Future Fuels

Flag Officers
&
Senior Executive Service

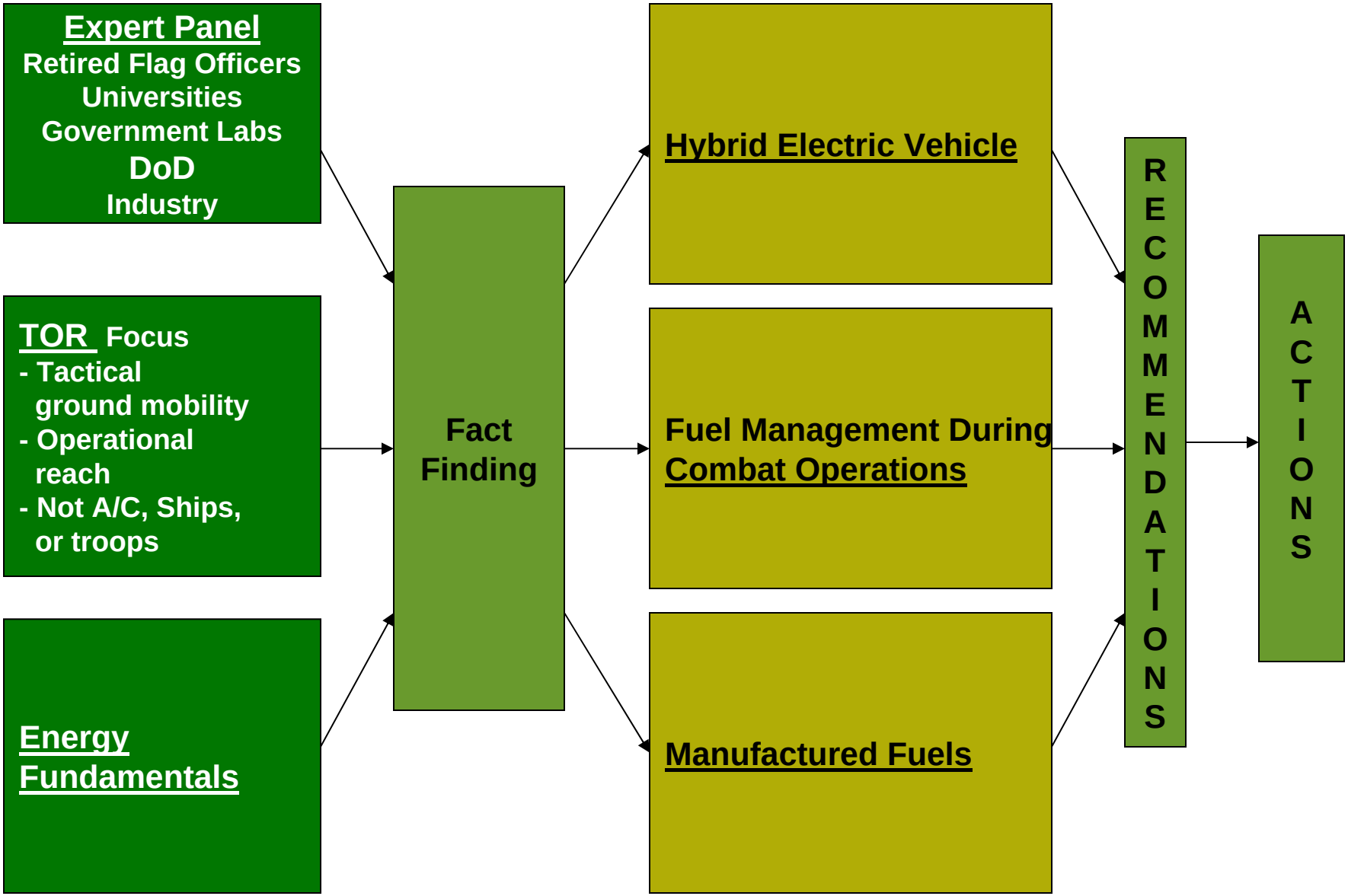
4 October 2005
The Pentagon Auditorium

Terms of Reference

- ***Focus on tactical ground mobility and increasing operational reach***
- ***Identify, review, and assess***
  - ***Technologies for reducing fuel consumption, including alternative propulsion technologies***
  - ***Militarily useful alternative fuels***
- ***Recommend a strategy to leverage the cooperative research among DoD, DoE, and industry***

"Unleash us from the tether of fuel."
-LtGen James Mattis, USMC

Study Flow


Expert Panel
Retired Flag Officers
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DoD
Industry
TOR Focus
- Tactical ground mobility
- Operational reach
- Not A/C, Ships, or troops
Energy Fundamentals
Fact Finding
Hybrid Electric Vehicle
Fuel Management During Combat Operations
Manufactured Fuels
RECOMMENDATIONS
ACTIONS

Fact-Finding

Briefings from…

Service Perspectives

MCCDC, HQMC
DASN (RDT&E), ONR, NRL
HQDA (S&T), TARDEC, Army PM (Unit of Action)
USAF AFRL

Energy & Emissions Policy

DoE, OSD, OPNAV N42

Fuel Logistics

MCCDC, Army TRADOC, DLA/DESC

Propulsion & Energy Storage Systems

Oshkosh, Caterpillar, General Dynamics LS
U Wisconsin, Battelle, DoE NTRC, NRC
ONR, TARDEC, ARL, NAVSEA, NAVAIR
Japan: Toyota
UK: Rolls-Royce, DSTL, Royal Navy

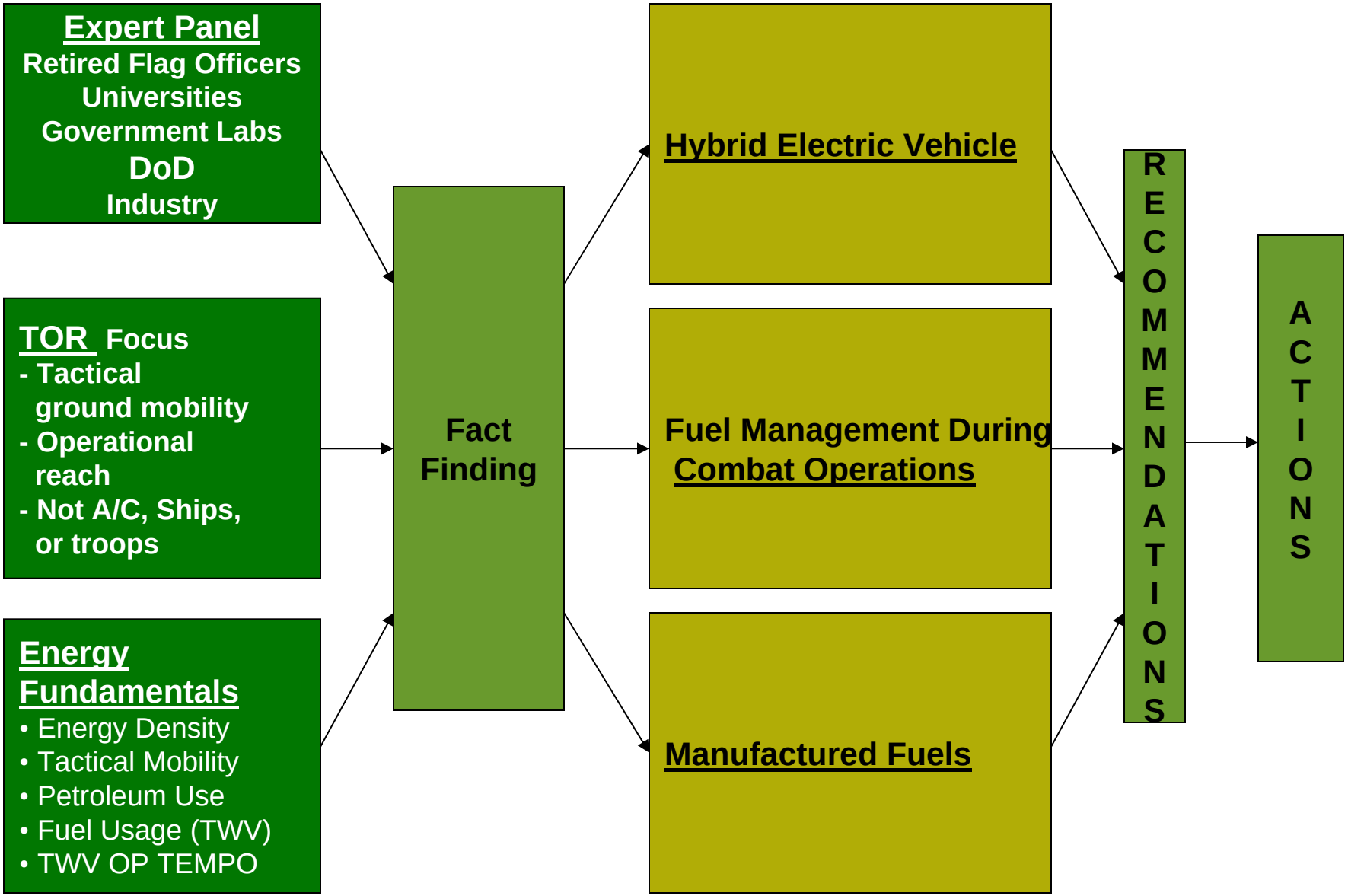
Alternative Fuels & Fuel Manufacturing

DoE HQ, Oak Ridge National Laboratory
OSD, DARPA, ONR, NRL, NSWC
Shell Oil, Baard Generation, Rentech

