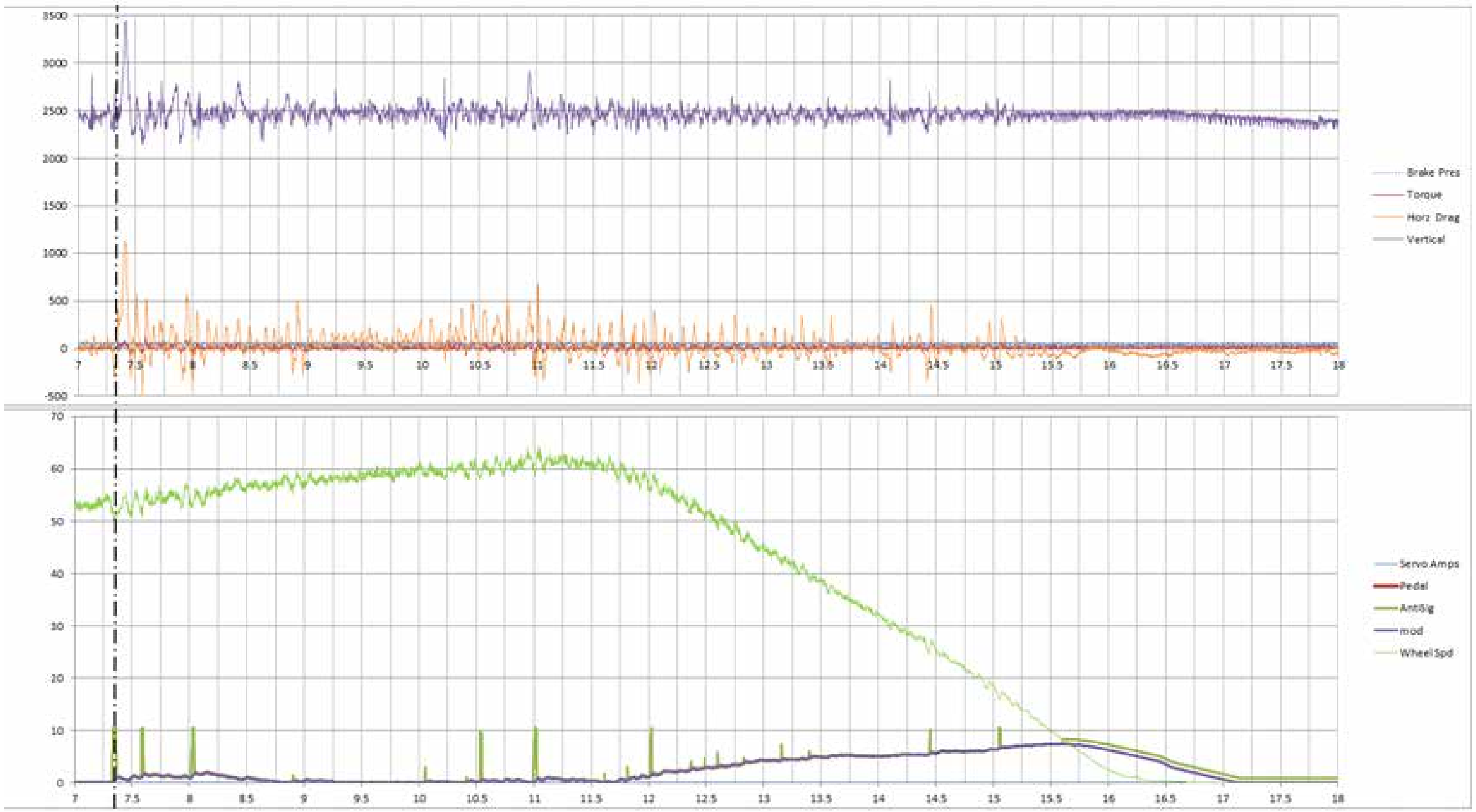

Figure C-2. Test Run 1 Data From the BAT Vehicle

Side	left
Target Speed (fps)	44.1
Vertical load (lb)	High
Brake (Y/N)	Y
Wet/Dry	Dry

2

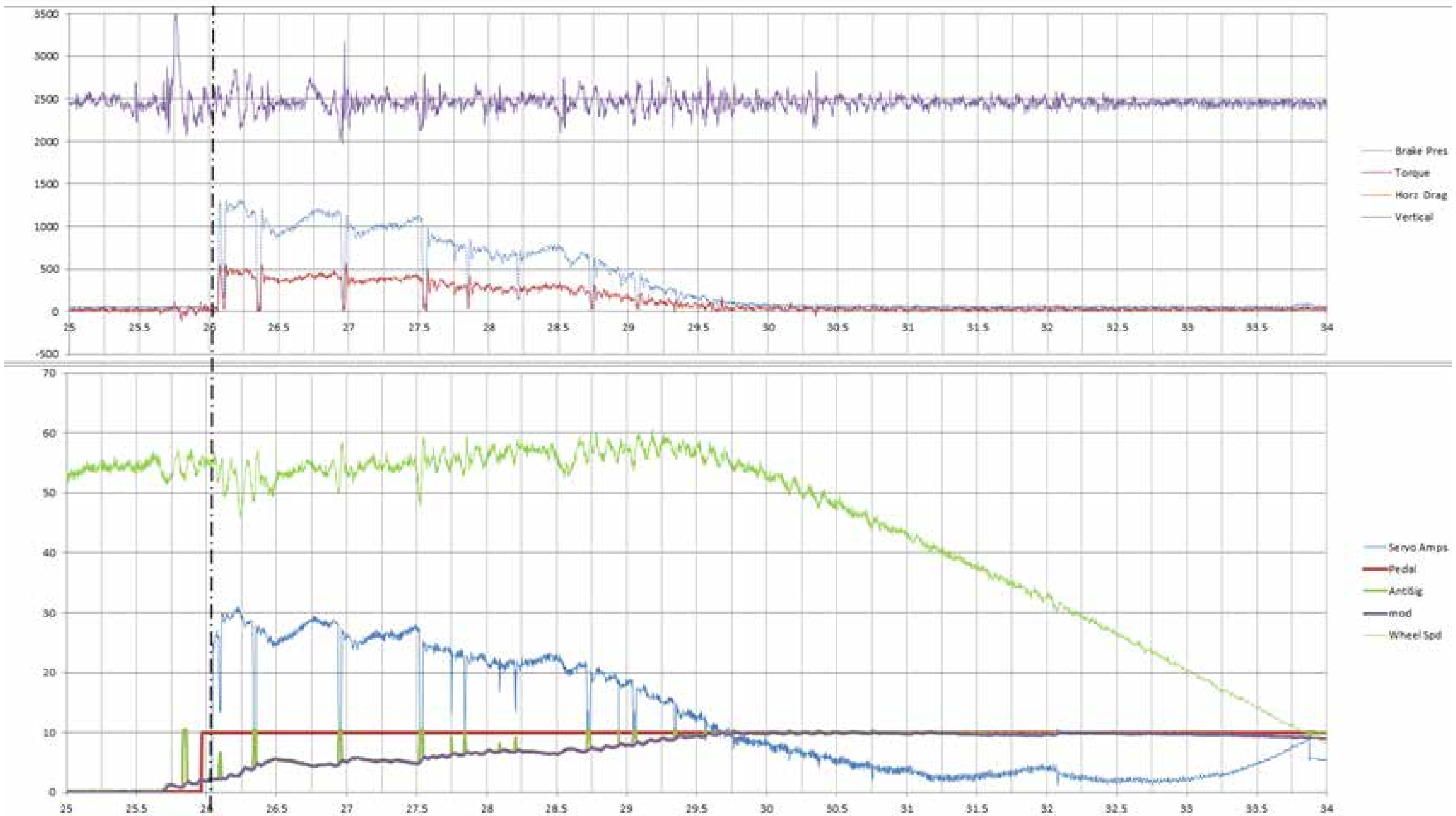

Figure C-3. Test Run 2 Data From the BAT Vehicle

Side	left
Target Speed (fps)	58.8
Vertical load (lb)	High
Brake (Y/N)	Y
Wet/Dry	Dry

