Section 6.1 PEO LS S&T Focus Area

POWER AND ENERGY

"As a Corps, we have become more lethal, yet we have also become increasingly dependent on fossil fuel. Our growing demand for liquid logistics comes at a price. By tethering our operations to vulnerable supply lines, it degrades our expeditionary capabilities and ultimately puts Marines at risk. To maintain our lethal edge, we must change the way we use energy.."

—A Cooperative Strategy For 21st Century Seapower, March 2015

The Marine Corps is improving its capabilities as a crisis response force so that it will have extended operational reach, more staying power, and greater independence from sustainment operations. In order to become more energy independent, the Marine Corps will need to achieve the following goals, as stated in the *Marine Corps Service Campaign Plan for 2014-2022:*

- Develop and implement programs and policy to extend the operational reach of the Marine Expeditionary Brigade (MEB) and increase training readiness of our forces.
- Develop and integrate plans to embed expeditionary energy into the USMC ethos. Incorporate energy considerations into doctrine, training, and education.
- Reevaluate MEF/MEB/ Marine Expeditionary Unit (MEU) fuel consumption rates to ensure naval sufficiency to support Marine contingency operations ashore from the sea base.
- Put new processes in place and complete all tasks of the Expeditionary Energy Strategy and Implementation Plan of Action and Milestones.

As these goals are set for the Marine Corps, PEO LS must address increasing energy and fuel efficiency wherever it is practicable. The PEO LS S&T team has created a two-faceted approach to address the needs and requirements of power and energy development: *Fuel Efficiency* projects and *Intelligent Power and Thermal Management* projects. Fuel Efficiency projects focus on increasing the efficiency of mechanistic systems (e.g., the engine, drive train, vehicle aerodynamics) to increase the amount of energy that can be extracted from Marine Corps vehicles per every gallon of fuel used. Intelligent Power and Thermal Management projects concentrate on solutions that increase the utility of electricity and other sources of power once it has been generated. These two Focus Areas are inherently aligned and will continue to maximize the power and energy available for the USMC vehicle fleet.

6.1.1 Fuel Efficiency

The Challenge

The existing tactical vehicle fleet and associated fossil fuel consuming end items will be in the Marine Corps inventory for quite some time. Any improvements to efficiency will have dramatic primary, secondary, and tertiary effects on fuel consumption within the Marine Corps. Multiple avenues are being explored to maximize the energy extracted from each gallon of fuel and to minimize losses to heat, friction, and other inefficiencies. When implemented together these S&T investments, which are not limited to one vehicle or even one component, can minimize fuel use and maximize operational maneuver for each gallon of fuel used.

Potential Solutions

ONR Efforts

Fuel Efficient Medium Tactical Vehicle Replacement (MTVR) – Future Naval Capability

The objective of the Fuel Efficient MTVR effort is to develop, optimize, integrate, and demonstrate a 15% fuel efficiency improvement over the existing MTVR across a set of driving cycles that are representative of likely operational conditions while maintaining MTVR affordability, current mobility, transportability and survivability capabilities. This $87.5 million ONR FNC effort is currently in Phase II and III of development. After the three 'technology packages' are developed, they will be added to a series of test MTVRs to establish actual fuel savings. The FNC project is expected to transition to the fleet in 2017.

Fuel efficient MTVR components are shown in Figure 6.1-1.

In designing our future force, we will…. Improve operational energy capabilities that enhance our reach and energy security. These measures will include the use of Marine Corps initiatives to improve deployed energy consumption, the development of bio-fuels, and other programs that emphasize energy efficiency.

