Military Fuel Cells & Infrastructure for Energy and Environmental Security

Seattle, WA
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Business Development

National Automotive Center

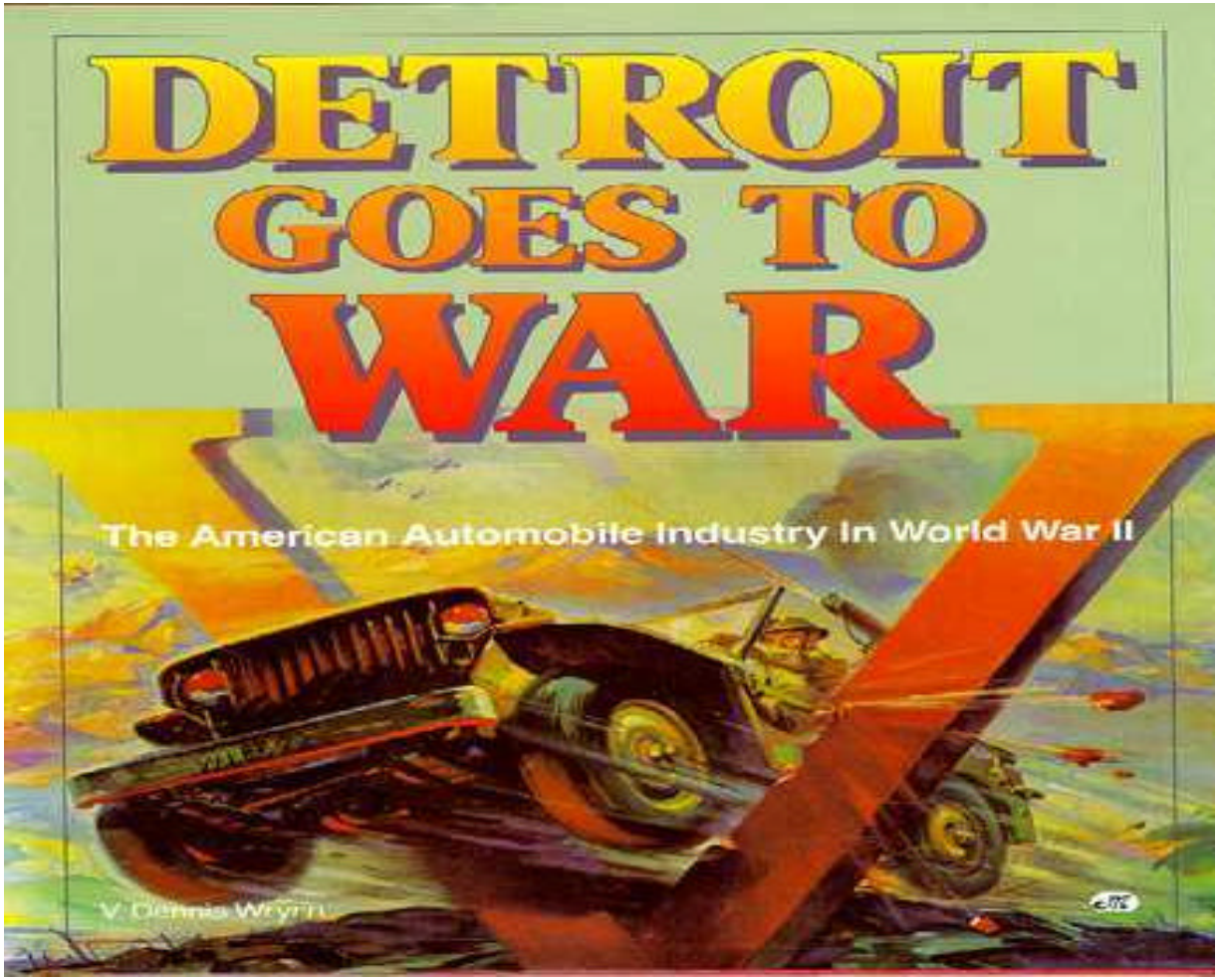
U.S. Army TACOM

Outline

- National Automotive Center (NAC) Mission
- DOD/NAC Methods of Engagement
- Energy Policy Act and Executive Orders
- Programs of interest and technologies
- Transitions, risk mitigation and initiatives