3

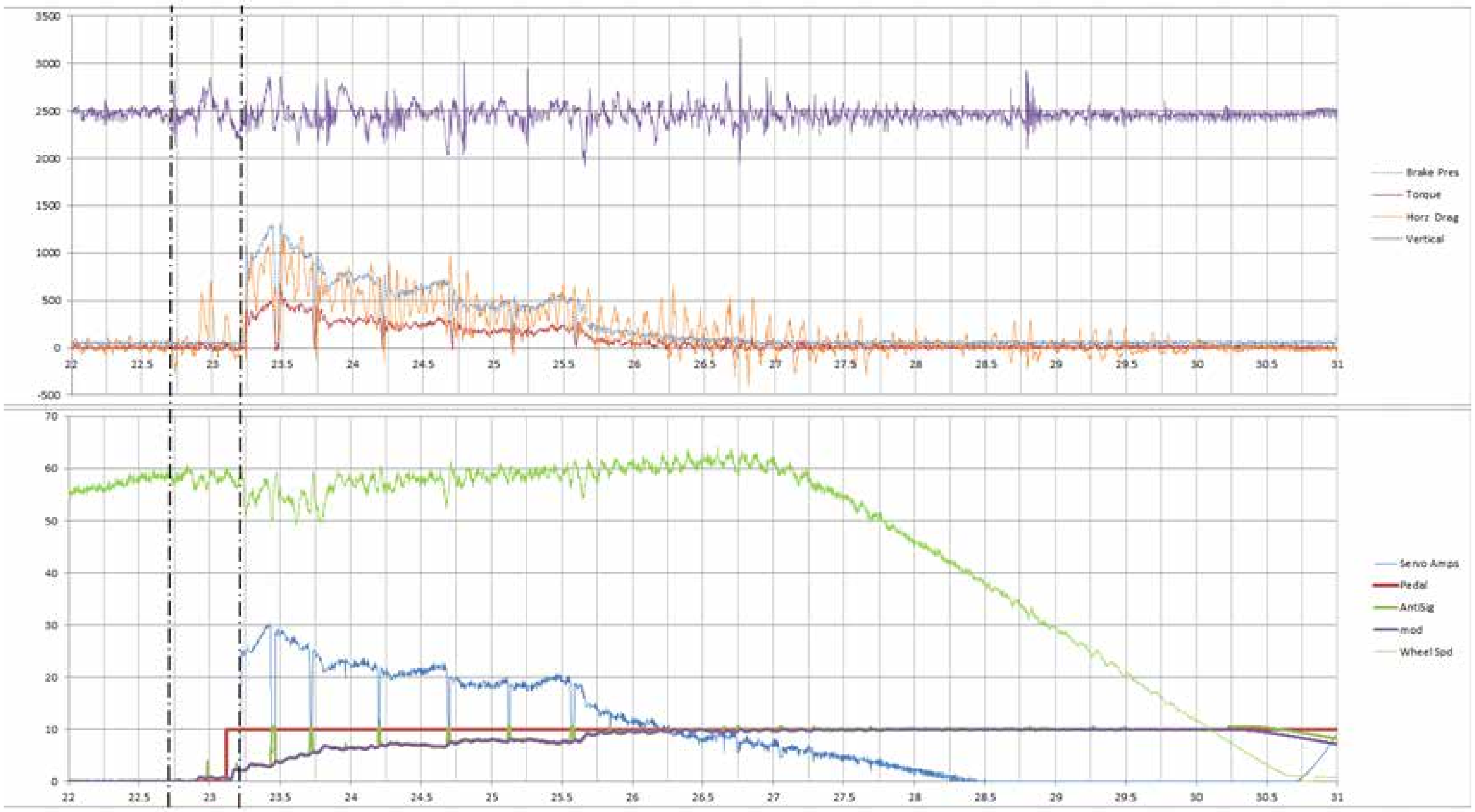

Figure C-4. Test Run 3 Data From the BAT Vehicle

Side	left
Target Speed (fps)	73.5
Vertical load (lb)	High
Brake (Y/N)	Y
Wet/Dry	Dry

4

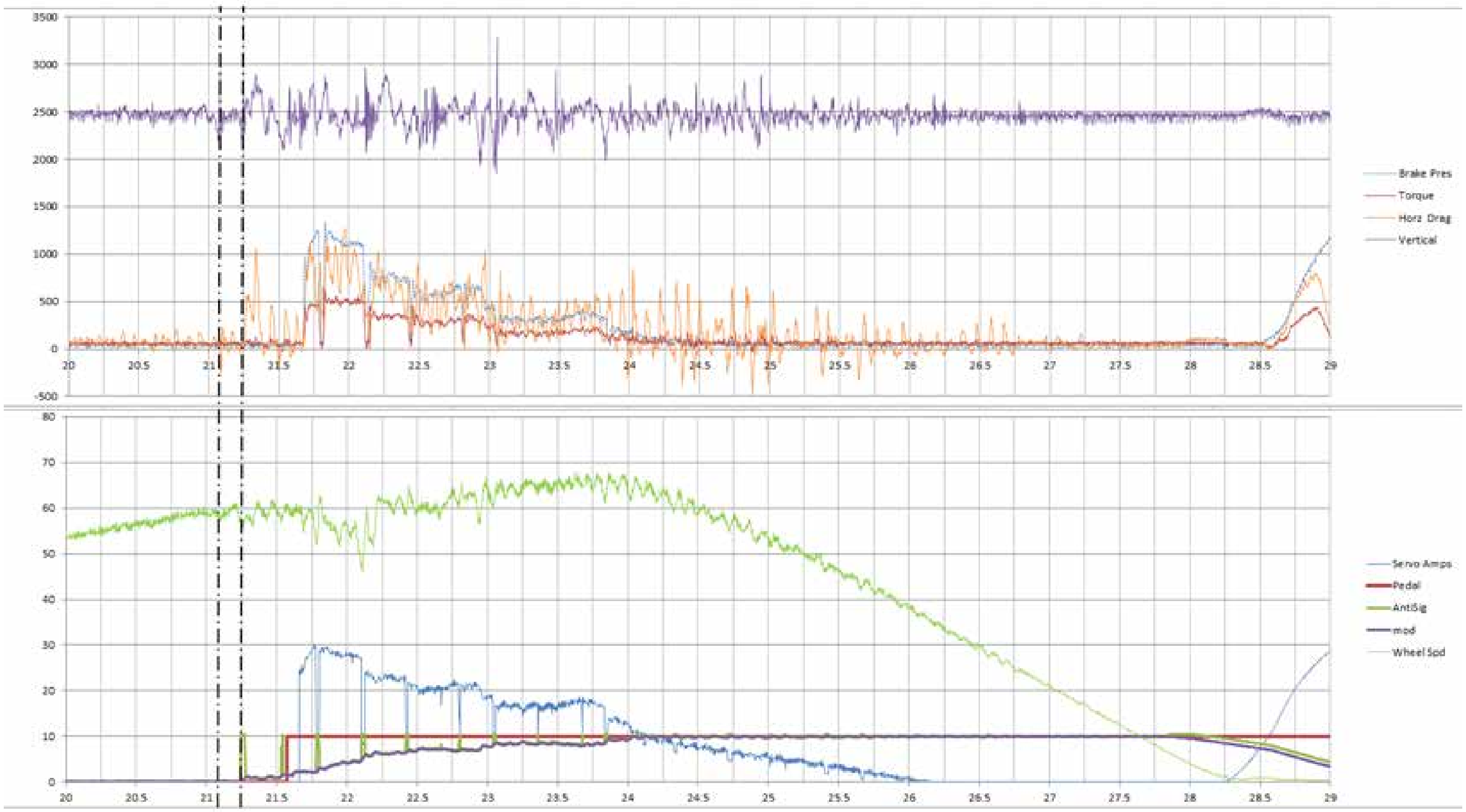

Figure C-5. Test Run 4 Data From the BAT Vehicle

Side	right
Target Speed (fps)	44.1
Vertical load (lb)	High
Brake (Y/N)	N
Wet/Dry	Dry