—A Cooperative Strategy For 21st Century Seapower, March 2015

Additional ONR S&T projects that are of interest to PEO LS include:

- Advanced Concepts for Fuel Efficiency
- Fuel Efficiency Improvements

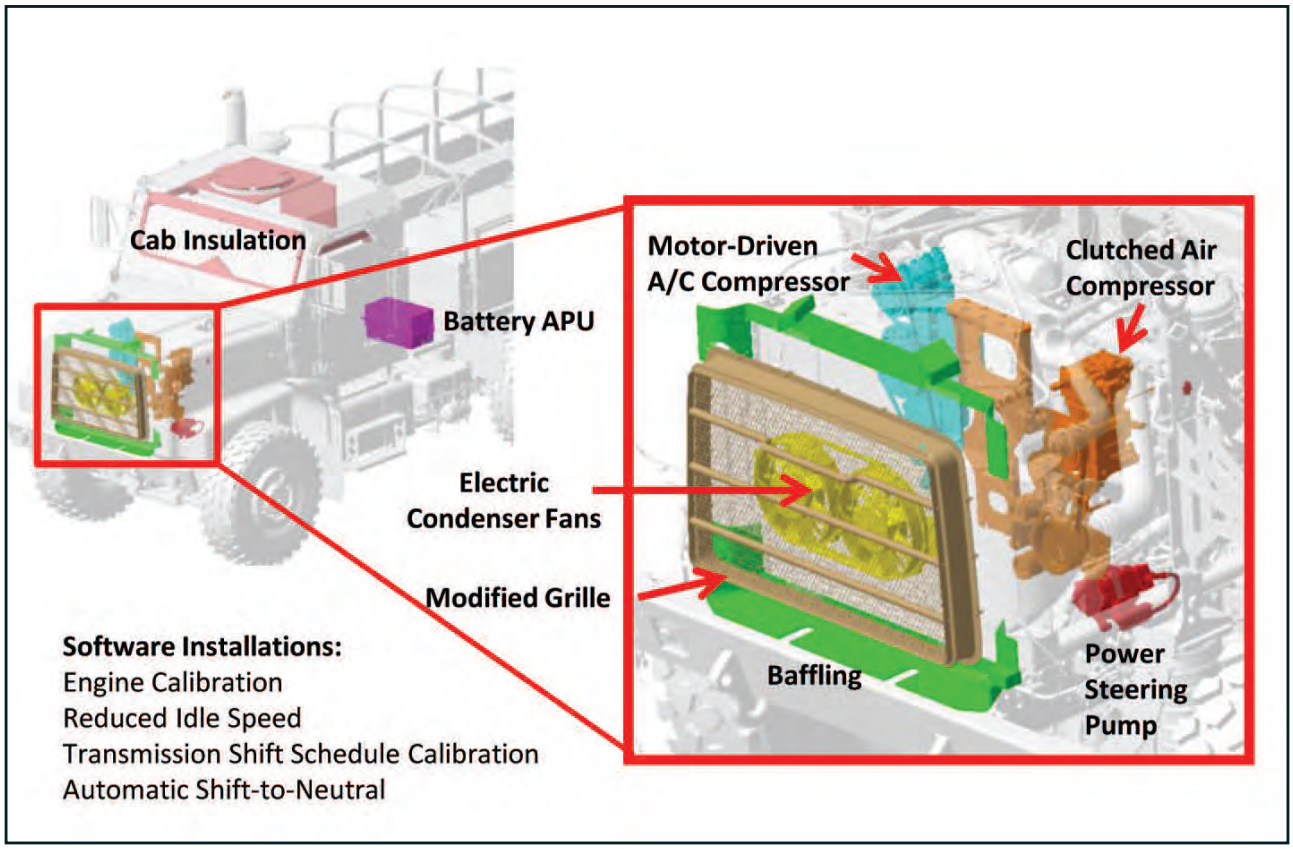


Figure 6.1-1. Fuel Efficient MTVR Components

TARDEC Efforts

Alternative Fuels Qualification (AFQ)