Takeaways

- ***Fuel Economy is Combat Power …***
  a key performance parameter
- ***Liquid hydrocarbons …***
  the ideal transportation fuel
- ***No single "silver bullet" to 50% reduction in fuel consumption***
- ***Key actions:***
  - ***Commit to hybrid electric architecture for Tactical Wheeled Vehicles (TWV)***
  - ***Long term commitment to manufactured liquid hydrocarbon fuels from domestically abundant feedstocks***

Study Flow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• Energy Density
• Tactical Mobility
• Petroleum Use
• Fuel Usage (TWV)
• TWV OP TEMPO
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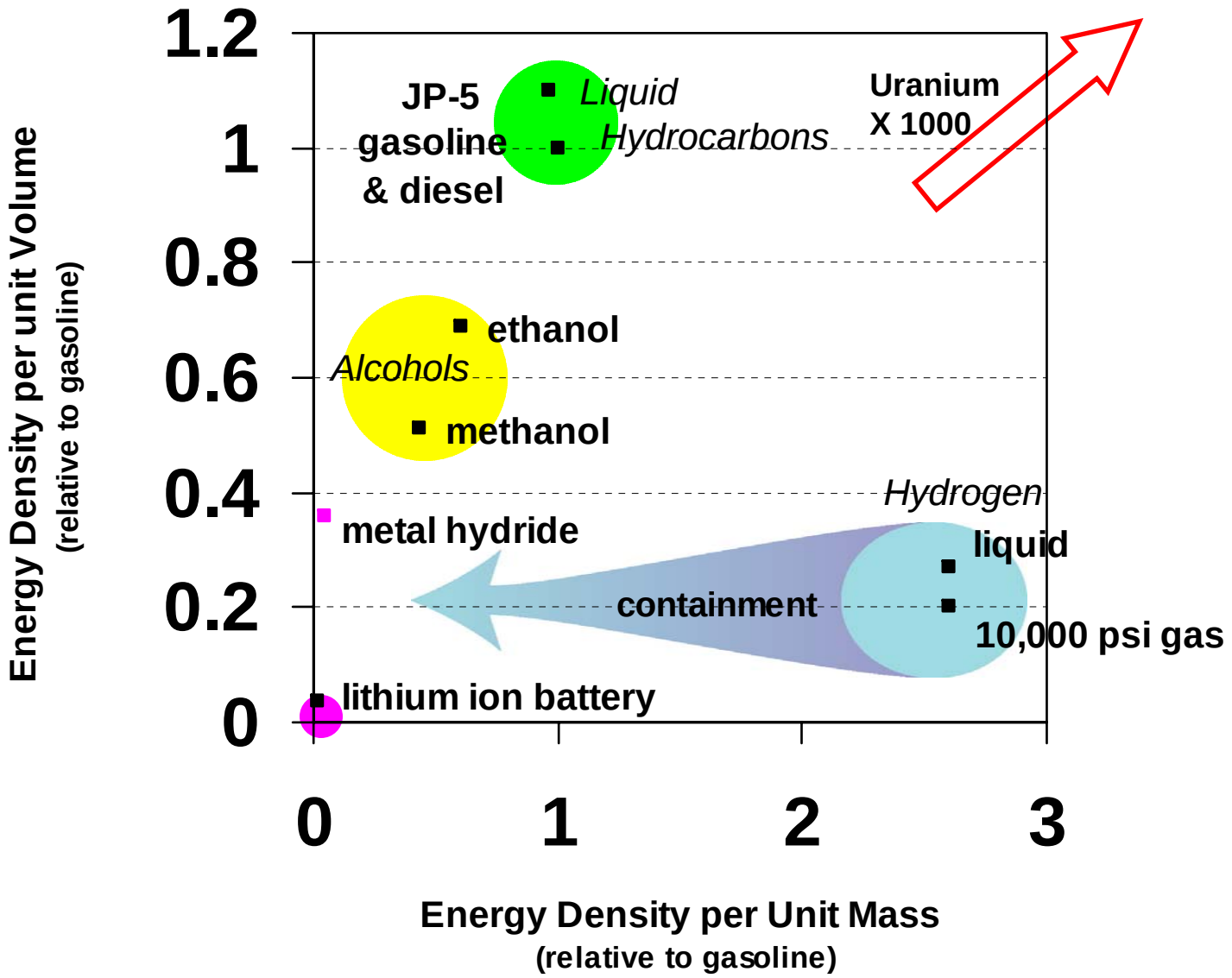
Energy Density of Fuels

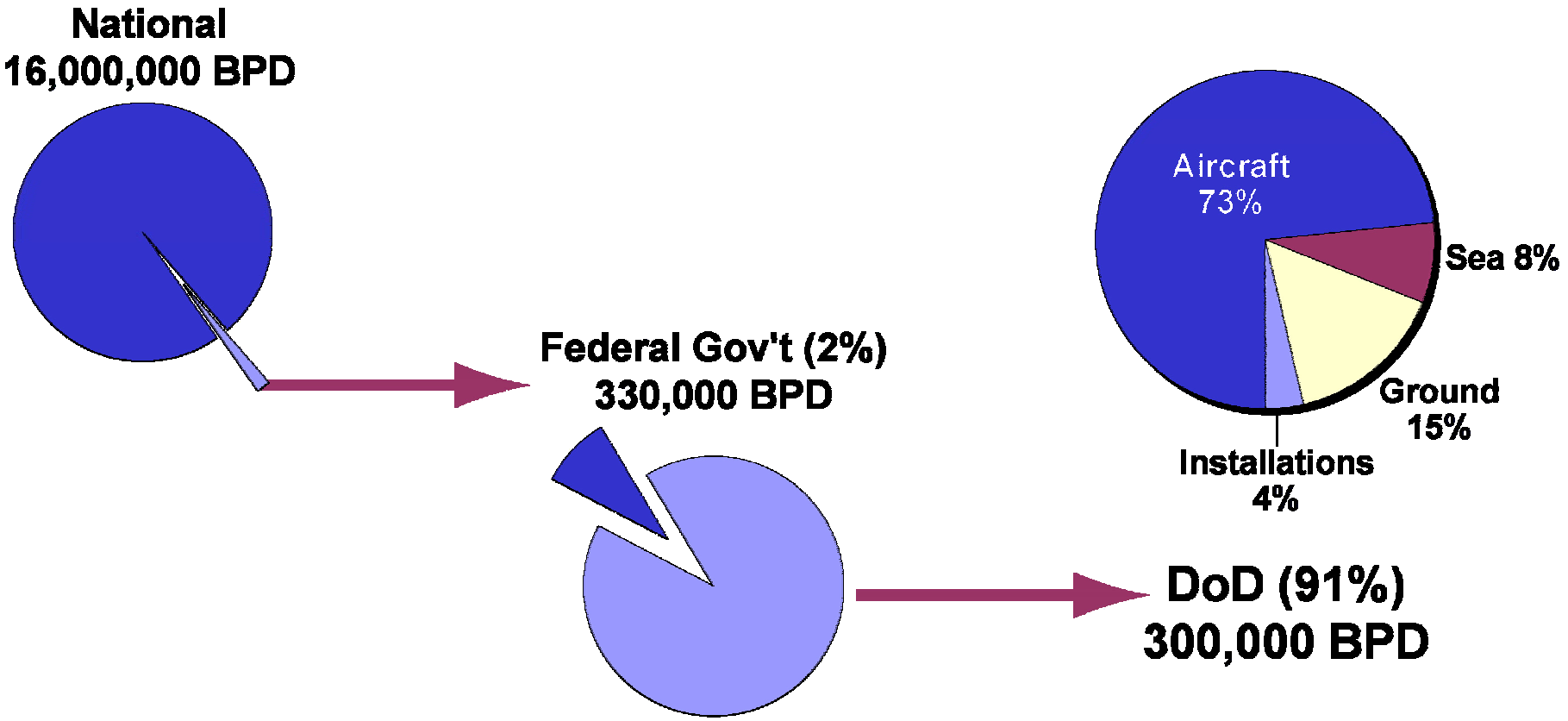


Tactical Mobility Fuel

- *Tactical Vehicle designs impose severe limitations on volume and weight*
- *Energy Density is therefore the primary figure of merit for transportation fuels*
- *Hydrogen presently unsuitable for a tactical mobility fuel*
  - *made using other fuels*
  - *containment reduces energy density a factor of 10 to 20*

