Technical Supplement
For
Accelerated Vehicle Durability Testing (AVDT)
Drivetrain Simulator

Version 11.0
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1.0 INTRODUCTION

1.1 Scope

This Technical Supplement describes the Government's need for a capability to provide a hardware-in-the-loop simulator used to characterize and test the durability and reliability of military wheeled vehicle powertrain systems and their components. The Drivetrain Simulator is intended to replicate time wave torque data accumulated in the field on military wheeled vehicles. To achieve accurate durability simulation on the wide range of military vehicle systems, the simulator will need to satisfy the technical requirements listed below.

1.2 Background

The Heavy Vehicle Durability Simulator (HVDS), composed of a drivetrain simulator and a chassis simulator, test capability is needed to accelerate wheeled vehicle reliability and durability testing. Testing will be accelerated four to five times, significantly shortening test durations and the time to evaluate vehicle reliability. This capability supports Department of Defense (DoD) directives to integrate modeling and simulation tools into acquisition development and testing. The ultimate goal is to streamline acquisition by quickening and improving assessments of vehicle system reliability. The project focuses on stressing high risk drivetrain components on heavy, multi-axle wheeled vehicles, but also extends to reliability of all drivetrain systems.

1.3 Demonstration

The selected vendor will be required to conduct a technical performance demonstration of their prototype solution using the contractor developed test procedures at or before the Critical Design Review (CDR). The demonstration may be a computer simulation of the entire system or individual dynamometer or a hardware demonstration of an individual dynamometer. If a computer model is used, technical details of the model components shall be presented with sufficient evidence of validity for the system under development (e.g., motor, power inverter, and inertia details). Time waveform data of vehicle torque and speed will be provided by the government for use at the demonstration. Furthermore, the selected vendor will be required to conduct a demonstration of their full-system prototype at Initial Operational Capability (IOC) and Full Operational Capability (FOC). The demonstration at IOC will be fit and function based only. The demonstration at FOC will be for full test capability. The IOC and FOC demonstrations will occur at the Aberdeen Test Center government facility where the simulator system will be installed and maintained. Evaluation of the demonstrations at CDR and FOC will be based on the KPPs, KSAs, and functional requirements, as well as MIL-STD-810G Method 525.1 (Time Waveform Replication) and Method 527.1 (Multi-Exciter Test). More specific objectives of each demonstration will be established jointly by the vendor and Government team.

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2.0 TECHNICAL REQUIREMENTS AND OBJECTIVES

Certain requirements are specified in terms of minimum and goal values where:

a) Minimum - Level of performance that is considered achievable at low-to-moderate risk.
b) Goal - Level of performance which is the ultimate, desired operational goal.

2.1 Technical

2.1.1 Critical System Level Attributes

A summary of key system performance parameters (KPP) and attributes (KSA) required in the drivetrain simulator are listed in Table 1. The simulator will be expected to meet the minimum requirements to adequately simulate off-road terrain and satisfy the government's requirements.

TABLE 1. HVDS DRIVETRAIN SIMULATOR KPP AND CRITICAL REQUIREMENTS SUMMARY

Attribute	Minimum	Goal
Vehicle Weight Capacity	80,000 lbf	100,000 lbf
Number of Vehicle Axles	4	5
Overall System Power	600 HP	750 HP
Simulation Frequency Bandwidth	0 - 12 Hz	0 - 25 Hz
Maximum Axle Speed	750 rpm	1,000 rpm
Axle Longitudinal Spacing	50 in.	48 in.
Maximum Wheel Torque	22,500 lb-ft	30,000 lb-ft

2.1.2 Chassis Vertical Movement

The joint angles of constant velocity and universal joints in the vehicle driveline should be varied throughout testing to achieve realistic wear results and produce a sufficient range of self-induced secondary moments within the driveline. Articulation is achieved in the vertical direction by cyclically moving the axles or vehicle sprung mass during testing. The vertical motion is expected to be low frequency, up to 1 Hz.

Minimum: Ability to achieve 12 inches of vertical movement at a rate of 1 inch per second.
Goal: Ability to achieve 20 inches of vertical movement at a rate of 1 inch per second.

2.1.3 Simulator Operating Software

The simulator shall have an end-to-end software package for operation. The software shall integrate the machine configuration, instrumentation setup, machine tuning, system identification and drive file development process, and test management. The software shall provide the ability to generate frequency response functions (FRFs) between the vehicle engine control inputs and dynamometer speed or torque commands. The software shall integrate within the same interface a method for inverting the FRFs and creating initial dynamometer drive command files. The software shall then allow iterative modification of the drive files based on feedback error to create the final desired drive command file.

2.1.4 Simulation of Concurrent Test Items

Use of the drivetrain simulator can be extended if two vehicles can be tested concurrently. The setup would allow simulation of one 2-axle vehicle and one 3-axle vehicle at the same time.

Minimum: Simulation of one vehicle system.

Goal: Ability to simultaneously simulate 2 vehicle systems (combination of up to 5 axles).