Problem Statement: On-going revisions to jet fuel specifications will allow non-petroleum based (NPB) content posing risk due to the Army's use of jet fuel in ground (diesel) engines. Allow Defense Logistics Agency (DLA)-Energy procurement and delivery of JP-8/F-24 fuel containing NPB to DoD/ Army installations. TARDEC qualification delivers spec requirements needed for Army approval of jet fuel containing NPB as a military ground fuel. Current JP-8 spec only contains requirements for Synthesized Paraffinic Kerosene (SPK) (Fischer-Tropsch, Hydroprocessed Esters and Fatty Acids). Tri-Service harmonized qualification plan targets qualification of Alcohol to Jet [Fuel] (ATJ), Direct Sugar to Hydrocarbon (DSHC), Hydroprocessed Depolymerized Cellulosic (HDC), and Catalytic Hydrothermolysis (CH) as drop-in replacements for JP-8 (same performance as current JP-8).

Purpose: Determine JP-8 fuel spec requirements needed for approval of alternative jet fuels (ATJ, DSHC, HDC, & CH) as military ground fuel that enables DLA-Energy to source these fuels when they are commercially available at cost-competitive prices.

Advanced Thermal Management System (ATMS)

Develop efficient and intelligent cooling technology components and sub-systems and integrate with a powerpack to reduce the thermal burden and enhance operational movement and tactical mobility. The products support PM Combat Vehicle Program (CVP) and other armored ground vehicles.

- Advanced Fan System - Provide optimized fan geometry and intelligent fan drive for improved static efficiency and reduction of fan power consumption
- Advanced Heat Exchangers - Increase heat transfer within same space claim; reduce weight/volume buying back performance and internal volume.

Energy Efficient Hydraulic Fluids (EEHF)

Reduce energy (fuel) consumption in Construction Equipment/Material Handling Equipment (CE/ MHE) equipment by developing an energy efficient hydraulic fluid formulation and hydraulic fluid efficiency models. The EEHF requirements will be documented in a performance specification with qualified products for DLA-Aviation to purchase. Project will verify hydraulic fluid efficiency models developed for CE/MHE to further understand the efficiency gains that can be attributed to hydraulic fluid formulations. Efficiency testing will be conducted via laboratory rig and vehicle level testing.

Fuel Efficient Gear Oils (FEGO)

This project will develop the necessary tools and methods to identify fuel efficient gear oils that can be competitively purchased by the DLA.

Fuel Cell In-House

Maintain and strengthen in-house technical knowledge and competencies through hardware testing, system integrations, collaborations with industry, government and academia and managing technical research efforts that push the state of the art and reduce system cost and complexity.

Advanced Combat Engine (ACE)

Development of a 1500hp, high power dense engine (>150 hp/liter) with greater fuel economy (10-15%), improved thermal efficiency (15%), and lower heat rejection (20%) for use in future combat vehicles and demonstrated in the CVP platform.

Advanced Combat Transmission (ACT)

Development of a high efficient cross-drive transmission for a track vehicle mated to a 1500hp high power dense engine while offering greater fuel economy (10-15%), improved thermal efficiency (15%), and lower heat rejection (20%) for use in future combat vehicles and demonstrated in the CVP platform.

"Transforming the way we use energy is essential to rebalance our Corps and prepare it for the future."
—Gen James F. Amos, 35th Commandant of the Marine Corps

Additional TARDEC S&T projects that are of interest to PEO LS include:

- Manufacturing of Fuel Cell Hybrid Systems for Extended Missions
- Capability Demonstration 2: Battlefield Fuel Reduction & Water Generation Analysis

Small Business Innovation Research (SBIR) Efforts

Adaptive Diesel Engine Control via Variable Valve (Smart Lifter Technology) (Phase II)
Issue Addressed: Current use profile shows engine operates at two different and distinct load levels 400 brake horse power (BHP) to climb slopes, accelerate under full payload, or traverse soft soils 10 – 20 BHP to support idle vehicle operation generating electricity and heating, venation, and cooling (HVAC) functions. Current state of the art only allows engine optimization at a single operational point. Demonstrate multi-operation point optimization thru use of prototype Smart Lifters operating on a Caterpillar C-12 engine by the end of Phase II.