NAC Vision

Serve in a leading role as a catalyst linking industry, academia and government agencies in the development and exchange of automotive technologies by leveraging government, commercial industry and academia R&D investments focused on those technologies that have commercial and military benefits. We must satisfy our military customers and our taxpayers by pushing the deployment of technologies in a rapid and cost effective manner.


DETROIT
GOES TO
WAR
The American Automobile Industry in World War II

Methods Working Together

Automotive Research Center (ARC)

Cooperative Authority Agreements (CAA)

Dual-Needs/ Dual-use Automotive Technology Contracts

Cooperative Research and Development Agreement (CRADA)

Broad Agency Announcements (BAA)

Small Business Innovation Research (SBIR)

Technology Demonstration Programs

Who's Involved

- Dept of Energy
- Army/Navy/USMC/Air Force
- Dept of State
- Dept of Commerce
- EPA
- State Gov's

- Industry
- Transportation
- Energy Companies
- Independents
- Non Profits
- Academia
  - Universities
  - Community colleges
- International
  - Europe
  - Asia

On Going NAC Efforts

Partnerships for effective and commercially viable fuel cell and advanced fuels technologies to military vehicle systems.

Current partners and contractors:

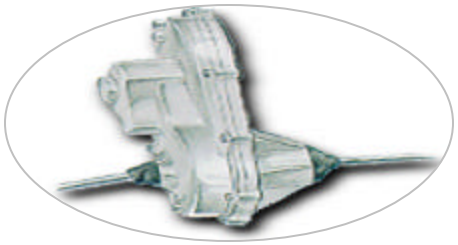
Delphi Automotive
Ballard Power Systems
Freightliner
University of Alabama
SunLine Services Group
Southwest Research Ins.
General Dynamics C4 Systems
Syntroleum Corporation
Hydrogenics
UTC Fuel Cells
Dynetek
EMP
Pittsburgh Electric Engines, Inc.
Ricardo
University of Michigan
Michigan Technological University
Kettering University

DOD (Federal) Justification

- **EO 13149: Fleet & Transportation Efficiency**
  - Directs Federal Agencies to Fulfill Intent of EPAct
  - Reduce Petroleum Usage by 20% by end of 2005
  - Maximum use of AFVs
- **EO 13123: Leadership in Environmental Management**
  - Emerging Technologies
  - Reduced Emissions
  - Reduced use of petroleum based fuels
- **Energy Policy Act (EPAct)**
  - Statutory requirements for acquisition of AFVs
  - 75% of acquired light-duty Vehicles must be AFVs
  - EPAct credits for purchase of AFVs

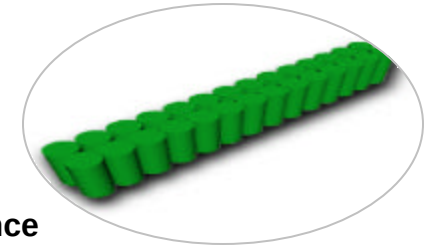
Developing Technologies

- Automotive Research Center
  - Eight universities
- 21st Century Truck Initiative
  - SmarTruck, COMBATT, IMPACT
  - Fuel Cell and Alt fuels
- Fuel Cell Locomotive
  - Grid connection
- APU Power Generation
  - Tactical, combat, mobile, stationary, manned, un-manned
- Fuels
  - Flexible JP-5, Syntroleum



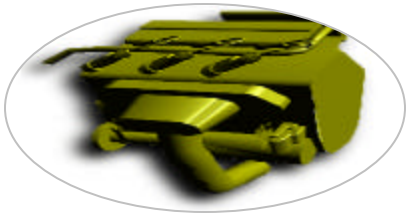
DRIVETRAINS
- Manual
- Automatic
- Continuously Variable Transmission/Planetary
- Wheel Motors