Liquid Hydrocarbons are the ideal fuel for tactical mobility

Petroleum Usage 2003



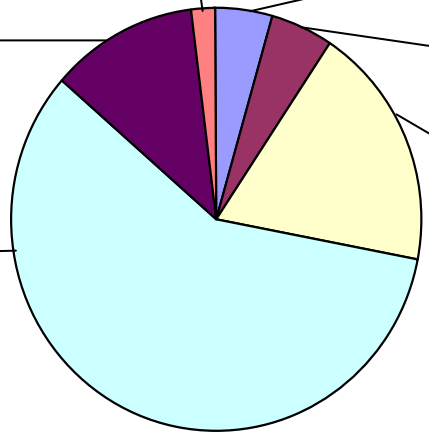
DoD Is Petroleum-Dependent ...But Cannot Drive The Market

Fuel Usage
Tactical Wheeled Vehicles (TWV)

69.7%

HMMWVs – 11.7%

5-Ton – 58%



Other – 2.2%

Tanks – 4.5%

AAVs + LAVs – 4.8%

LVS – 18.8%

Tactical Wheeled Vehicles Account for 88.5% of Fuel Usage

TWV Operational Tempo and Mission Profile

- ***May 2005 IGMC Findings from OIF:***
  - ***"The fleeting nature of insurgents demands highly responsive, highly maneuverable and highly agile ground combat power"***
  - ***All classes of TWV's average 70-75% off road/unimproved roads***
  - ***Heavy reliance on Mobile Electric Power (MEP) throughout the AOR***
- ***Distributed Op's further complicate TWV power & fuel***
- ***Electrical power requirements growing rapidly***

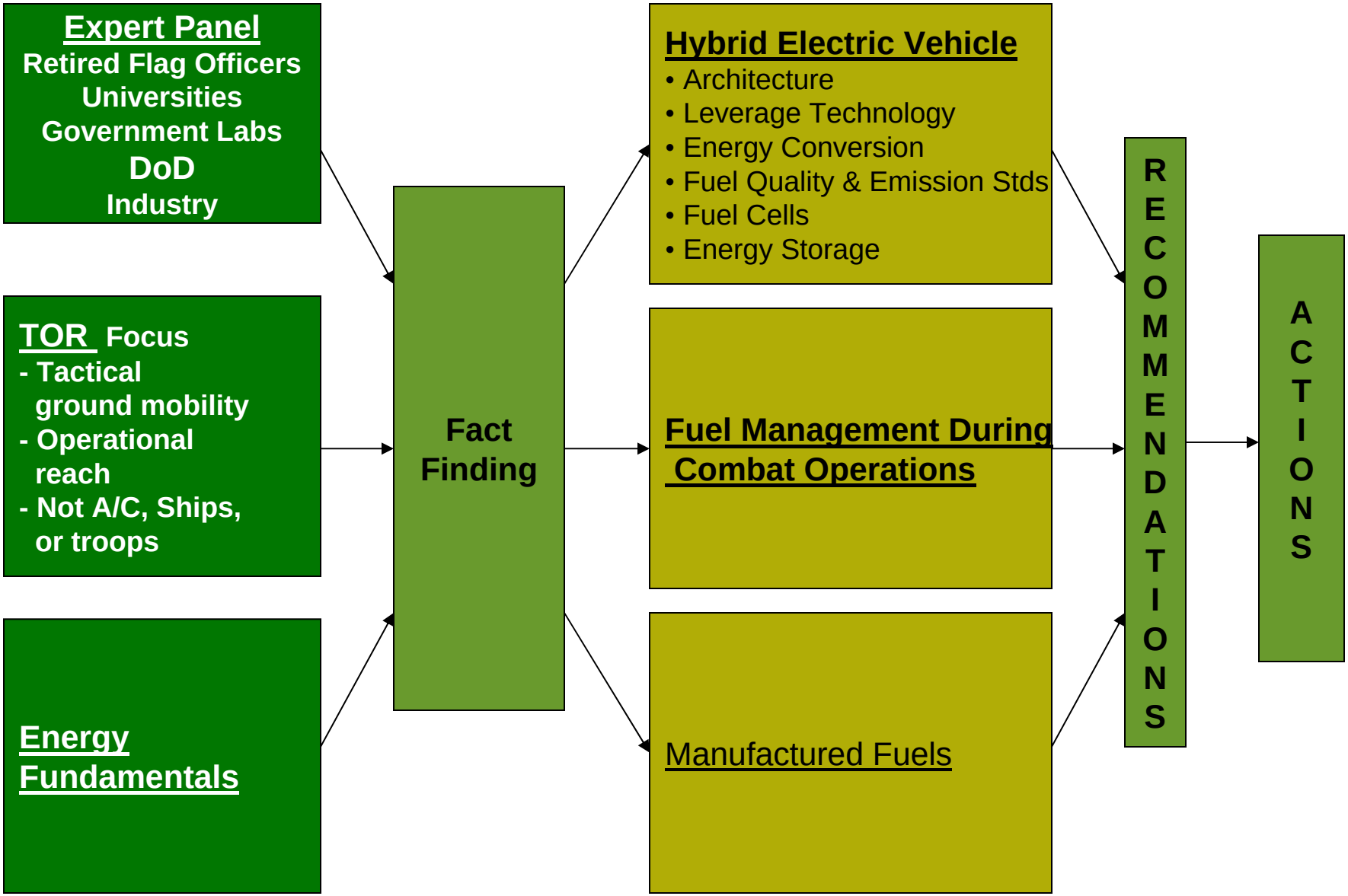
Future TWV's…off-road fuel efficient with power generation

Findings

Future battlefield mobility requires effective utilization of fuel

- ***Nearer-term payoff (PR 07/POM 08)***
  - ***Vehicle architecture implementation***
  - ***Commander's fuel management***
- ***Longer-term payoff (2015 & beyond)***
  - ***Fuel manufacturing***