Objective: Demonstrate the benefit of cylinder deactivation and variable valve timing on Diesel/JP-8 engine fuel economy and power output. Estimates from Phase I suggest up to 31% fuel economy improvement during idle/surveillance mode and up to 15% fuel economy improvement during driving.

Parasitic Load Reduction to Improve Engine Efficiency (Phase II)
This SBIR program focuses on a combined software/hardware solution to reduce the volume of fuel consumed by the MTVR engine during mission operations while increasing the power output of the engine. These goals will be reached thru modification of the Caterpillar C-12 enabling full and independent control of diesel engine components allowing the engine to operate at maximum efficiency across the full spectrum of engine loads.

Variable Speed Accessory Drives (Phase II)
The objective of this Phase II research is to develop a variable ratio cooling fan drive for the MTVR. The MTVR currently utilizes a clutch style fan drive operated with air pressure. It is believed that the fuel economy of the MTVR can be improved by implementing a variable ratio cooling fan drive and controlling the cooling fan speed as a function of coolant temperature.

6.1.2 Intelligent Power and Thermal Management

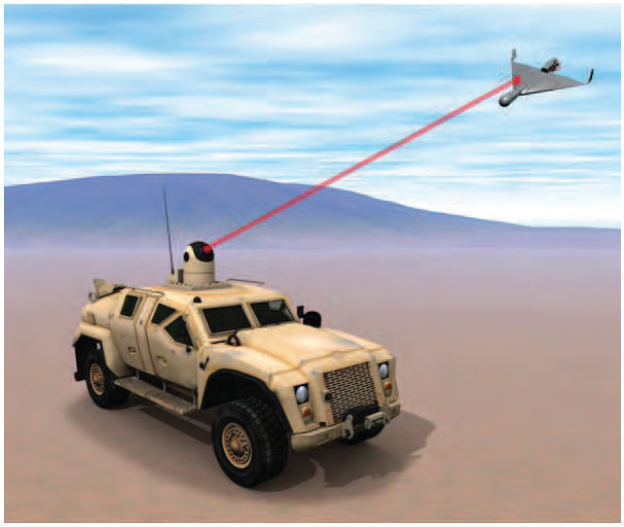
The Challenge

Protecting electrical systems from temperature extremes is imperative to maintaining functionality, efficiency, and operational readiness. Thermal analysis is important to the design of heat shields, anti-icing systems, propulsion system integration, and maintenance of controlled environments in cabins. Using power generated in an optimized manner and managing the different thermal loads can extend vehicle operations. The projects described below address many of the needs associated with this challenge through management of thermal loads and energy consumption on Marine Corps tactical vehicles.

Potential Solutions

PEO LS Efforts

MTVR Auxiliary Power Unit (APU) Phase II Study
Issue Addressed: Reduce fuel use by MTVR during



GBAD OTM Concept

extended static operations. Use information gathered to inform requirements:

- Fuel savings versus baseline static MTVR
- Fuel savings versus standard 10kW generator
- Operations and maintenance costs
- Cost to upgrade each MTVR
- Changes to MTVR weights and capacities
- Operator and maintainer training impacts
- Provide qualitative user assessment
- Demonstrated capability using only of COTS equipment

Objective: Demonstrate capability of an MTVR with a 10kW Auxiliary Power Unit integrated behind vehicle cab. Support development of operational capability documentation and formal CD&I requirement. Phase II objective is to stand-up 5 MTVRs for User Evaluation and Testing.