5

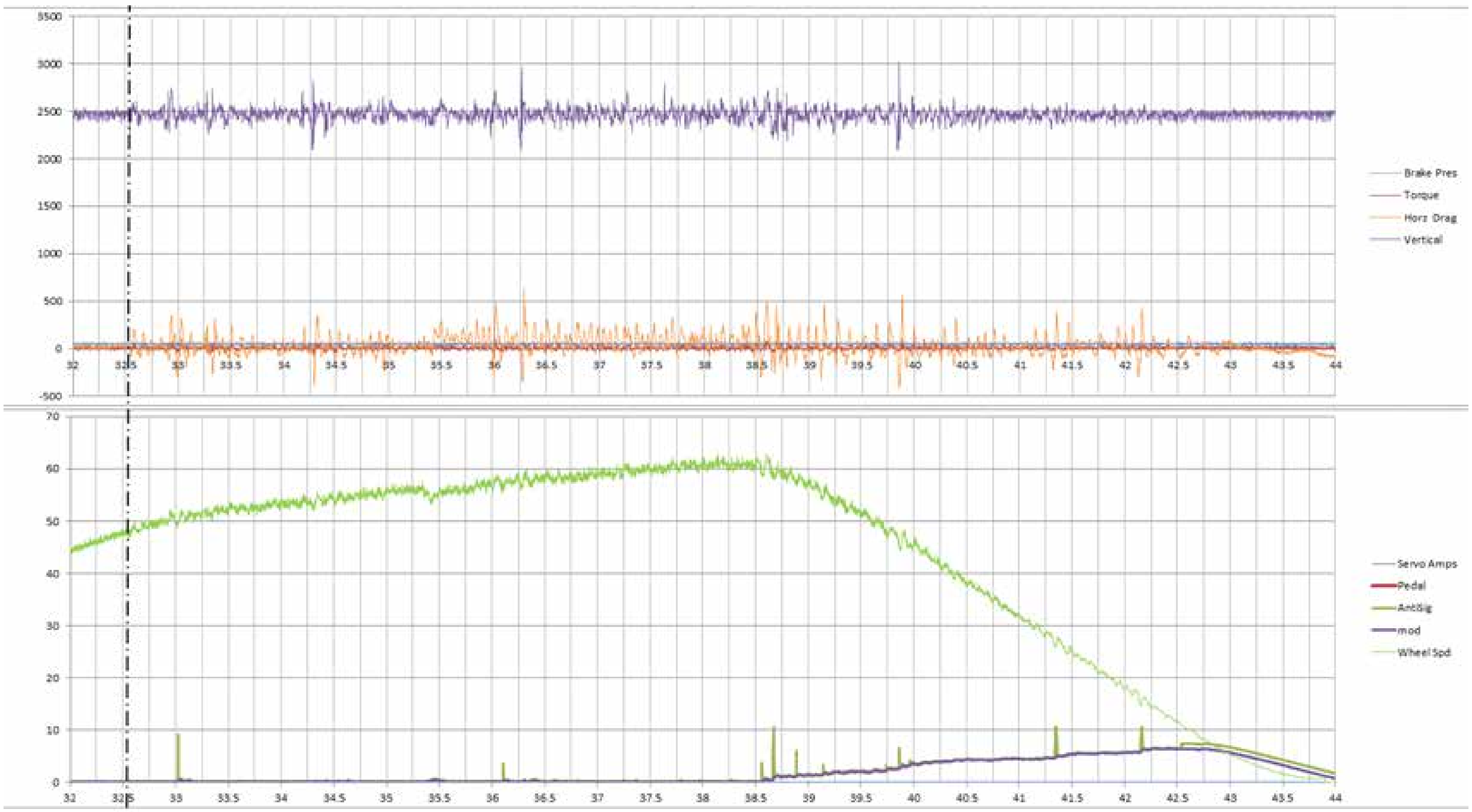

Figure C-6. Test Run 5 Data From the BAT Vehicle

Side	right
Target Speed (fps)	44.1
Vertical load (lb)	High
Brake (Y/N)	Y
Wet/Dry	Dry

6

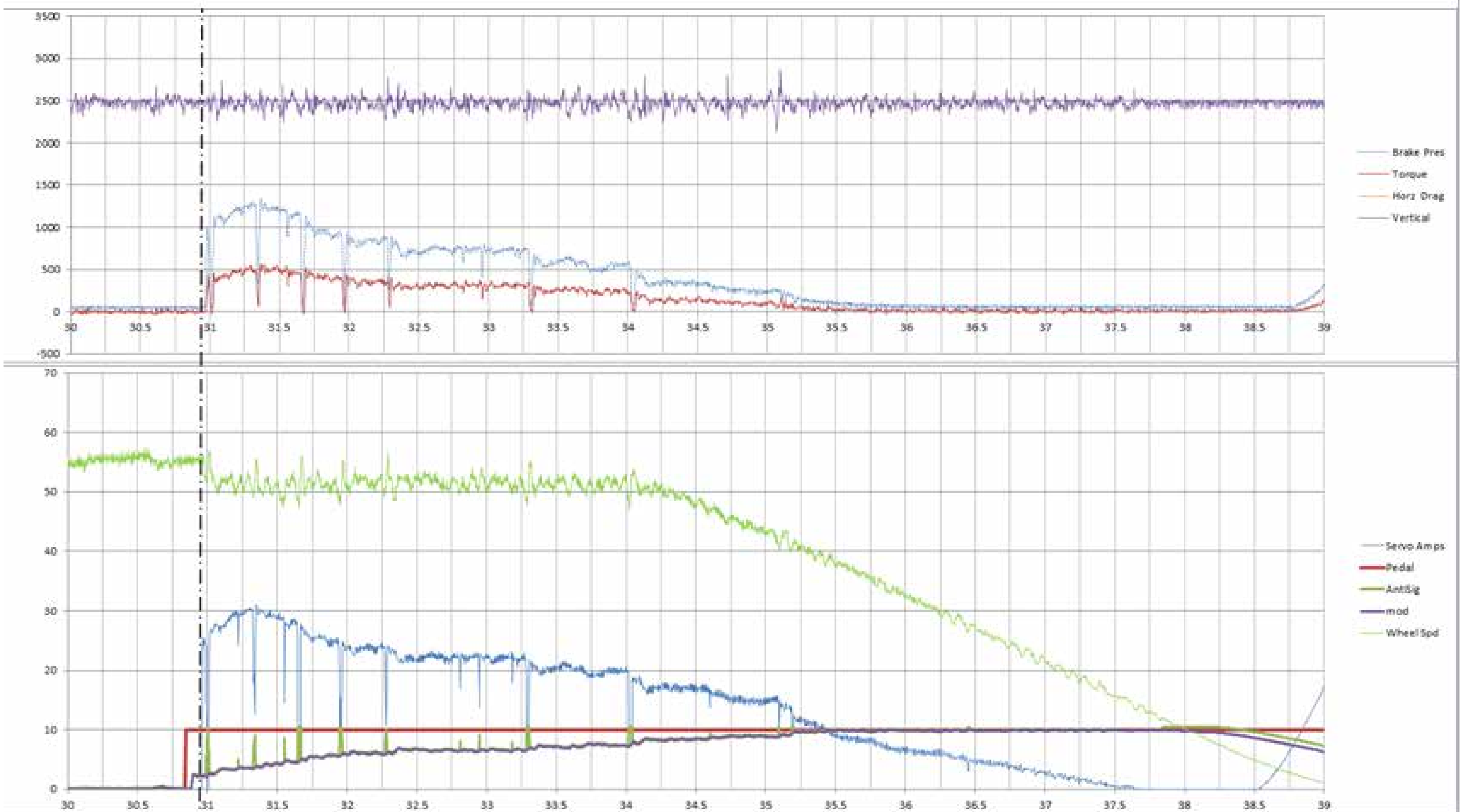

Figure C-7. Test Run 6 Data From the BAT Vehicle

Side	right
Target Speed (fps)	58.8
Vertical load (lb)	High
Brake (Y/N)	Y
Wet/Dry	Dry

7

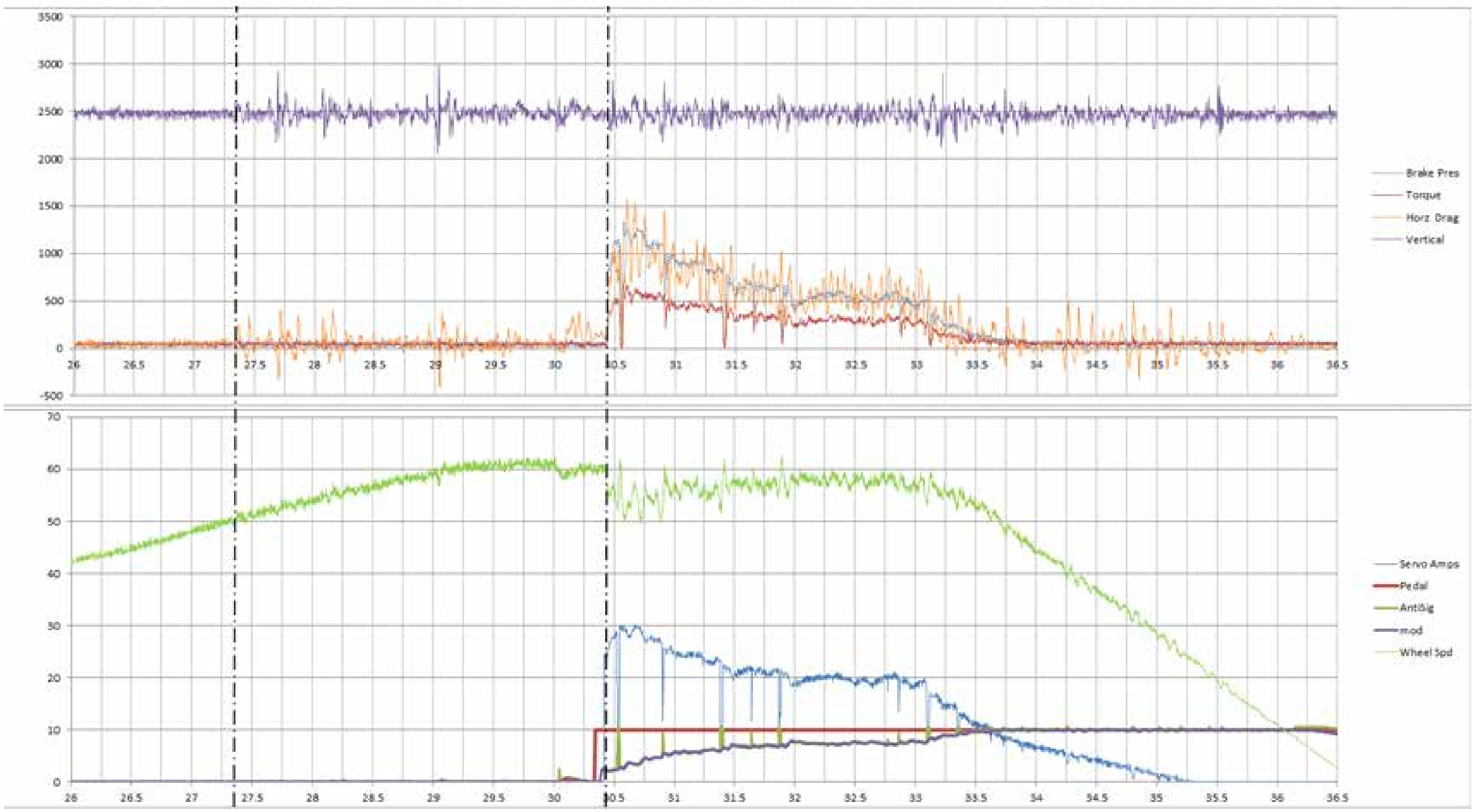

Figure C-8. Test Run 7 Data From the BAT Vehicle

Side	right
Target Speed (fps)	73.5
Vertical load (lb)	High
Brake (Y/N)	Y
Wet/Dry	Dry