ENERGY STORAGE
- Lead Acid
- Nickel Metal Hydride
- Lithium Ion



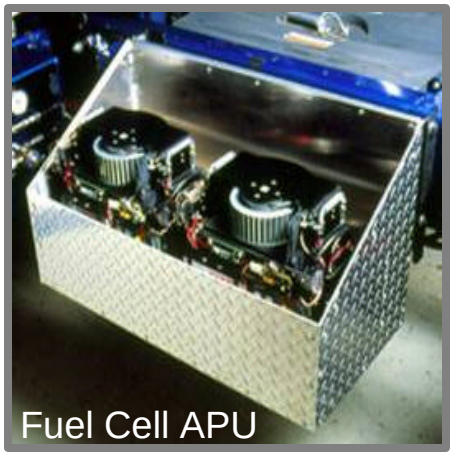
Vehicle Intelligence
Advanced Materials
High Output Diesel Engine
Silicon Carbine-Aluminum Metal Matrix Composite
Electro-Mechanical Suspension
Electronically Controlled Active Breaking
C4ISR

PROPULSION
- Advanced Diesels
- Turbo-Generator
- Fuel Cell



Hydrogen and Fuel Cells

Fuel based solutions
Defense/industry partnerships
Fuel cells enhance mobility of soldiers
Technologies to enable Army meet deployment & sustainment goals


Fuel Cell APU

Light Duty
Fuel Cell System

Fuel cell
passenger vehicles

Tactical Wheeled Vehicle

NAC Fuel Cell Program

Leverage emerging commercial fuel cell technologies for use in military ground vehicles

Chief research interests:

- Achieving high net propulsion system power density
- Reforming high sulfur fuels
- Water recovery and conditioning
- Fuel cell propulsion system-level modeling

- **Current projects**
  - Diesel Reformer Fuel Cell Truck
  - Solid Oxide Fuel Cell Auxiliary Power Unit (APU) for Long Haul Trucks
  - Fuel Cell Auxiliary Power Unit for Heavy Trucks
- **Pending project**
  - Tubular solid oxide fuel cell engine
  - APU for Vocational Class 2 truck
- **Under evaluation**
  - Fuel cell APU with regenerative H2 storage for the Light Armored Vehicle

Fuel Cell APU Unit

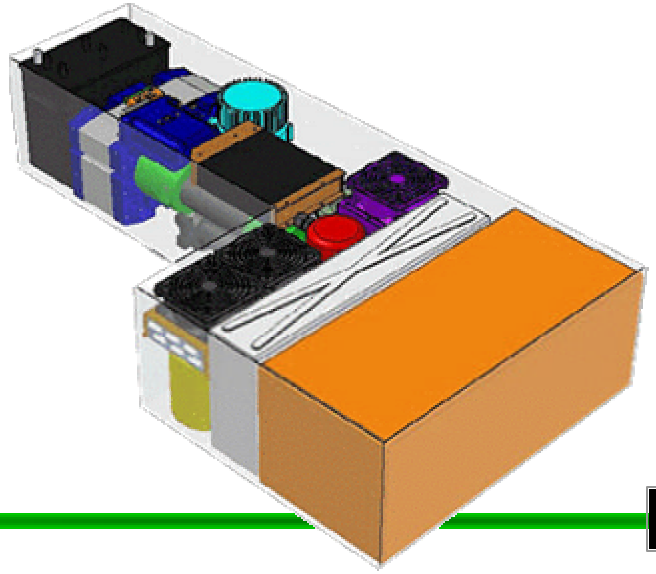
Regenerative Fuel Cell System

System weights 138kg

Base concept design to fit same 130L battery compartment

Deliver up to 6KW instantaneous (cranking)

6-20 hours of usability; range high function (2kW) to silent watch (800W) conditions



