Exhibit F - UTCRS

UTC Project Information	
Project Title	Prototyping and Testing of Electrically Conductive Thermoplastic Polyurethane (TPU) Railroad Suspension Pad
University	The University of Texas Rio Grande Valley (UTRGV)
Principal Investigator	Robert Jones, Ph.D., Mechanical Engineering (PI) Constantine Tarawneh, Ph.D., Mechanical Engineering (Co-PI)
PI Contact Information	Mechanical Engineering EENGR 3.246 Dept. (956) 665-2394 Office (956) 665-5019 robert.jones@utrgv.edu
Funding Source(s) and Amounts Provided (by each agency or organization)	Federal Funds (US DOT UTC Program): $63,251 Cost Share Funds (UTRGV): $20,868
Total Project Cost	$84,119
Agency ID or Contract Number	DTRT13-G-UTC59
Start and End Dates	February 2017 – August 2018
Brief Description of Research Project	This research will take formulations of carbon nanofibers in thermoplastic polyurethanes (TPU), which have shown promising levels of electric conductivity, for use in a conductive steering pad, and prepare them for deployment in a commercially viable product. Plain elastomers are insulators and prevent transmission of current from rail to frame to signal door or gate opening devices. In addition, the thermal insulating properties of these materials reduce the rate of heat flow from bearings through the bearing adapter and into the side-frame, where it can be dissipated. Previous studies performed by the University Transportation Center for Railway Safety (UTCRS) revealed that traditional conductive additives, such as carbon black, must be applied at high volume fraction in order to generate sufficient conductivity, which in turn results in substantial increases in pad stiffness and

	degradation of pad durability. Vapor Grown Carbon Nanofibers (VGCNF) are extremely efficient conductive additives that can produce the desired conductivity at much lower concentrations and with less impact on mechanical performance than traditional additives. Prior efforts have identified a TPU carbon nanofiber combination and fiber loading that produces excellent conductivity, and results in an electrically conductive part when molded under commercially useful molding temperatures. The identified system first needs to be scaled from laboratory quantity testing to injection molding quantities, and then prototyped. Moreover, the microstructural contributions to conductivity as well as the allowable processing range need to be fully described in order to support process development and quality control processes in commercialization.
Describe Implementation of Research Outcomes (or why not implemented) Place Any Photos Here	Pending Project Completion.
Impacts/Benefits of Implementation (actual, not anticipated)	Pending Project Completion.
Web Links • Reports • Project webs	http://www.utrgv.edu/railwaysafety/research/mechanical/2017/prototyping-conductive-tpu-railroad-suspension-pad/index.htm

Exhibit F - UTCRS

UTC Project Information	
Project Title	Low Power Wireless Sensors for Railroad Bearing Health Monitoring
University	The University of Texas Rio Grande Valley (UTRGV)
Principal Investigator	Heinrich Foltz, Ph.D., P.E., Electrical Engineering (PI) Constantine Tarawneh, Ph.D., Mechanical Engineering (Co-PI)
PI Contact Information	Electrical Engineering EENGR 3.225 Dept. (956) 665-2609 Office (956) 665-5016 heinrich.foltz@utrgv.edu
Funding Source(s) and Amounts Provided (by each agency or organization)	Federal Funds (US DOT UTC Program): $63,389 Cost Share Funds (UTPA): $22,477
Total Project Cost	$85,866
Agency ID or Contract Number	DTRT13-G-UTC59
Start and End Dates	February 2017 – August 2018
Brief Description of Research Project	We propose to develop an integrated, self-powered condition monitoring system for rail vehicle bearings. This system will leverage previous research at UTCRS on damage detection sensors and algorithms, service life prediction, signal processing for rail environments, and energy harvesting. Our UTRGV railroad research group has already shown that a combination of vibration, temperature, and load sensing can detect bearing defects and damage at a very early stage, and before it becomes a safety hazard, enabling selective preventive replacement during planned maintenance stops. The research group has also demonstrated signal processing electronics that allow detection of critical signals in challenging noise environments. The developed system will consist of self-powered miniature modules, directly mounted on bearing adapters, which will monitor the vibration spectrum, temperature history, and total applied vertical load on the bearing, and wirelessly transmit the data to a compact analysis module located on the rail vehicle. While there have been similar

	systems, ours would be unique in: (a) incorporation of our signal processing electronics that have proven success in extracting usable data from high noise situations, (b) a combination of vibration, temperature, and load sensors and sampling rates that have been optimized in both laboratory and field testing environments, (c) initial data analysis at the bearing sensor level to determine whether further analysis is warranted, (d) spectrum analysis algorithms, embedded in the compact analysis module, that have demonstrated superior performance in detecting and classifying bearing defects, and (e) self-powering using energy harvesting techniques. Benefits of the proposed system include the following: • Accident prevention through early detection of impending failures, • Reduced operating costs through fewer stoppages, and more efficient and effective replacement and maintenance schedules, and • Creation of a large-scale database of bearing incidents, enabling further research. Deliverables will include a set of working prototype modules for one railcar, a compact analysis module (CAM), design information including schematics, signal processing parameters, and algorithms, and comprehensive test data. System validation and verification will be carried out through extensive laboratory testing.
Describe Implementation of Research Outcomes (or why not implemented) Place Any Photos Here	Pending Project Completion.
Impacts/Benefits of Implementation (actual, not anticipated)	Pending Project Completion.
Web Links • Reports • Project website	http://www.utrgv.edu/railwaysafety/research/mechanical/2017/wireless-sensors-for-railroad-bearing-health-monitoring/index.htm