8

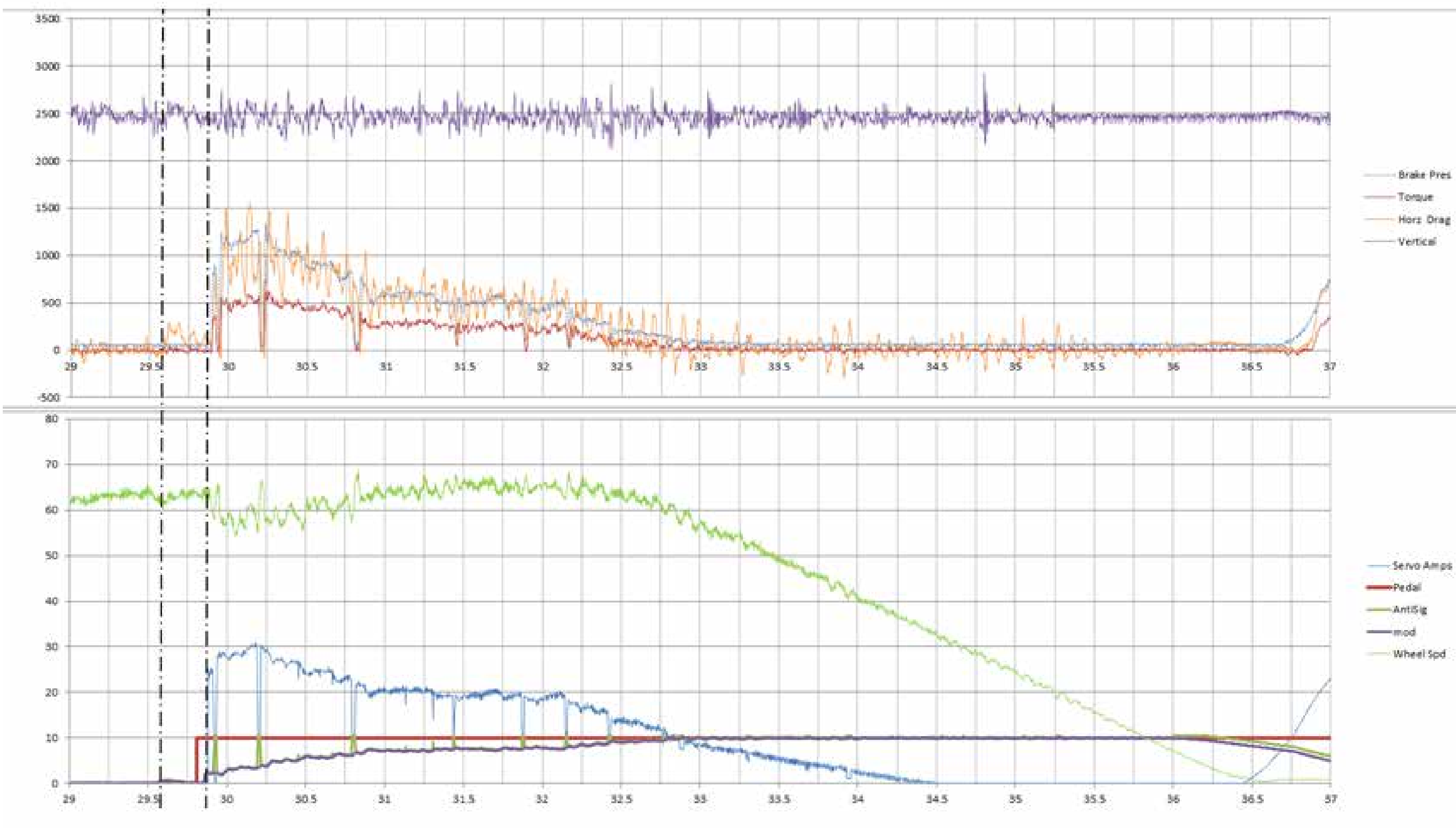

Figure C-9. Test Run 8 Data From the BAT Vehicle

Side	left
Target Speed (fps)	44.1
Vertical load (lb)	Low
Brake (Y/N)	N
Wet/Dry	Dry

9

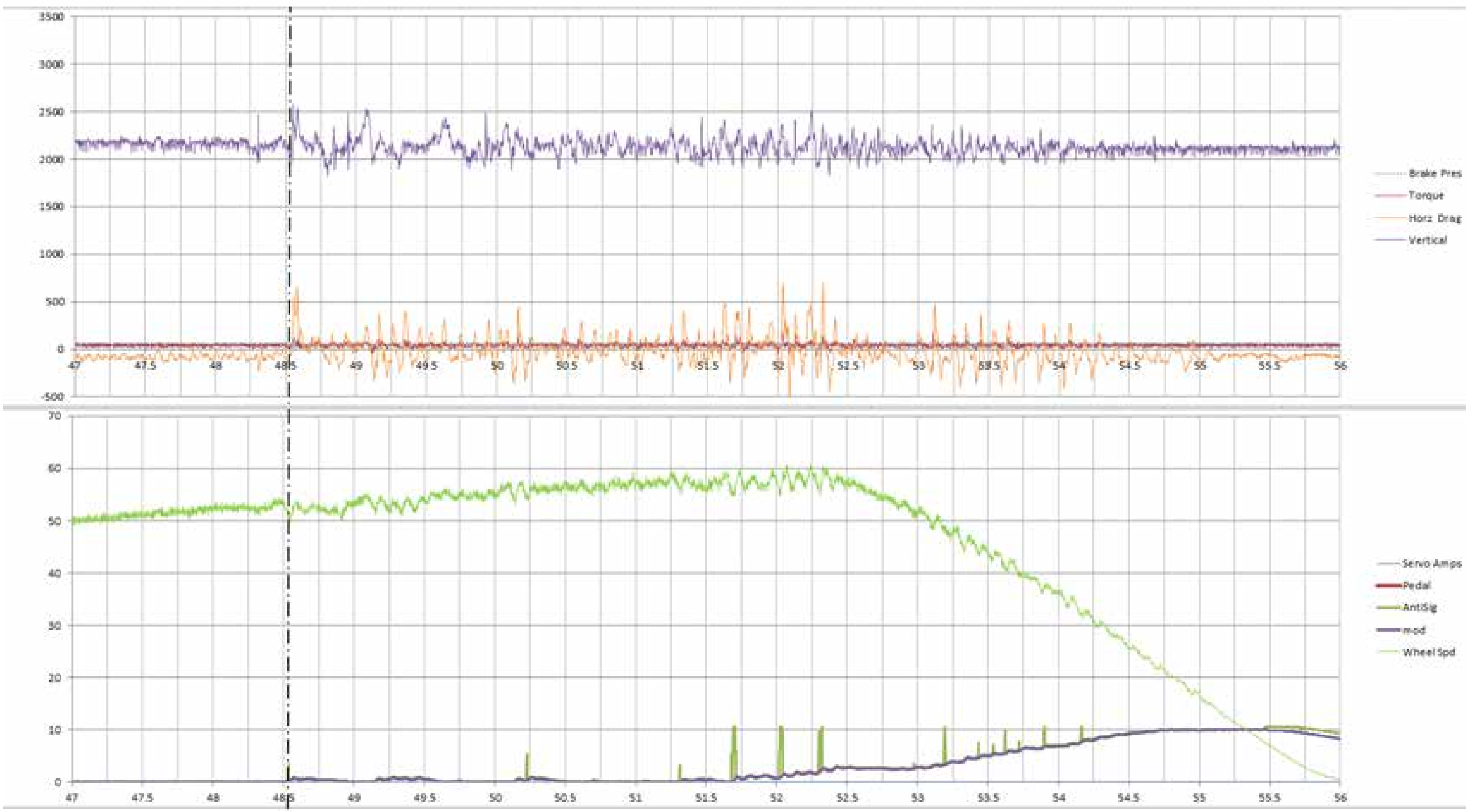

Figure C-10. Test Run 9 Data From the BAT Vehicle

Side	left
Target Speed (fps)	44.1
Vertical load (lb)	Low
Brake (Y/N)	Y
Wet/Dry	Dry