Study Flow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Hybrid Electric Vehicle
• Architecture
• Leverage Technology
• Energy Conversion
• Fuel Quality & Emission Stds
• Fuel Cells
• Energy Storage
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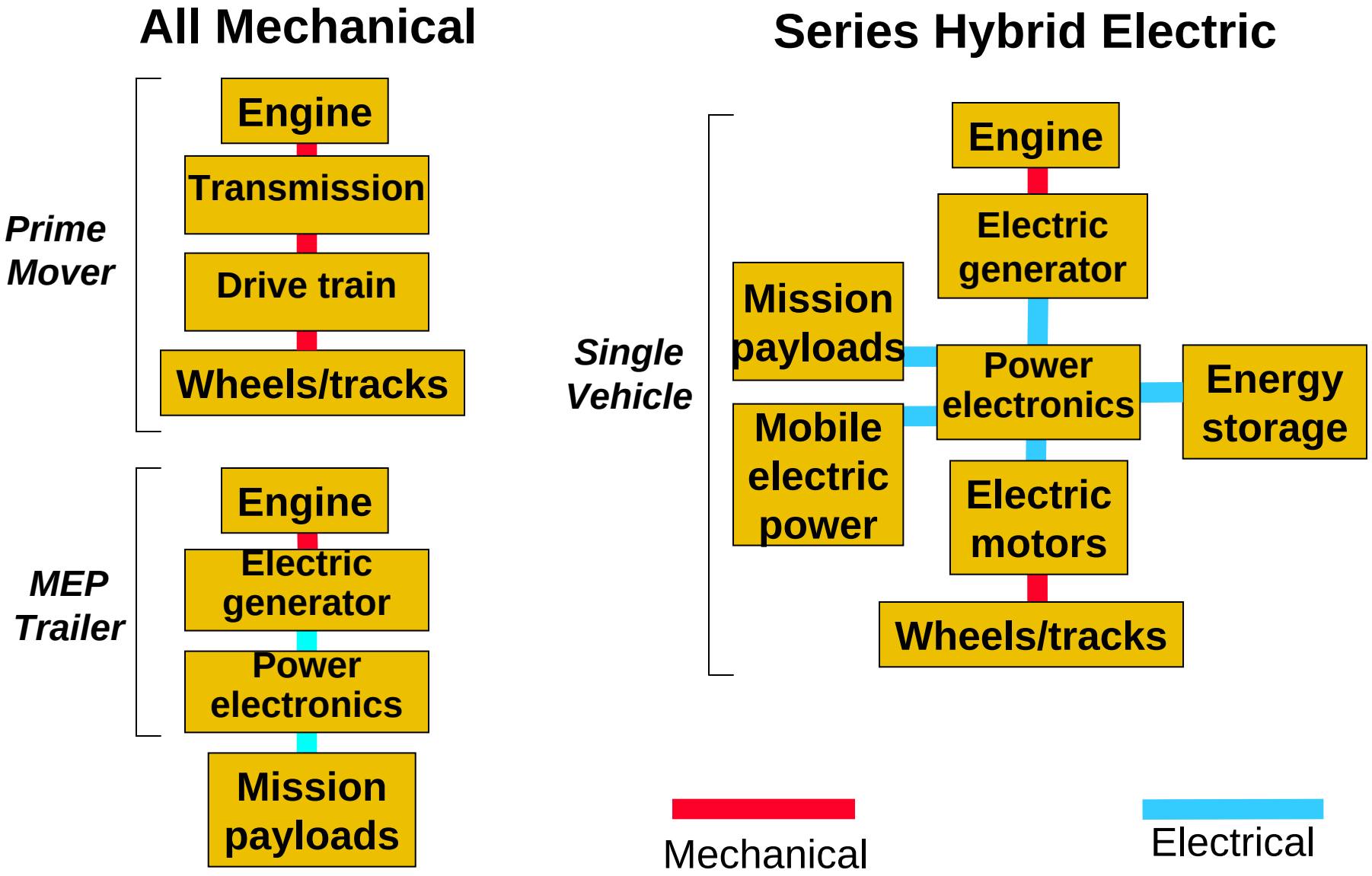
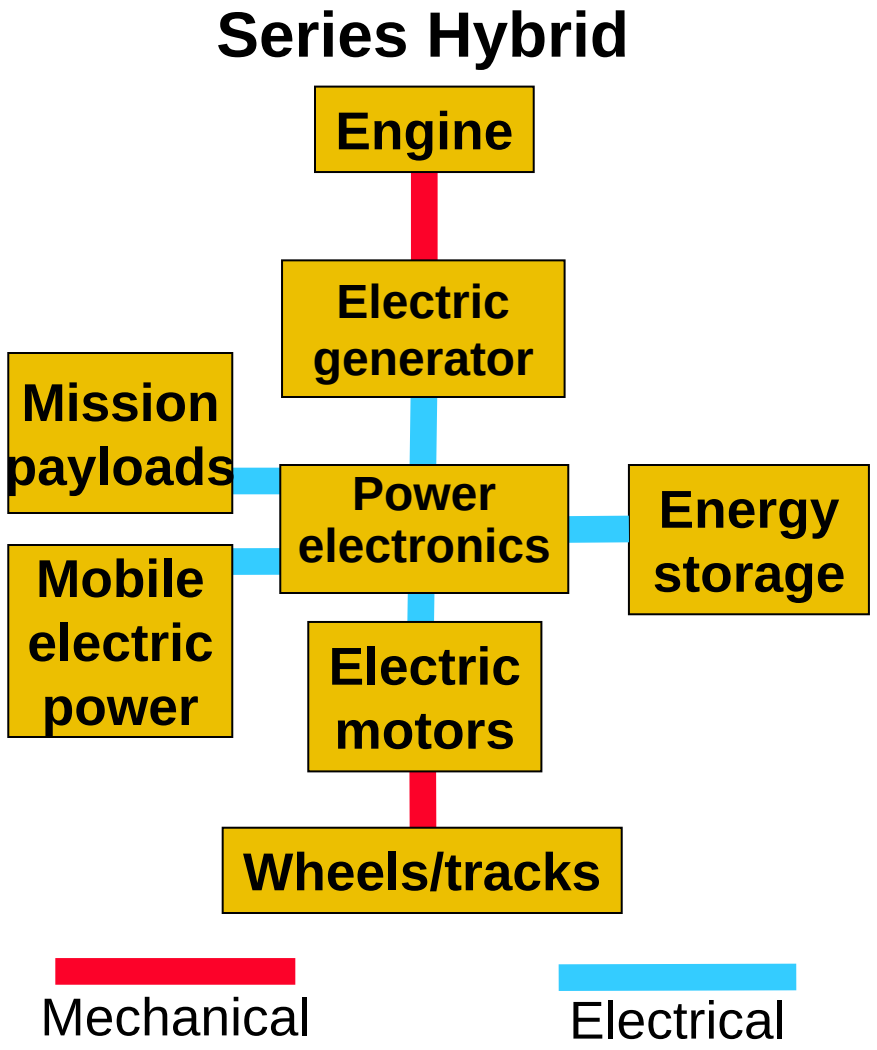
Comparison of Vehicle Architectures



Hybrid Electric Vehicle Architecture

- *Vehicle design flexibility*
- *Power distribution flexibility*
  - *traction power*
  - *mission payloads*
  - *mobile electric power*
- *Improved survivability*
- *Inherent modularity improves maintainability & upgradability (readiness)*
- *Design growth to emerging electric sources (e.g. fuel cells)*



Opportunities to Leverage Technology
Hybrid Electric Vehicles

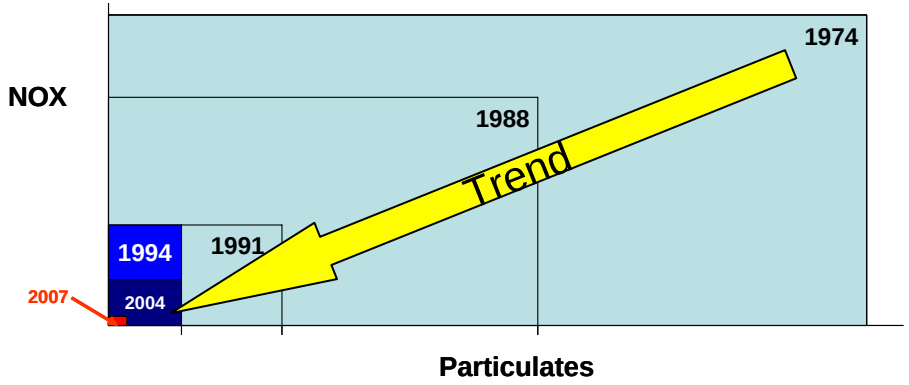
Technology/Action	Commercial	Army	Needed (Naval)	
			Fund	Adapt
Systems Engineering	●	●	●	
Power Electronics and Controls				
– Size		●		●
– Thermal Management		●		●
Energy Storage				
– Batteries	●	●		●
– Ultra-Capacitors	●	●		●
– Flywheels		●		●
Energy Conversion				
– Engines	●			●
– Fuel Cells	●			●
– Reformers and Desulfurization		●		●
Motors				
– Permanent Magnet		●		●
– Wound Rotor	●		●	
Series Architectures and Integration				
– Modeling and Simulation		●		●
Active Heavy-duty Suspensions		●	●	
Integration of Mission Systems				
– Weapons and Armors		●	●	
– Pulse Power Technology		●		●
Mobile Electric Power		●	●	
RST-V Demonstration			●	

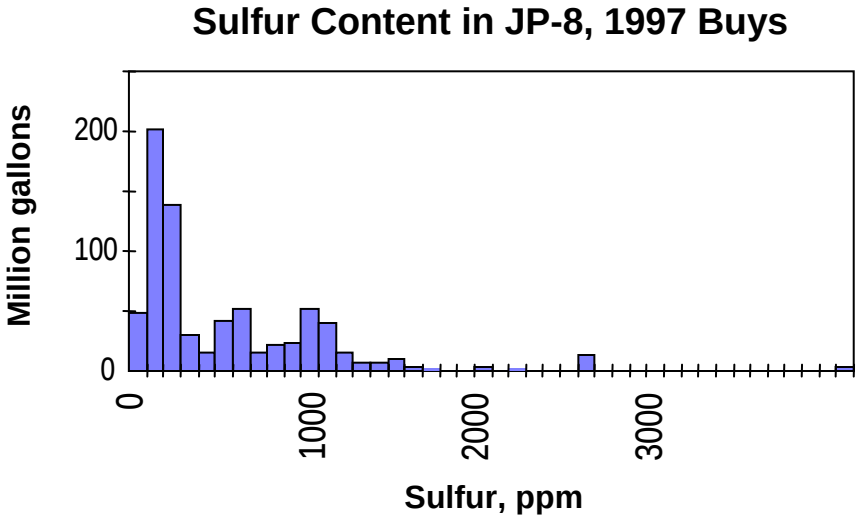
Energy Conversion
Diesel Engines

- ***Most fuel efficient***
- ***Commercial engines (or derivatives) offer the most affordable choice***
- ***But… commercial sector emphasis on emissions reduction leads to problems by 2010***
  - ***Performance and RAM-D sensitivity to substandard fuels***
  - ***After-treatment emission control systems cause significant vehicle integration and signature issues***
  - ***Increased importance of emissions waiver***