ONR Efforts

Ground Based Air Defense On the Move (GBAD OTM) – Future Naval Capability

This Enabling Capability (EC) demonstrates close-in, low altitude surface-to-air laser fire in defense of MAGTF assets defending forward combat areas, maneuvering forces, vital assets installations, and/or units engaged in special/independent operations. This EC will demonstrate the capability of a rugged expeditionary high energy laser demonstrator cued by a radar that is capable of detecting low radar cross section threats and performing soft and hard kills of unmanned aerial systems (UAS) to prevent reconnaissance, surveillance, targeting, and acquisition of expeditionary forces.

SBIR Efforts

Atomic Layer Deposition Technology for Gallium Nitride Microwave (Phase II)

This project targets the development of a commercially viable silicon-nitride (SiN) Atomic Layer Deposition (ALD) process for gallium nitride (GaN) Monolithic Microwave Integrated Circuits (MMIC) applications. In particular, this project will provide a higher quality substitution for commonly used Plasma-Enhanced Chemical Vapor Deposition (PEVCD) SiN passivation layers.

An Additional SBIR project that is of interest to PEO LS includes:

- Compact Auxiliary Power System for Amphibious Vehicles

"One of the most mature "game changing" technology areas is Directed Energy, and specifically, High Energy Lasers."
—Statement Testimony of Mr. Alan R. Shaffer, Principal Deputy, Assistant Secretary of Defense for Defense Research and Engineering Before the United States House of Representatives, Committee on Armed Services Subcommittee on Intelligence, Emerging Threats, and Capabilities March 26, 2014

TARDEC Efforts

Integrated Starter Generator (ISG)
The purpose of this is to develop, test and integrate a 160kW ISG system & controls to be implemented as part of the advanced powertrain demonstrator demonstrated at Transition Readiness Levels (TRL) 6.

Advanced Li-Ion Modular Batteries (AMB)
Problem Statement: Current military battery technologies have insufficient energy density to meet silent watch requirements and support the introduction of enhanced capabilities such as an ISG, APU and start/stop functionality on our military vehicle platforms. In addition, current batteries have restrictions with respect to recharge rate and operating temperature limitations. Commercial industry is not addressing this gap by developing batteries capable of meeting military requirements in military specific form factors.

Purpose: Apply recent commercial advances in Lithium-ion based anode, cathode, electrolyte and separator battery materials to electrode, cell, and military specific pack designs to:

- Double the energy density from current lithium-ion batteries from 80Whr/kg to >160Whr/kg while increasing power density by >50%.
- Increased the operating temperature range for the Li-ion batteries from (-20^{0}C to +50^{0}C) to (-46^{0}C to +71^{0}C).

Advanced Auxiliary Power Unit
Supporting CVP. Provide electrical power for ground vehicle main engine off operations. Develop a compact, scalable APU to provide power while meeting size and weight requirement.