10

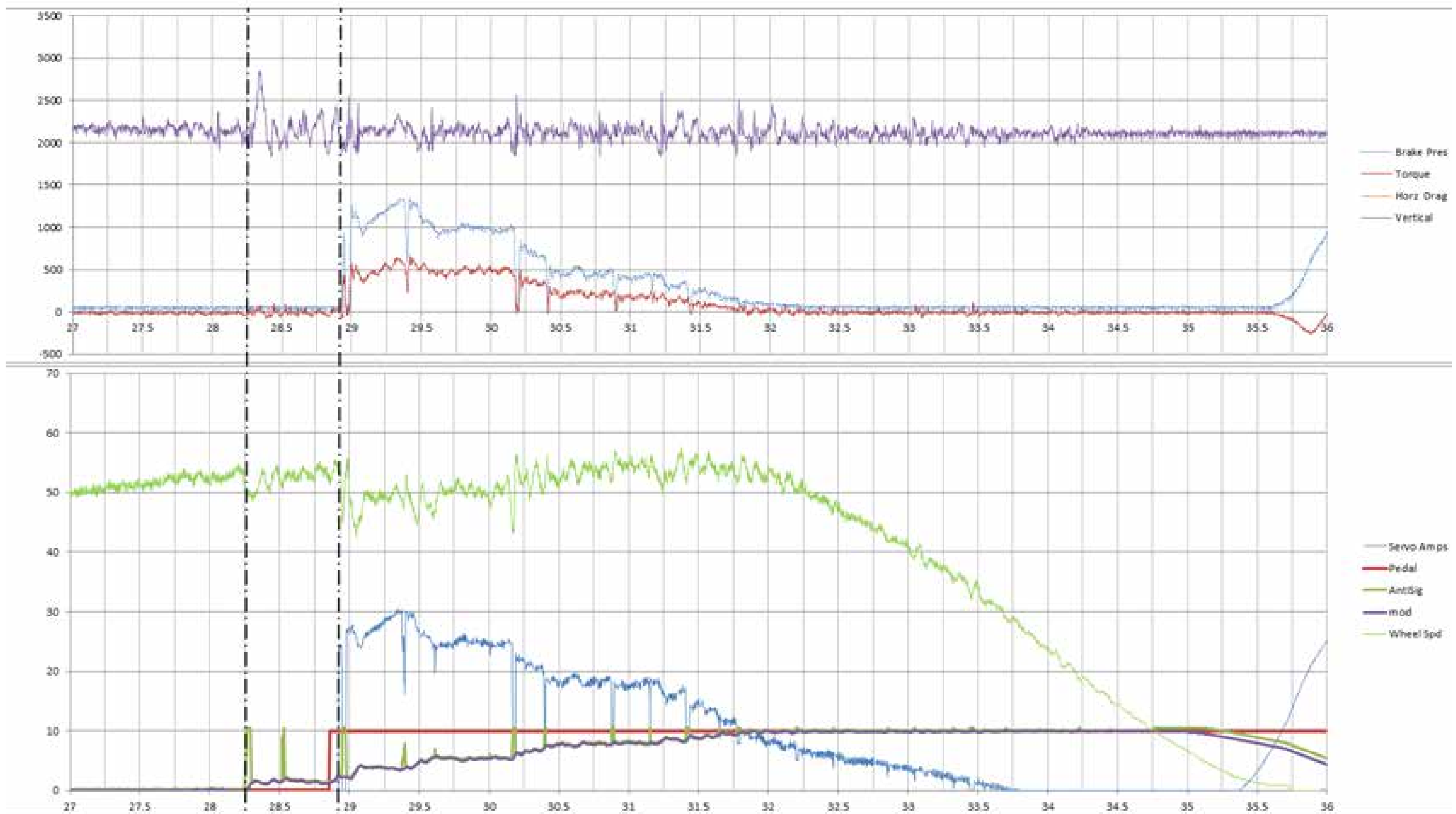

Figure C-11. Test Run 10 Data From the BAT Vehicle

Side	left
Target Speed (fps)	58.8
Vertical load (lb)	Low
Brake (Y/N)	Y
Wet/Dry	Dry

11

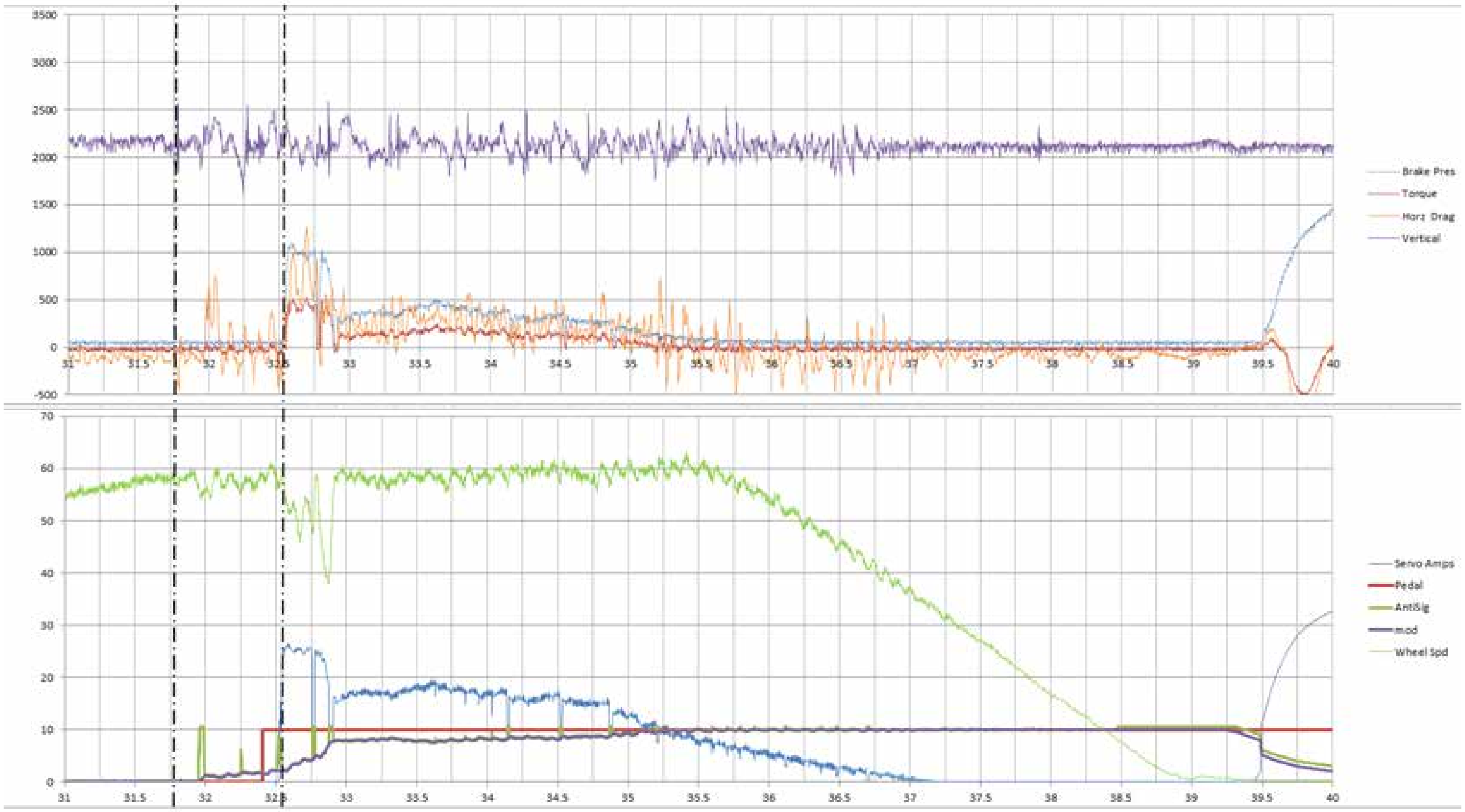

Figure C-12. Test Run 11 Data From the BAT Vehicle

Side	left
Target Speed (fps)	73.5
Vertical load (lb)	Low
Brake (Y/N)	Y
Wet/Dry	Dry