Emissions and Fuel Quality Impacts

- ***2010 Emission Standards -- Drastic Impact on DOD Tactical Vehicles***
  - ***After-treatment system as large as engine***
  - ***Cooling system 30% larger***
  - ***Cannot use substandard fuels without technological fix***





EPA Emission Waivers Need Support

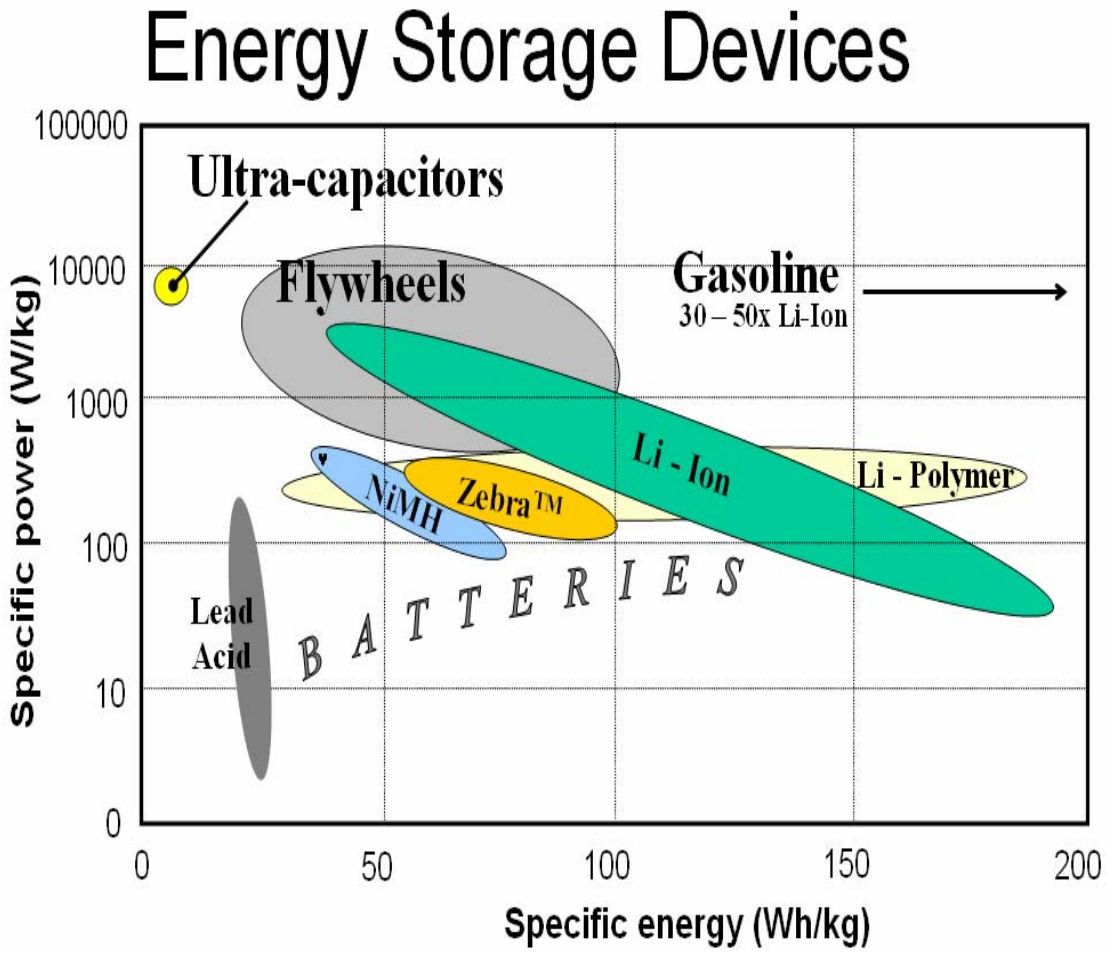
Fuel Cells

Long Term Alternative to Engines?

- ***Potential benefits***
  - ***Efficiency***
  - ***Pollution free, low signature***
  - ***Electric power availability***
- ***Commercial sector***
  - ***primary source of technology for vehicle applications***
  - ***focused on hydrogen fuel***
- ***Military use: diesel fuel reformer / desulfurizer development critical***
- ***Technical challenges include:***
  - ***power density***
  - ***cost***
  - ***low temperature operation***
  - ***start-up time, throttle response***
  - ***durability***

Not required for hybrid electric vehicles

Energy Storage

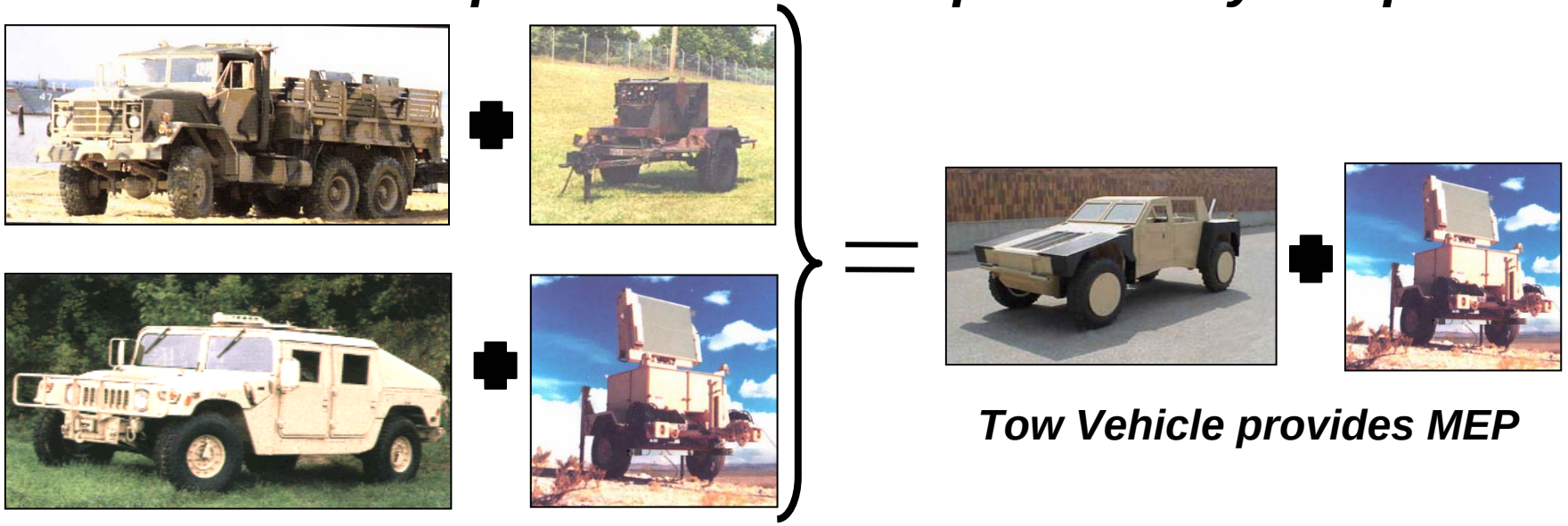


- ***Increases fuel efficiency***
  - ***Reduces engine power requirement***
  - ***Regenerative braking***
- ***Challenges:***
  - ***Energy density***
  - ***Cost***
  - ***Durability***
  - ***Safety***
- ***DoE and industry: Lead***
- ***DoN: Stay informed***

Benefits of HEV

- *20% improvement in fuel economy can significantly reduce existing MEF transportation shortfall*
  - *Up to 56K gal per day (12+ trucks @ 4,500 gals/ea)*

- *HEV electrical power reduces expeditionary footprint*



Tow Vehicle provides MEP

HEV Technology for TWV Replacements Can Improve Fuel Economy and Enhance Operational Capability