2.1.5 Engine and Transmission Remote Control

An integrated remote control system should be provided that allows the simulator to start/stop the vehicle engine, control the engine throttle, and control the transmission shift console gear selection. The control system architecture shall be configurable to allow use on multiple military systems. As such the control will support both mechanical (actuators) and electrical (drive by wire) designs. The remote control system shall integrate with the simulator operational software as specified in technical requirement 2.1.3.

Minimum: One remote control system for the engine and transmission.

Goal: Two remote control systems for the engine and transmission to test a 2 axle and 3 axle vehicle concurrently.

2.1.6 Road Speed Fan

Supply the necessary road speed fan to provide intake air flow to the radiator for cooling the vehicle.

Minimum: At least a 36 inch by 48 inch outlet with wind speed of 60mph.

Goal: At least a 36 inch by 48 inch outlet with wind speed of 80mph. Outlet air temperature control from 0 degrees Fahrenheit to 120 degrees Fahrenheit.

2.1.7 Fluid Temperature Conditioners

The simulator shall have a means to condition the engine oil, transmission oil, and engine coolant of the system under test. The conditioners shall have the capability to regulate the fluid temperatures.

Minimum: For a vehicle with a 600HP engine. Maintain fluid temperature under 250 degrees Fahrenheit for engine, and transmission oil. Maintain fluid temperature under 200 degrees Fahrenheit for engine coolant.

Goal: For a vehicle with a 750HP engine. Maintain fluid temperature under 250 degrees Fahrenheit for engine, and transmission oil. Maintain fluid temperature under 200 degrees Fahrenheit for engine coolant.

2.1.8 Differential, Transfer Case, and Wheel End Cooler

The simulator shall have a method to cool the vehicle differential, transfer case, and wheel ends to maintain continuous running of the vehicle. The coolers should function without need for fluid exchange of the differential, transfer case, or wheel end oil.

2.1.9 Fuel Measurement, Conditioning, and Refill

A method for measuring and conditioning the vehicle fuel is required. The system should also be capable of bypassing the vehicle fuel tank and keep the vehicle constantly running by automatically refilling. Due to the varying size of engines expected to be tested, 2 different systems may be necessary to meet the fuel measurement and conditioning specifications.

TABLE 2. FUEL CONDITIONING AND MEASUREMENT SPECIFICATIONS

Attribute	Minimum	Goal
Temperature Control	10-80 degC	10-100 degC
Fuel Mass Flow Rate	300 kg/h	400 kg/h
Fuel Circulation	450 l/h	500 l/h
Fuel Feed Pressure	0.5-60 psi	0.5-80 psi
Fuel Density Measurement	0.5-2 g/cm^3	0.5-2 g/cm^3
Fuel Refill Flow Rate	300 l/h	300 l/h
Fuel Compatibility	DF2, F24, JP8	DF2, F24, JP8, Gasoline, Alcohol added
Fuel Flow Rate Uncertainty	0.1% at Full Scale (FS)	0.05% at FS
Fuel Density Uncertainty	0.1% at FS	0.05% at FS

2.1.10 Combustion Air Conditioning

A combustion air system that can control temperature, humidity, and pressure. Humidity and pressure control performance specifications are not required to be achieved over the full temperature control range.

Minimum: Temperature control from 15-70 degrees Celsius, relative humidity from 25-90 percent, air mass flow up to 1600 m^3/h.

Goal: Temperature control from 30-120 degrees Celsius, relative humidity from 25-90 percent, pressure control +/-100mbar from ambient pressure, air mass flow up to 2400 m^3/h.

2.1.11 Simulator Data Acquisition

The simulator shall record external analog sensor data that will be merged with the simulator drive and response data. The drivetrain simulator needs to monitor and record the data traffic between the onboard controllers. Also, sensors used for data acquisition and monitoring transmit data via CAN bus and the simulator needs to interface with these data acquisition systems. The data acquisition should integrate with the simulator operational software as specified in technical requirement 2.1.3.

Minimum: 64 high-level analog channels, 64 thermocouple inputs, four controller area network (CAN) data buses, eight high-level analog outputs, 8 digital inputs, and 8 digital outputs, 8 frequency inputs, along with 1 EtherCat digital transmission protocol inputs, shall be provided.

Goal: 128 high-level analog channels, 128 thermocouple inputs, eight controller area network (CAN) data buses, eight high-level analog outputs, 16 digital inputs, and 16 digital outputs, 16 frequency inputs, along with 2 EtherCat digital transmission protocol inputs, shall be provided.

2.1.12 Cyber Security

The drivetrain simulator will be operated on DOD ranges so the system should be designed to minimize risks to system operations and data from cyber threats consistent with National Security Telecommunications and Information Systems Security Policy (NSTISSP) No. 11 and DOD Instruction 8500.01, Cybersecurity. The vendor should design this system consistent with the cybersecurity provisions of the System Security Plan (SSP) and support the Government in revisions to this SSP and related documents, where necessary, to reflect integration of the drivetrain simulator into the technical baseline.

2.1.13 Vehicle Emission Measurement and Removal

A method to measure particulate in vehicle emissions and then safely evacuate the emissions from the building.