Hydrogenics MREF

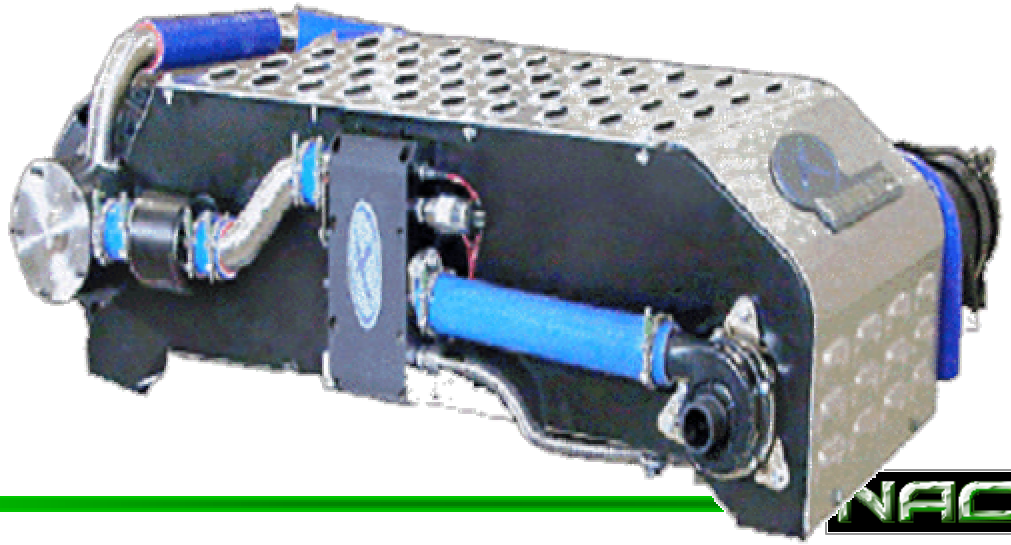
Multi-service Regenerative Fuel Cell

DOD/DND interest
PEM with Regenerative H2 Ability
5 kW peak 3 kW avg
15 kWh Storage
Minimal-sound and IR
O2, Potable H20, heat residuals
28V DC APU powers on-board electronic
Demonstrated on an FMTV and GM HEV (COMBATT) pictured

LP^2 FC Engine

Low Profile / Low Pressure

PEM
Non-regenerative
20 kW (24 kW Actual)
Commercial & Military (Dual Use)
John Deere FC Gator
GM Autonomy
DoD/DND interest



Alternative Fuels and Fuel Cell Technology

Primary Applications

- Auxiliary power generation for manned ground vehicle
- Primary power generation for manned ground vehicles

Ancillary Applications

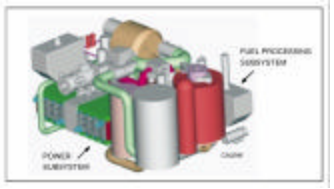
- Primary power for Unmanned Ground Vehicles
- Mobile electric power generators
- Fixed stationary power for fixed base

Customers determined within application niches as technology matures. Test bed platforms: commercial trucks, administrative platforms, personal mobility platforms, and ground support vehicles.

DOD Interests

- Benefits of fuel cells
  - No emissions / potential to use multiple fuels (renewable)
  - Apply to multiple platforms – stationary & mobile
- Existing DoD programs
  - DARPA – “Palm Power” program – small 20W fuel cells
  - Air Force – auxiliary power / ground support equipment
  - Navy (ONR) – 500 kW shipboard generator (DG)
  - Army – stationary, mobile, prime mover FC demos
- Technical issues
  - Reformer technology (TACTICAL) (PEM, solid oxide, etc.)
  - Power density (cost per KW)
  - Fuel type (Linking production, storage, distribution)

TAR-03/Reformer Based Fuel Cell APUs



Schedule & Cost

MILESTONES	FY04	FY05	FY06	FY07	FY08	FY09
Power system M&S						
Characterization of fuel cell and reformers	3					
Hardware integration						
Characterization of improved fuel cell						
Powertrain integration			6			
Total Army $2.4M Army ($M)	0.8	0.8	0.8			

Purpose:

Develop the hybridization of fuel cells and diesel engines.