Conclusion: Hybrid Electric Vehicle Architecture

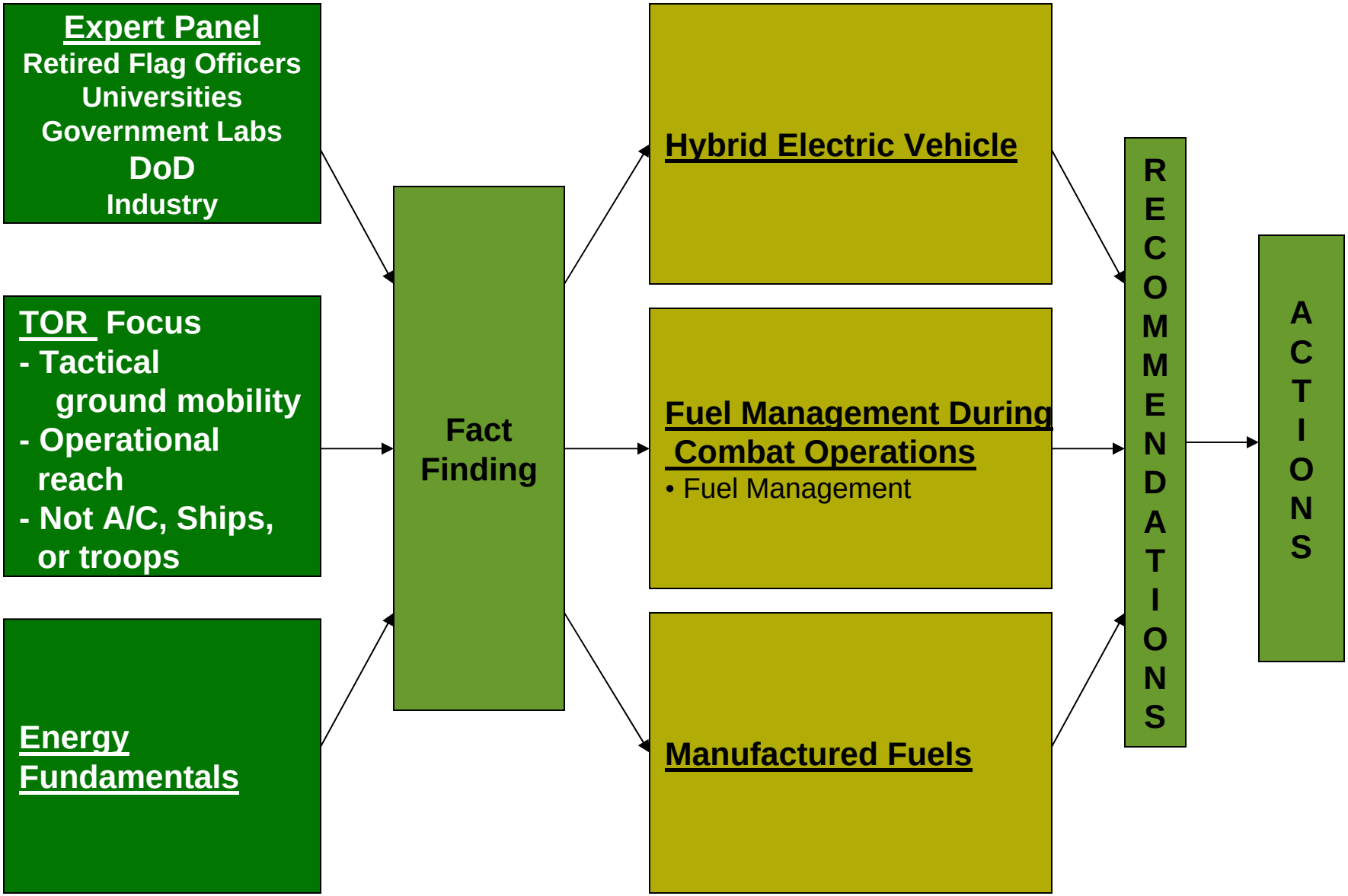
GDLS/USMC/DARPA RST-V Program: Complete
- *4 Prototypes in test*
- *2 in OIF JAN 06*

GDLS/Army: Advanced Hybrid Electric Drive (AHED)
- *One demonstrator*
- *19t*

Oshkosh/Army: HEMTT A3
- *20% better fuel economy*
- *C130 interface*
- *Exportable AC power*

- ***Demonstrated Mission Profiles - - -***
  - ***Traction Control for Maneuverability / Agility***
  - ***On/Off Road***
  - ***Overt/Covert***
  - ***Mobile Electric Power***
- ***Applicable to Unmanned Vehicles***
- ***20 % - Improved Fuel Usage…but limited data***
- ***Expanded Trade-offs - -***
  Reach & Mobility
  versus
  Added Systems Capability

Study Flow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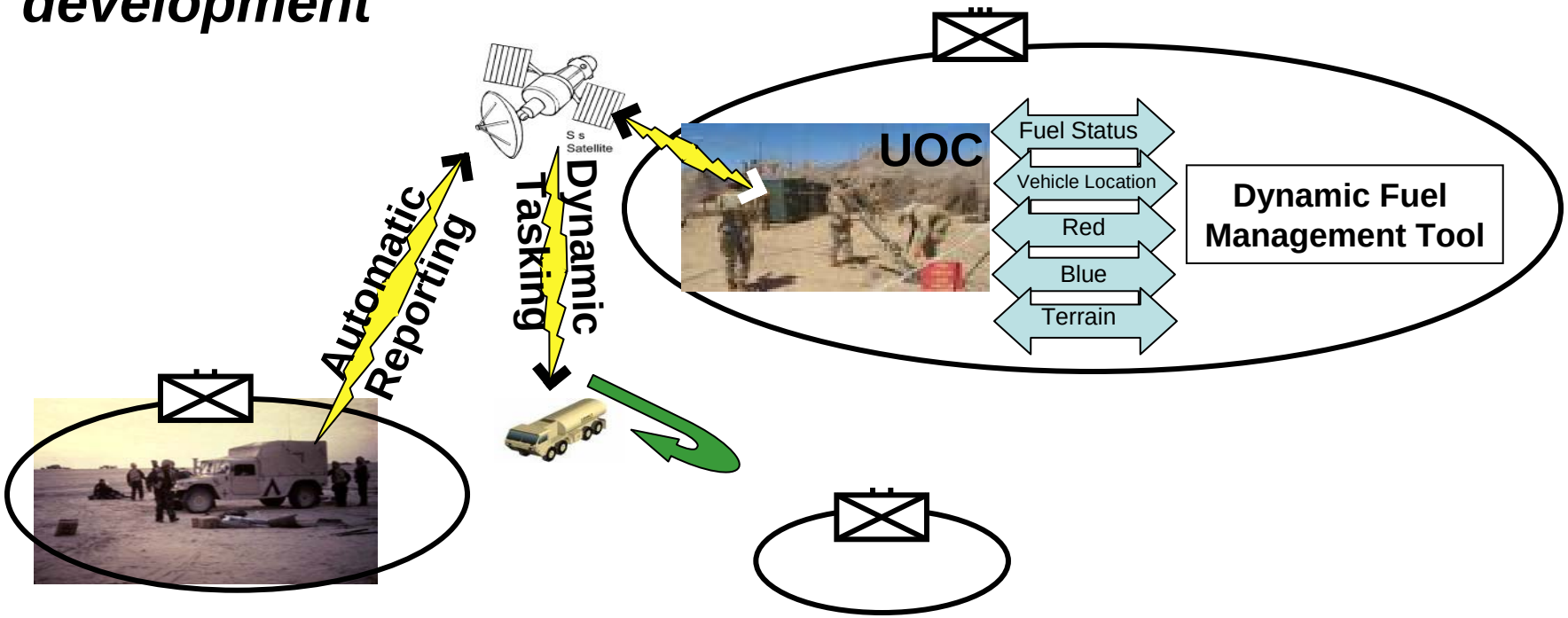
Fuel Management During Combat Operations

- *Improved fuel management increases operational reach*
- *Comprehensive fuel visibility/dynamic allocation:*
  - *Conserves fuel and sustains op tempo*
  - *Reduces the number/vulnerability of fuel trains*
- *Marine Corps' macro fuel estimating tool needs two additional critical elements*
  - *Automated vehicle fuel status and location reporting*
  - *Dynamic tasking via Blue/Red/Terrain data fusion*

Fuel is not simply a commodity or logistics issue – it is an operational imperative

Conclusion: Fuel Management

- *New tools to improve fuel management during combat operations*
- *Automatic vehicle location/fuel status reporting is the first step & is near term*
- *Dynamic allocation system requires substantial development*