12

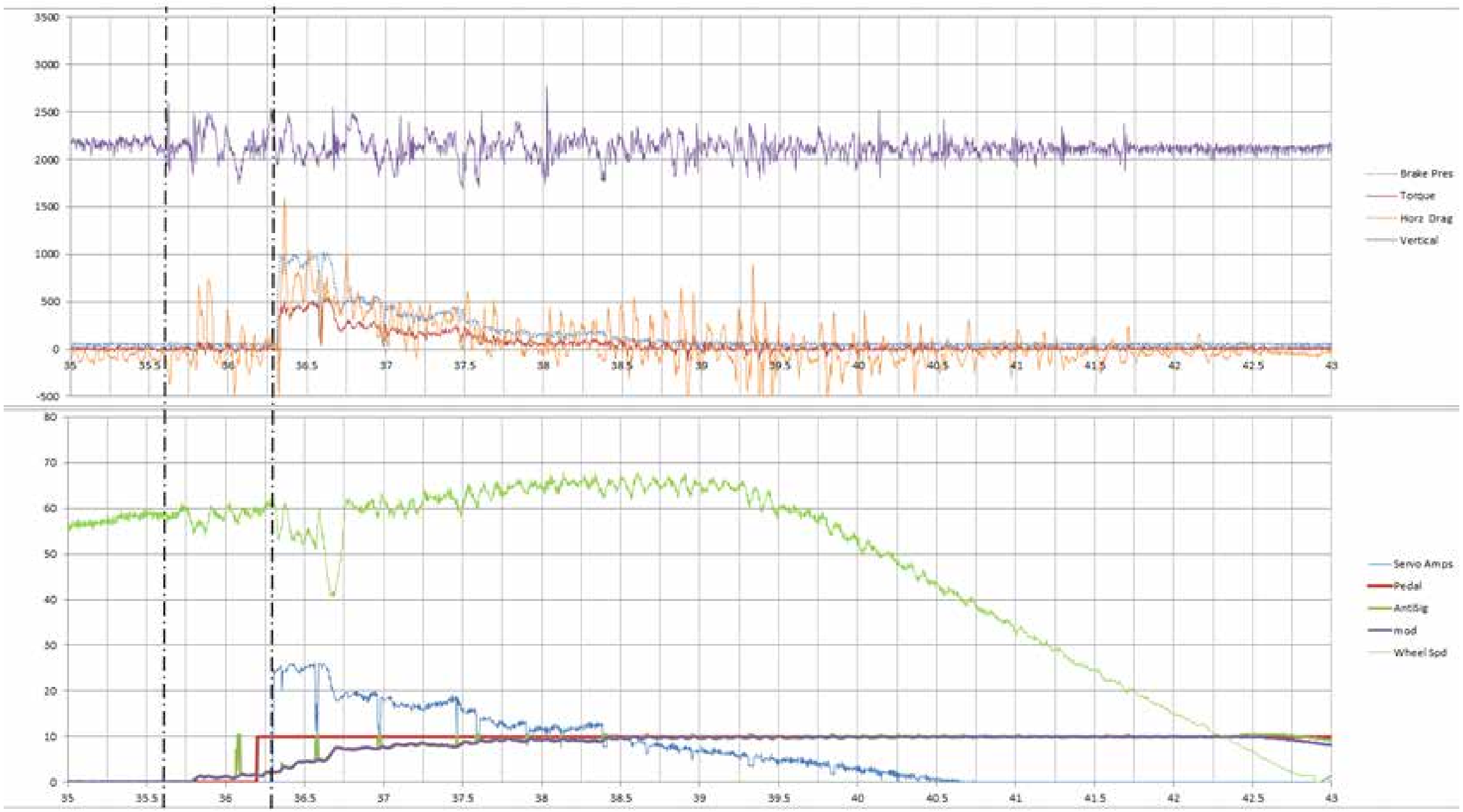

Figure C-13. Test Run 12 Data From the BAT Vehicle

Side	right
Target Speed (fps)	44.1
Vertical load (lb)	Low
Brake (Y/N)	N
Wet/Dry	Dry

13

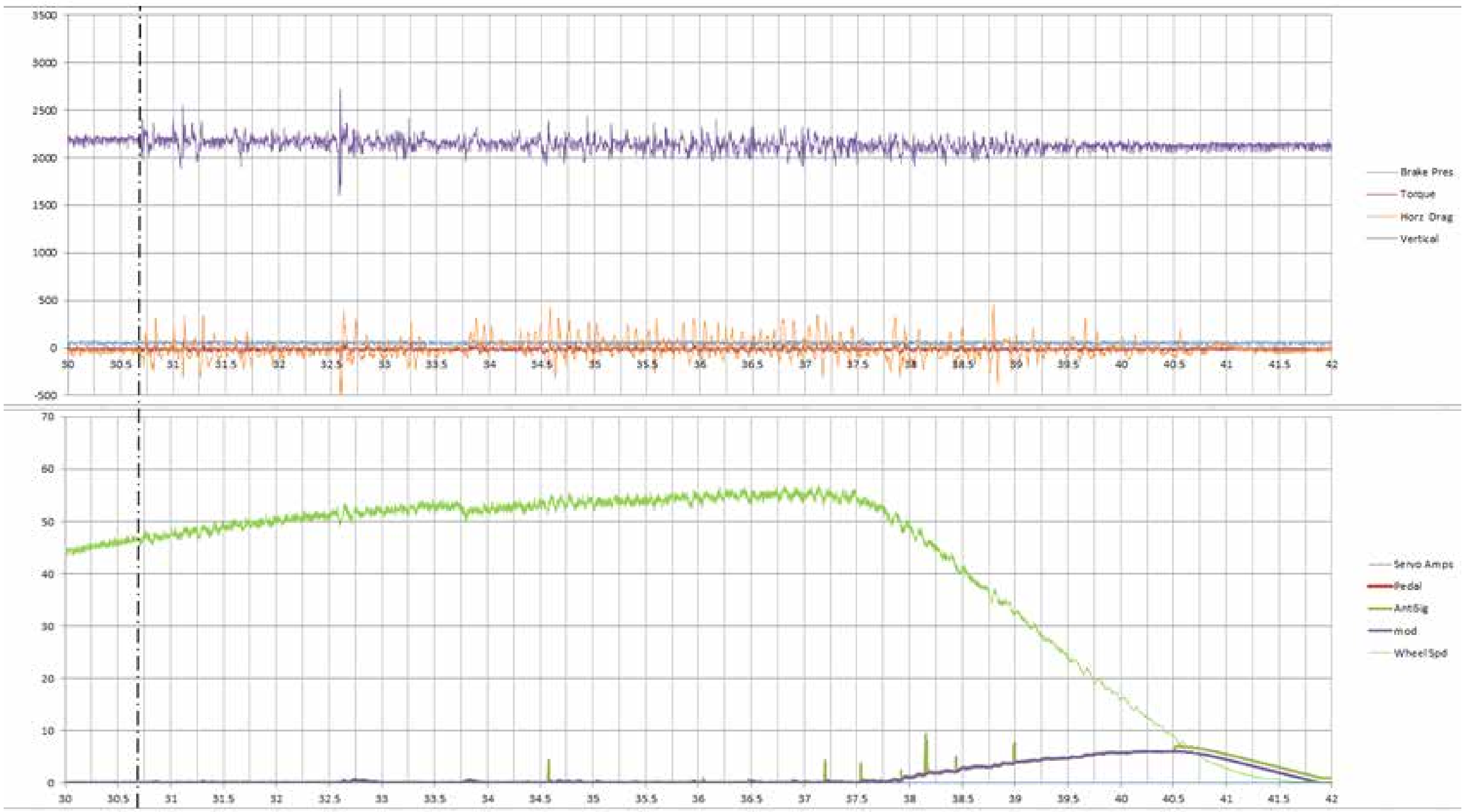

Figure C-14. Test Run 13 Data From the BAT Vehicle

Side	right
Target Speed (fps)	44.1
Vertical load (lb)	Low
Brake (Y/N)	Y
Wet/Dry	Dry