Define logistic fuel reformer design for 40-60kw FCS fuel cell APU.

Product:

A experimentally validated powertrain model.

Brassbroad hybridization of a fuel cell system and a heavy diesel engine.

Technical performance targets and optimized vehicle integration design for a logistic fuel reformer.

Technical objectives for hardware development of a logistic fuel reformer and fuel cell APU

Payoff:

Clear program objectives for a 40-60kw logistic-fueled combat vehicle fuel cell APU hardware program.

TAR-03/Reformer Based Fuel Cell APUs

FY04	FY05	FY06	FY07	FY08	FY09

TRL=3
Characterization of Nexa fuel cell module using hydrogen and simulated reformate
Select & model candidate reformer components; revise rankings

METRICS:
- Performance data
- Fuel consumption
- Volume
- Effectiveness
- Cost

TRL=3
Demonstration of hybrid power source concept
Identification, characterization and ranking of component & subsystem technologies for modeling

METRICS:
- Identify associated metrics

TRL=3
Characterization of larger fuel cell module

METRICS:
- Polarization
- Fuel consumption

TRL=6
Demonstration of fuel cell/diesel hybridization
Demonstration of mobile system sulfur management/removal

METRICS:
- Identify associated metrics

TRL=4
Specification of larger fuel cell module
Configure and model subsystem designs

METRICS:
- Electrical load profile

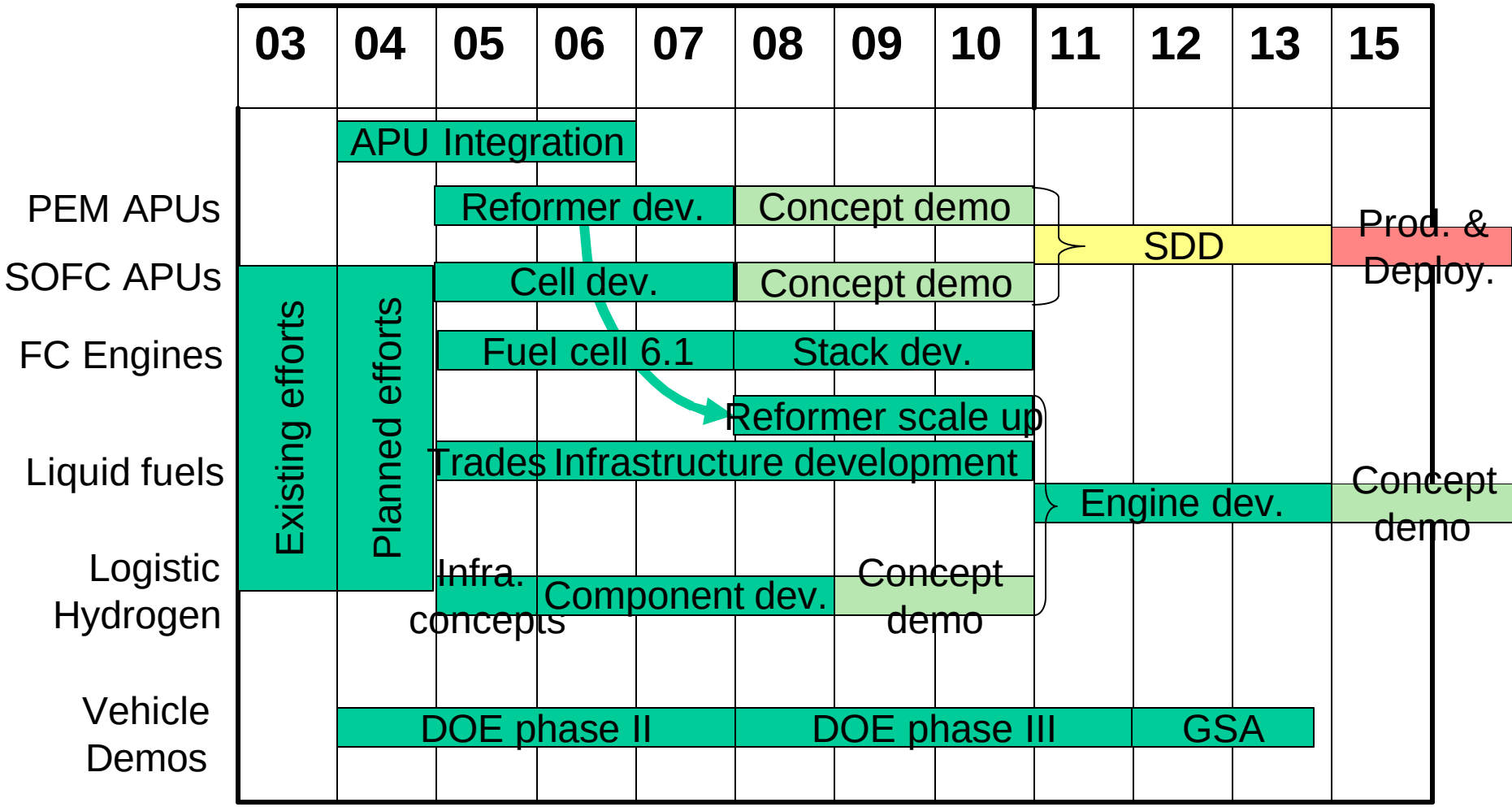
TRL=6
Model of hybridized system, including logistic fuel reformer