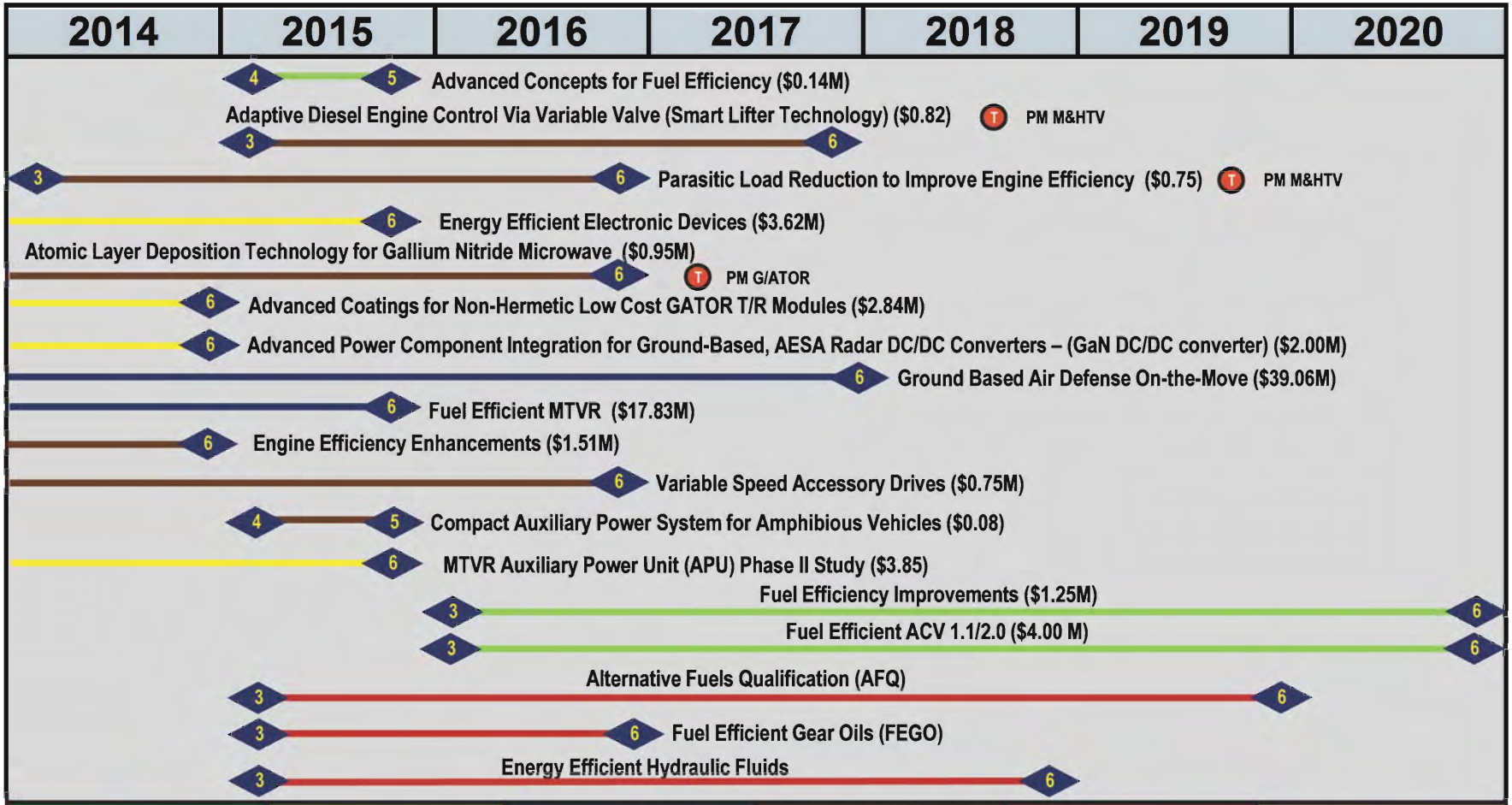
Advanced Running Gear (ARG)
Develop external suspension and high capacity lightweight track system that will improve the vehicle mobility and survivability. The products will support PM CVP with potential to support other heavy tracked vehicle customers.

Additional TARDEC S&T projects that are of interest to PEO LS include:

- Advanced Vehicle Power Technology Alliance (AVPTA)

The Power & Energy Focus Area charts on the following pages highlight critical efforts monitored and supported by the PEO LS S&T Director.