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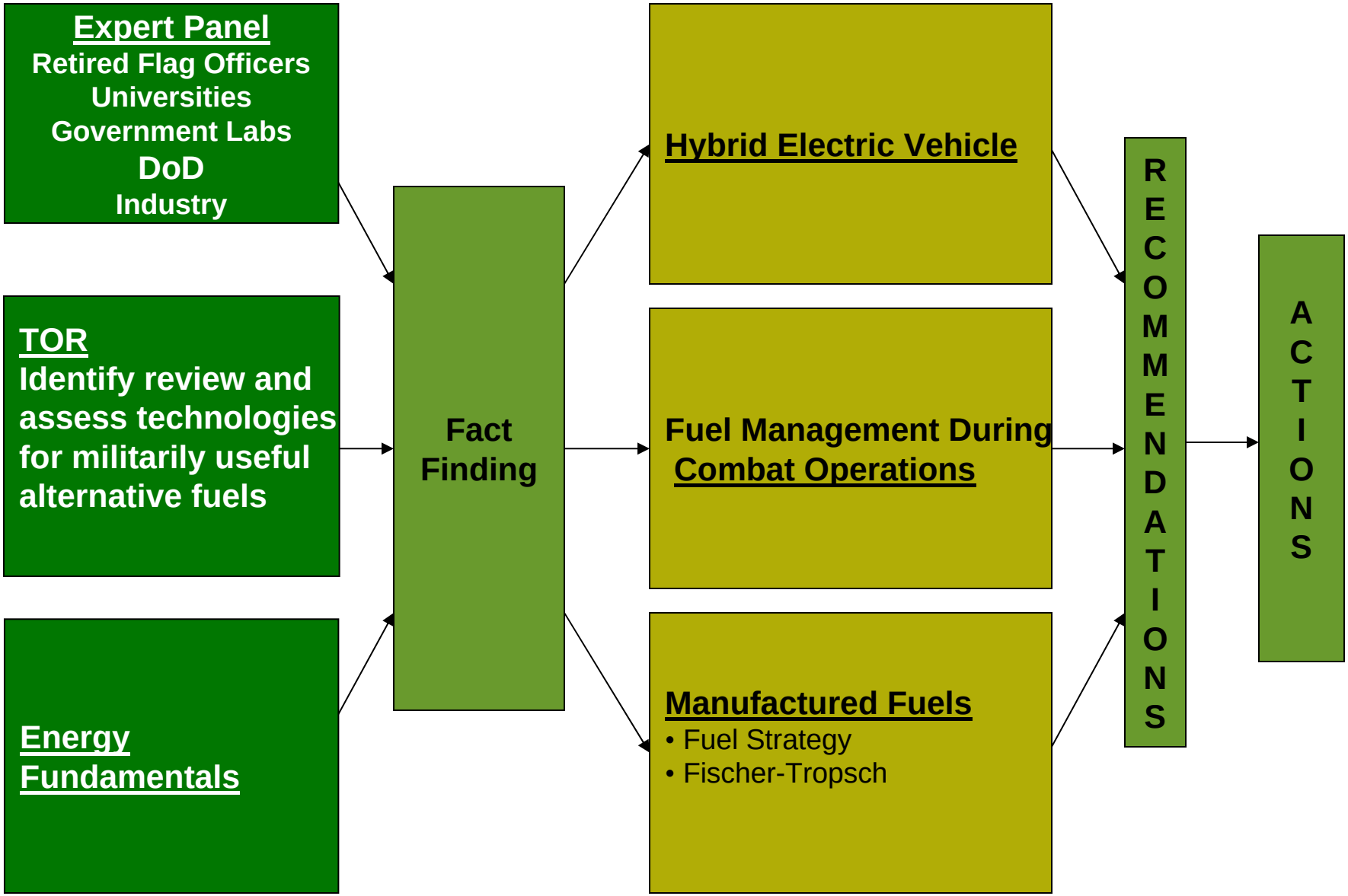
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• Fischer-Tropsch
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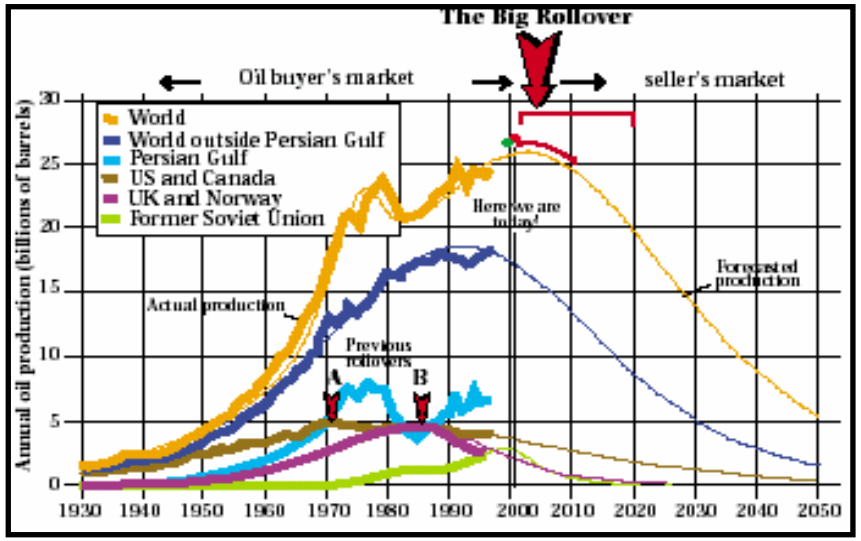
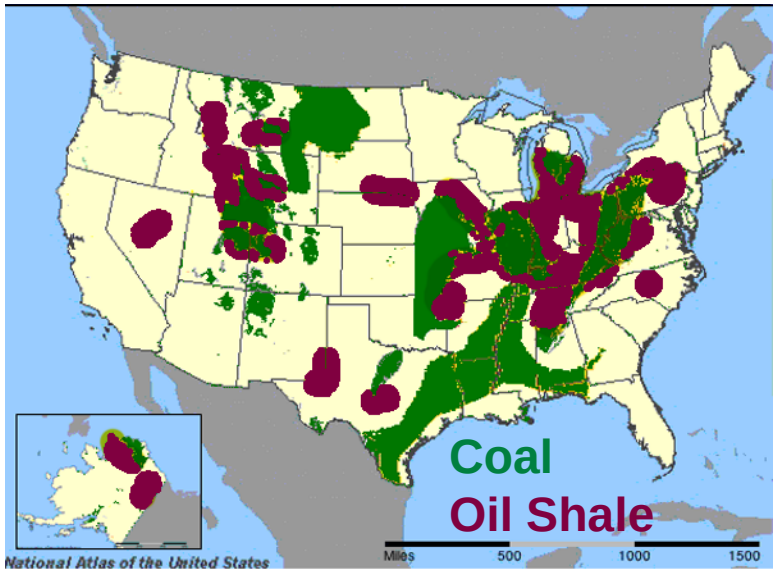
Mid-to-Far Term Fuel Strategy

- *Liquid hydrocarbon fuels have ideal properties and are needed as transportation fuels for the foreseeable future*
  - *Oil-derived fuels primarily imported and will become increasingly scarce*
  - *Existing refinery infrastructure*
    - *Predominantly coastal and vulnerable*
    - *Operating at capacity*
- *Alternative: Fuel efficiency, domestic resources, interior production*