METRICS:
- Overall fuel consumption

Pacing Technologies:

- Availability of fuel cell and reformer test and evaluation data
- Experimental validation of fuel cell/diesel engine hybridization
- Powertrain models with electrical accessories, diesel engine and fuel cell.

Fuel cell way ahead



Non-tactical Vehicles

- **Fuel Cell Administrative Vehicle and Infrastructure Pilot Program**
  - **DOD/DOE Infrastructure Demonstration**
  - **Military/Commercial Needs – credits/sales**
  - **Military Bases – potential test bed for FreedomCAR Program**
  - **Dual use facilities in non-attainment zones (airports)**

Summary

Auxiliary power solutions continue to be central to the fuel cell program.

Several new activity areas to be sought through the BAA process

- Light vehicle propulsion
- “Deployable” hydrogen production
- Fielding of prototype fuel cell vehicles in cooperation with the DOE

Fuel remains at the center of remaining challenges, either the reformation of existing logistic fuels or the logistic acceptance of alternate fuels

The NAC continues to execute and plan for future programs in primary and auxiliary fuel cell power center of the Defense/Industry Fuel Cell Partnership

Risk Mitigation

Explore multiple, complementary paths with achievable stepping stones.
Picking good partners and selecting the right project will reduce this risk.

- Back up

Risk Mitigation

- **Commercial developments set the pace for military vehicle technology insertion**
  - **A successful commercial fuel cell truck engine developed will probably work for a military truck**
  - **Combat vehicle propulsion is much more challenging**
  - **Electric drive systems must see concurrent development**
- **Auxiliary power units are a shorter-term commercial application of fuel cells, military market, no idle zones**
- **NAC Strategy: Develop APUs, use hybrids, clean fuels**
- **Partner with industry – work to future success**

Technology Readiness Levels - for Hardware and Subsystems

		Description
TRL 1	Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
TRL 2	Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there is no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
TRL 3	Analytical & experimental critical functions and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
TRL 4	Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
TRL 5	Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technology components are integrated with reasonably realistic supporting elements so that it can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
TRL 6	System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment, or in a simulated operational environment.
TRL 7	System prototype demonstration in an operational environment.	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment, such as an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.
TRL 8	Actual system completed and "flight qualified" through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
TRL 9	Actual system "flight proven" through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.