Power & Energy

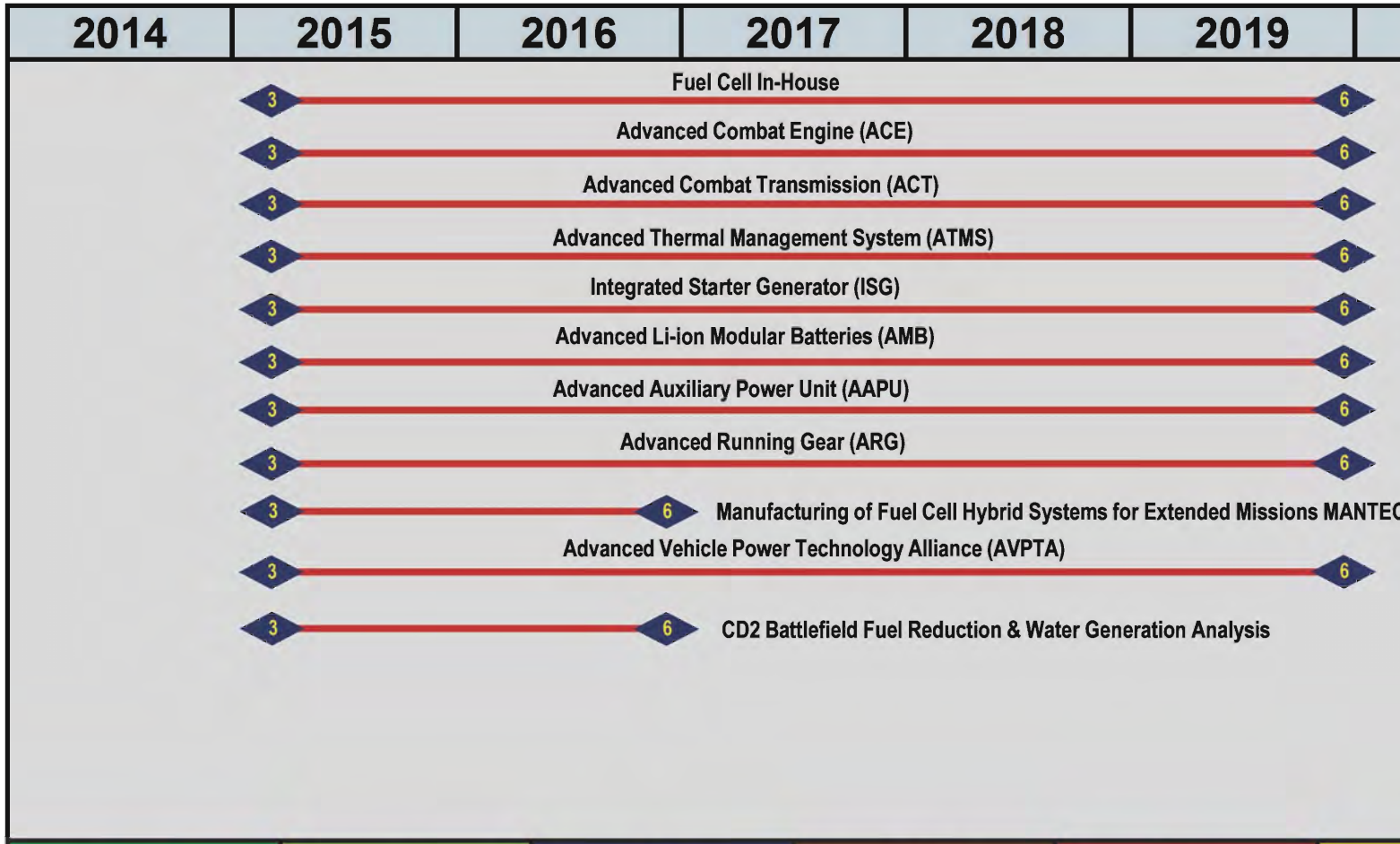


D&I	E&D	FNC	SBIR/STTR	TARDEC	Other

Funding Profiles ($M)	FY14	FY15	FY16	FY17	FY18	FY19	FY20
S&T (6.2 / 6.3)	17.31	17.72	11.90	9.81	6.20	4.19	4.25

6.1 ⟷ Science & Technology ⟷ 6.3 6.4 ⟷ System Development ⟷ 6.7

Power & Energy



D&I	E&D	FNC	SBIR/STTR	TARDEC	Other

Funding Profiles ($M)	FY14	FY15	FY16	FY17	FY18	FY19	FY20
S&T (6.2 / 6.3)		53.97	62.57	68.48	63.28	62.79	

6.1 ← → Science & Technology ← → 6.3 6.4 ← → System Development ← → 6.7