14

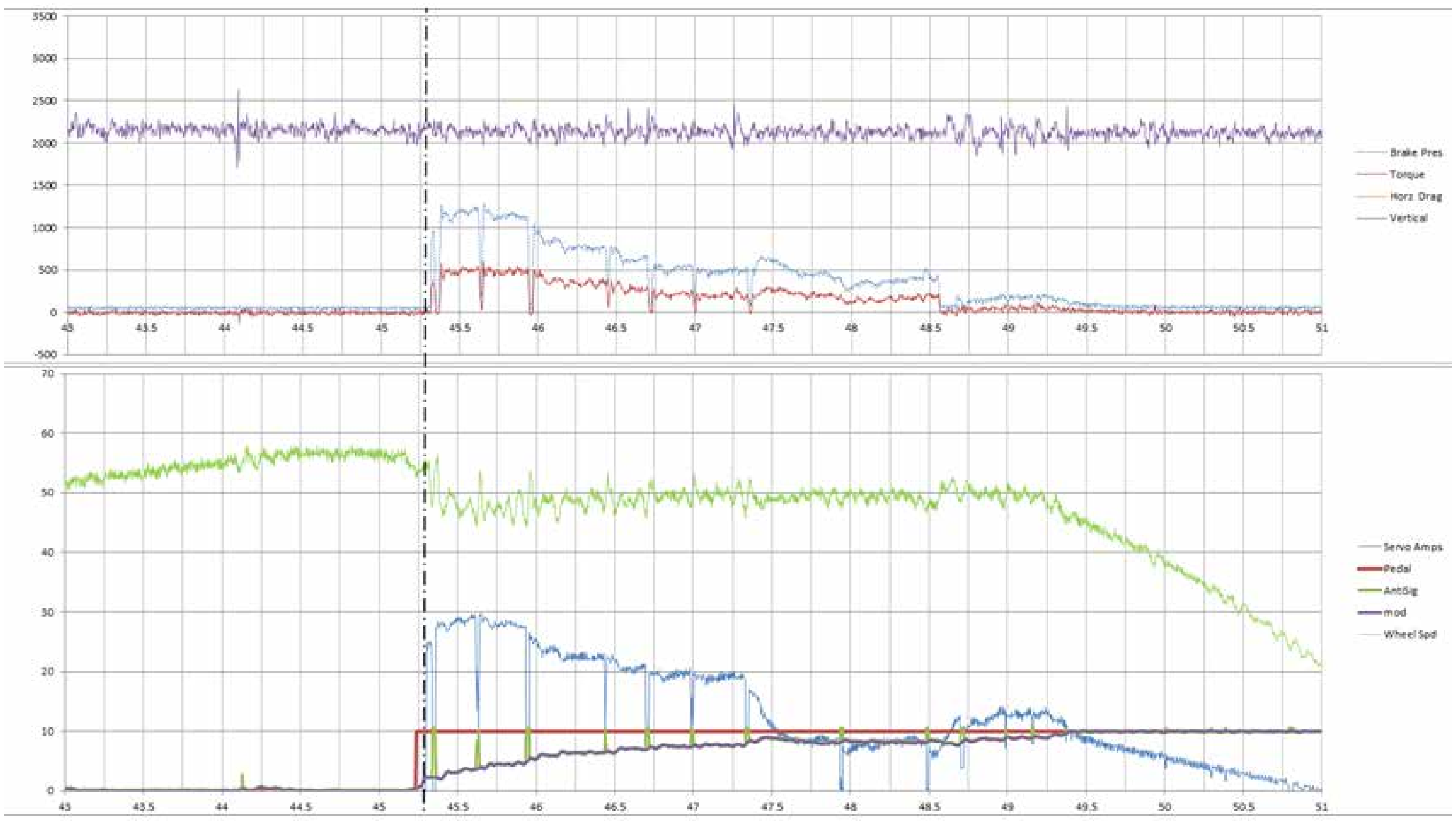

Figure C-15. Test Run 14 Data From the BAT Vehicle

Side	right
Target Speed (fps)	58.8
Vertical load (lb)	Low
Brake (Y/N)	Y
Wet/Dry	Dry

15

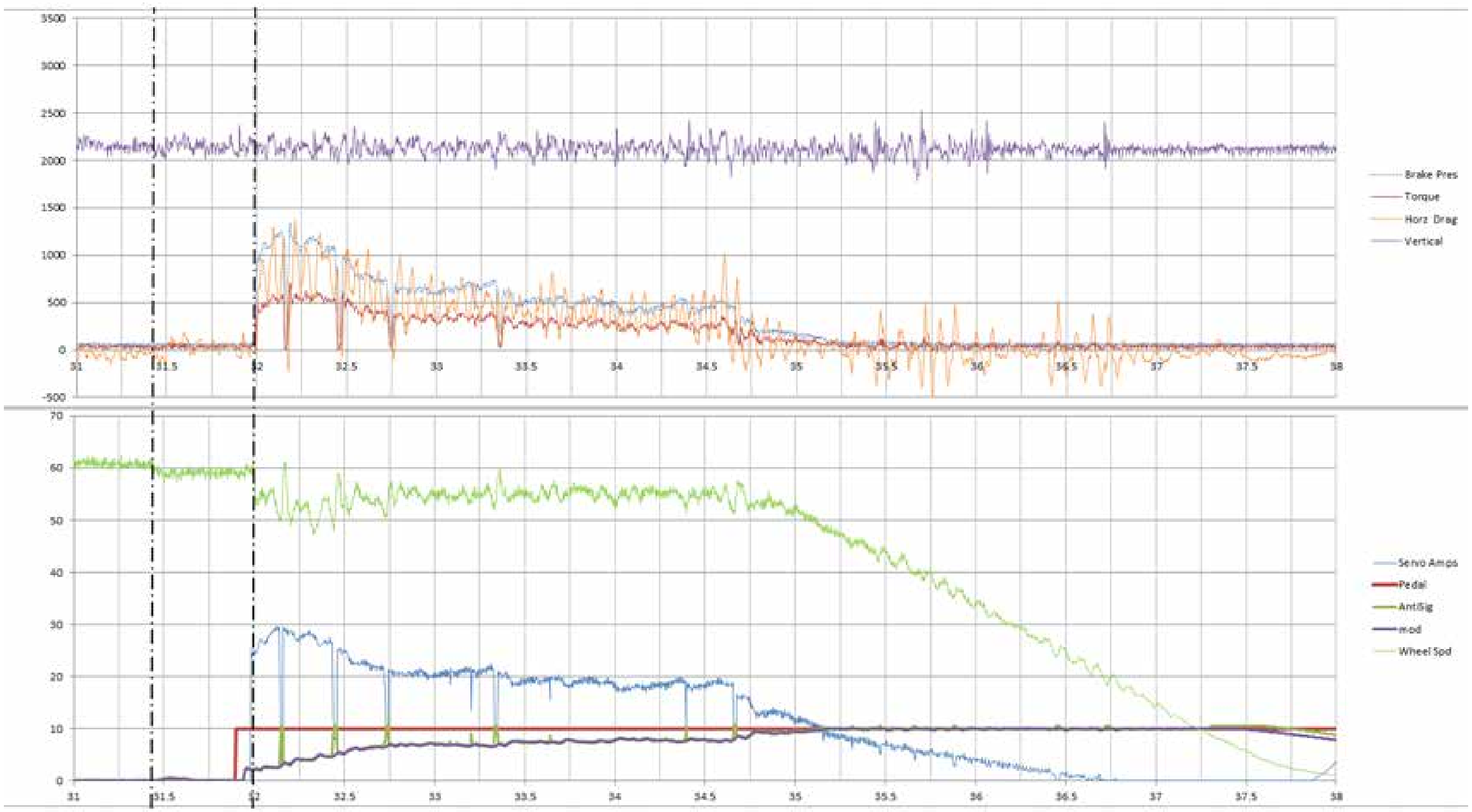

Figure C-16. Test Run 15 Data From the BAT Vehicle

Side	right
Target Speed (fps)	73.5
Vertical load (lb)	Low
Brake (Y/N)	Y
Wet/Dry	Dry

16

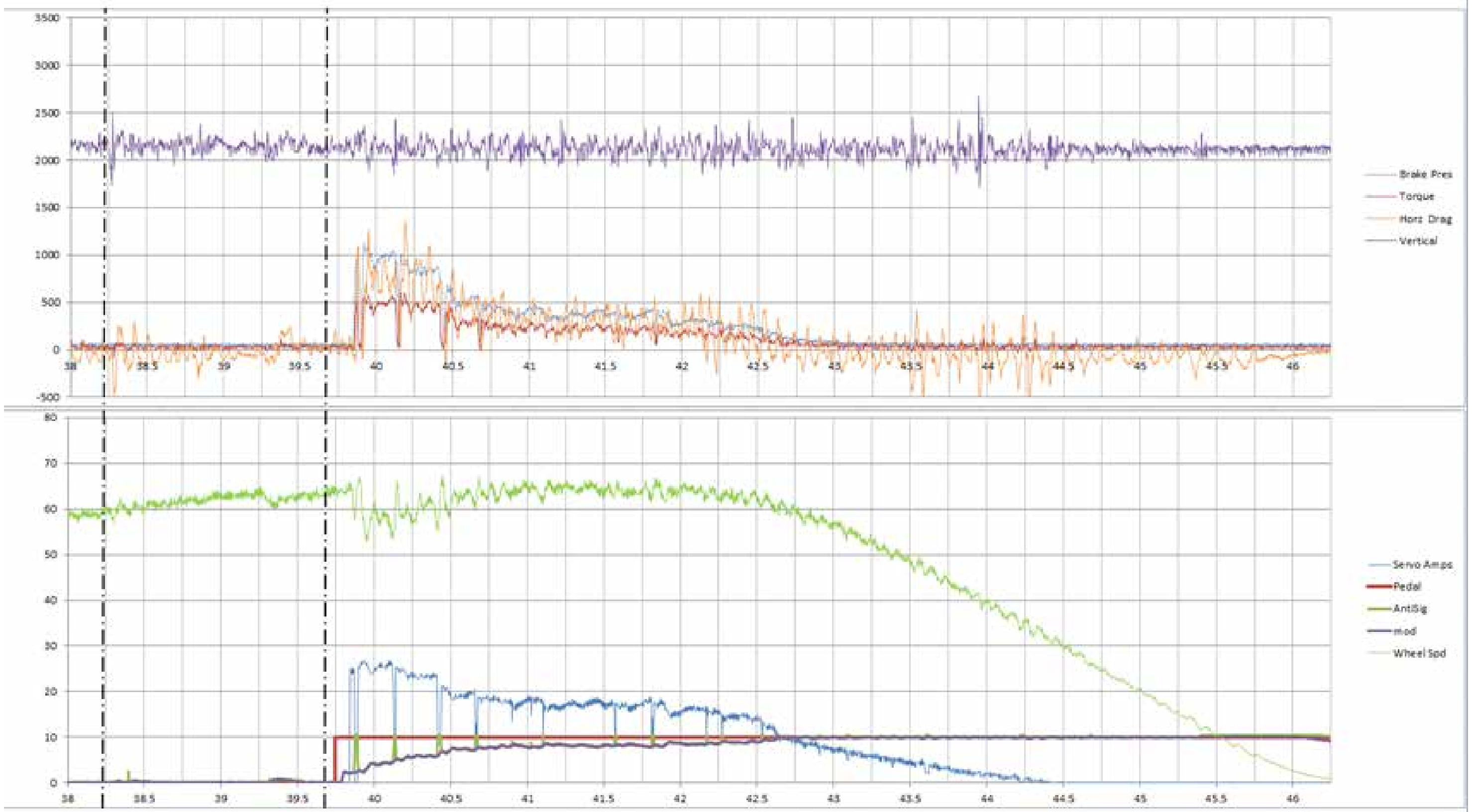

Figure C-17. Test Run 16 Data From the BAT Vehicle

Side	right
Target Speed (fps)	58.8
Vertical load (lb)	Low
Brake (Y/N)	Y
Wet/Dry	Wet