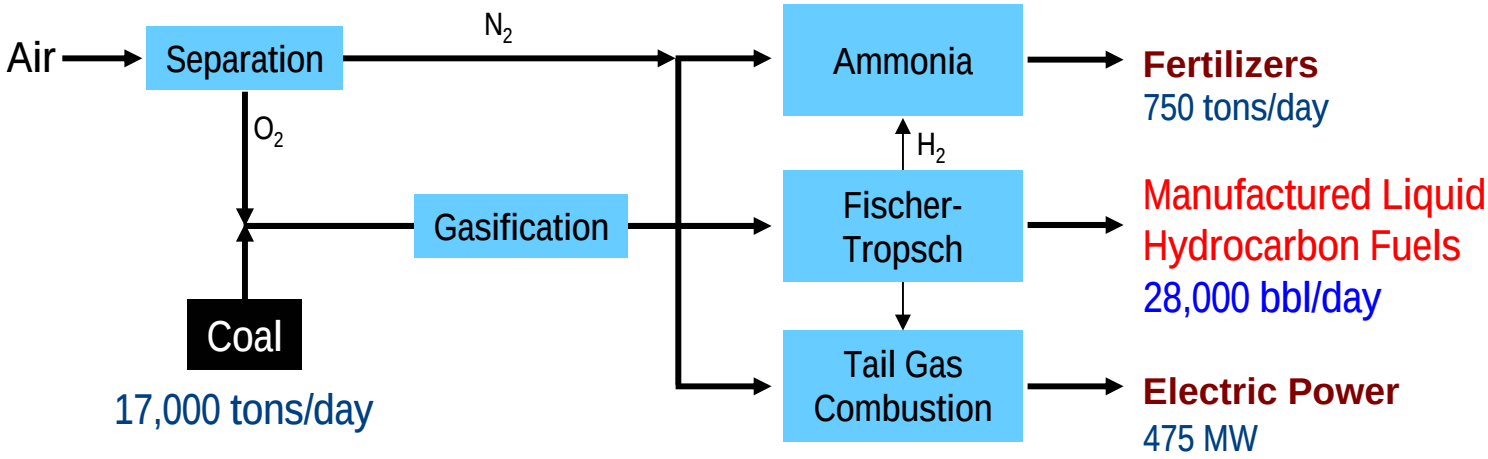


Median estimate of Hubbert's Peak
based on 11 authoritative sources: 2010



Manufacturing Fuel to Spec

- ***Gasification + Fischer-Tropsch = Clean fuel from domestic sources***
- ***Technology mature for natural gas, coal***
- ***Significant development underway by South Africa, China, Gulf States***



Sasol Fischer-Tropsch Plant, Secunda,South Africa

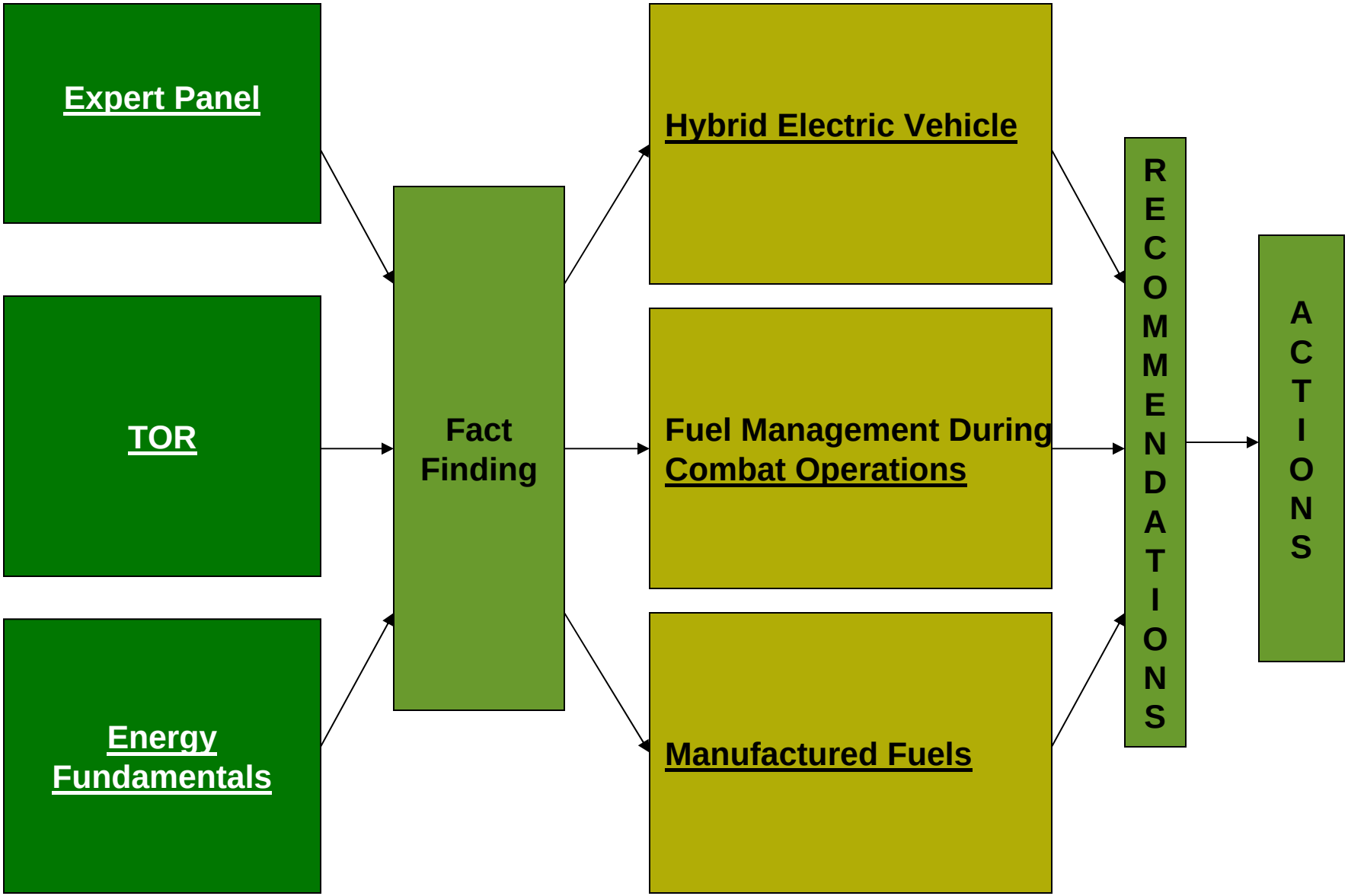
- *~10 such plants would provide all DoD fuel*
- *Commercial financing of such plants viable, given DoD commitment to purchase manufactured fuels at attractive prices*

Conclusions: Manufactured Fuels

- *Liquid hydrocarbon fuel production using domestic energy sources is feasible*
- *Commercial financing and infrastructure development will drive this process*
- *DoD action needed to catalyze development & ensure US military takes advantage of manufactured fuels*
- *Need to ensure military platforms can use manufactured fuels*

Manufacture Fuel from Domestic Sources — Decrease Dependence on Imported Crude Oil

Study Flow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Recommendations

Nearer-term Payoff (PR 07/POM 08)

- ***Fuel tether is still there, but...***
  - ***Found a way to lengthen it (HEVs)***
  - ***And untangle it (Fuel Management)***
- ***Commit to HEV technology for all future TWV***
  - ***Establish an HEV development roadmap***
  - ***Immediately initiate system engineering trade-offs***
  - ***Invest in on-going HEV development projects***
- ***Develop prototype system to enable real-time, in-stride fuel allocation for the Operational Commander***

Longer-term Payoff (2015 & beyond)

- ***DoD catalyze manufactured liquid hydrocarbon fuels infrastructure***
- ***Characterize the compatibility of manufactured liquid hydrocarbon fuels with DoN equipment***

Actions (1)

- ***Commandant of the Marine Corps (CMC)***
  - ***Support application for emissions waiver submitted by Army***
- ***ASN (RDA)***
  - ***With Services, advocate the use of multiyear procurement authority granted SECDEF in 2005 Energy Bill to <u>catalyze commercial financing</u> of large-scale FT plants producing transportation fuels***
- ***CG MCCDC (Request of CNR via CMC)***
  - ***Establish new program elements (6.2 & 6.3) for HEV technologies***
  - ***Demonstrate technologies for real-time fuel asset visibility***
  - ***Develop real-time dynamic fuel allocation prototype system***
  - ***Develop conditioning technologies for substandard tactical fuels***

Actions (2)

- ***CNR: Support these CMC tech investment requests***
  - ***Complete RST-V Technology Program***
    - *Transition from DARPA to ONR for final maturation*
    - *Develop on-the-fly mission profile selection technology*
    - *Transition Mature Design to CG MARCORSYSCOM*
  - ***Complete On-Board Vehicle Power Program***
    - *ONR Transition to CG MARCORSYSCOM*
  - ***Conduct real-time fuels status tech demos***
  - ***Develop Commander's real-time dynamic fuel allocation prototype system***
    - *Coordinate with DARPA to establish a joint program*
  - ***Develop technologies for conditioning expeditionary substandard tactical fuels***
  - ***Monitor status of FT Plant authorized by 2005 Energy Bill***
    - *Use fuel produced to conduct research on compatibility with current and future TWVs*

QUESTIONS?

Panel Membership

Dr. A. Michael Andrews II – Chair
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VADM Douglas J. Katz, USN (Ret.)
(Consultant)

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(Raytheon)

Mr. Richard L. Snead
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(Johns Hopkins University-APL)

RADM John T. Tozzi, USCG (Ret.)
(BMT Syntek Technologies Inc)

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(BAE Systems)

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(BearingPoint)

LtGen James N. Mattis, USMC
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Maj Graham C. Pierson, USMC
Executive Secretary
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