Minimum: Exhaust system to remove emissions from the building for a vehicle with up to 750HP engine.

Goal: Exhaust system to remove emissions from the building. An emission bench system to characterize exhaust gas composition. The system should measure the following compounds: THC, CH_4, NO/NO_2/NO_X, CO, CO_2, N_2O, O_2, and SO_2.

2.1.14 Hybrid, or Electrical Vehicle Cycling System

A battery emulator system should be provided for use with testing large electric or hybrid electric vehicles.

Minimum: Operating Range +12 to 750 Volts DC, Current -800 to +800 Amps DC, Power -250 to +250kW.

Goal: Operating Range +12 to 750 Volts DC, Current -1600 to +1600 Amps DC, Power -500 to +500kW.

2.1.15 Video Recording System

A system that can record and playback video of the simulator.

Minimum: Record 4 video stream simultaneously at 1080p quality.

Goal: Record 4 video stream simultaneously at 1080p quality and synchronized to the data acquisition system.

2.1.16 Environmental Enclosure Over Simulator

A modular enclosure or structure to cover the simulator and vehicle, so that the temperature can be controlled. The structure should be removable and assembled in place with a vehicle on the simulator.

Minimum: Control Temperature from 0 to 50 degrees Celsius.

Goal: Control Temperature from -20 to 50 degrees Celsius.

2.1.17 Facility Utility Requirements

The vendor shall provide a utility matrix as soon as possible after contract award. The matrix shall provide at a minimum electrical, cooling water, air handling, and base plate/inertial mass requirements.

2.1.18 Simulator Reliability

The vendor shall provide a reliable simulator system that meets the minimum specified maintenance requirements.

Minimum: Five years or 10,000 running time hours between overhaul and/or replacement of any major simulator components (fixtures, actuators, dynamometers, inverters). Six months or 1000 hours of running time between inspection and/or replacement of wearable parts (bearings, swivels, filters).

Goal: Ten years or 20,000 running time hours between overhaul and replacement of any major simulator components (fixtures, actuators, dynamometers, inverters). One year or 2000 hours of running time between inspection and/or replacement of wearable parts (bearings, swivels, filters).

2.2 Program Management

The vendor should accomplish all planning, execution, monitoring and controlling, reporting and related program management activities to ensure that the technical, schedule, and financial requirements of this contract are accomplished. Program Management documentation should include periodic technical, financial, and schedule status.

2.2.1 Communication

The vendor should establish and maintain regular communication with the Government team (both formal and informal) so that plan deviations are known, assessed, and resolved in a timely manner. This communication should include vendor participation in informal bi-weekly status meeting phone calls with the Government during which the vendor should cover the technical and programmatic status of the project.

2.2.2 Reviews

The vendor should host and conduct periodic reviews throughout the requirements analysis, design formulation, risk reduction, and test phases of the contract consistent with best commercial practices. Examples of best commercial practice include, but are not limited to, post

award conference (PAC), system requirements review (SRR), preliminary (PDR) and critical design review (CDR), technical interchange meetings (TIM) (as needed) and test readiness review (TRR). The vendor should summarize the review contents, action items, and any deficiencies and submit to the Government on an IPT-determined basis. The deficiencies found during each review shall be resolved before moving to the next milestone event.

2.3 System Support Documentation and Spares

The vendor should provide support documentation in the operation and maintenance of the drivetrain simulator. The expected documentation should include a technical data package (TDP) to support sustainment, as well as simulator operation and maintenance manuals with all appropriate interfaces to hardware and software. The vendor should also provide all documentation delivered with vendor equipment and software purchased under this contract.

The vendor shall provide a maintenance analysis with recommended service intervals. From the maintenance analysis the vendor shall also provide an initial spares kit that will enable 2 years of operation, without purchase of additional parts. The spares should include consumable parts for each corner assembly, such as: couplings, joints, bushings, and bearings. Additionally a single spare for each unique coupling, and servo hydraulic valve should be supplied.

2.4 Training

The vendor should provide familiarization and training on system operation and maintenance. The training should encompass each of the system operation modes. The Government envisions that training will be conducted at the facility prior to full operational capability. The training will involve collecting data on government vehicle test courses and then installing a vehicle on the simulator for training and system verification. The government envisions the vendor to provide individuals that are technically proficient and highly educated on the simulator attributes to allow for training to run as efficiently and productively as possible.

2.5 Government Responsibilities

2.5.1 Facility

The government will provide a facility with utility connections for the drivetrain simulator. The government will require the vendor to provide the following information to properly prepare the facility for the simulator.

1. Inertial mass reaction forces and size.
2. Base plate size and configuration.
3. Cooling water requirements.
4. Air supply requirement.
5. Electrical power requirements

The government will then contract the facility construction to meet the vendor requirements for inertial mass, base plate size and configuration, cooling water, air supply, and electrical power.

2.5.2 System Verification Testing

The government will provide a four or five axle test vehicle and personnel to support verification of the simulator performance criteria. The system verification testing will occur in parallel with training.