17

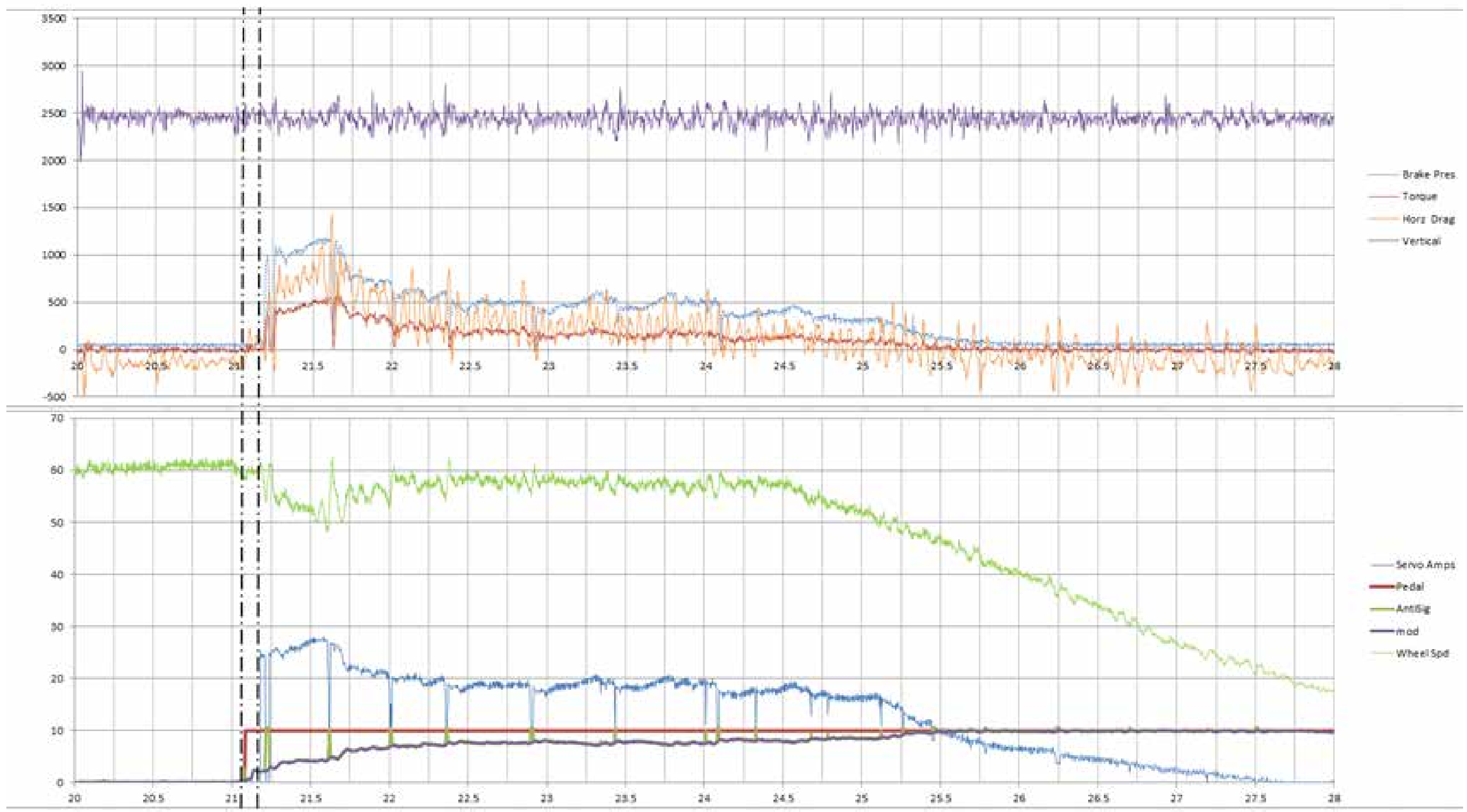

Figure C-18. Test Run 17 Data From the BAT Vehicle

Side	right
Target Speed (fps)	58.8
Vertical load (lb)	Low
Brake (Y/N)	Y
Wet/Dry	Wet

18

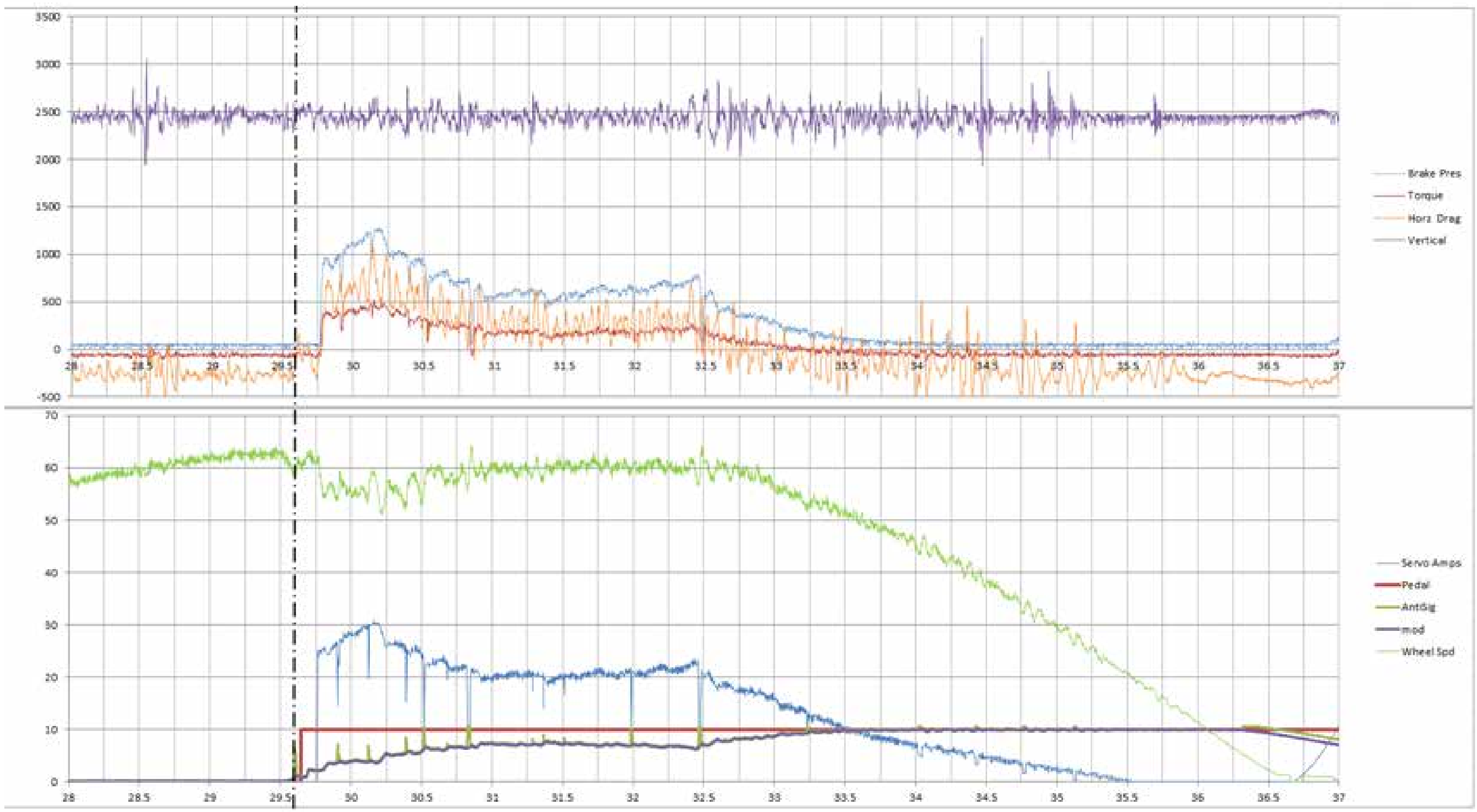

Figure C-19. Test Run 18 Data From the BAT Vehicle