



Presented to:

**Mech Aero 2015
(San Francisco, CA)**

Unmanned Aircraft System (UAS) Engine Research at U.S. Army Research Laboratory

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October 7, 2015

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Multiple advantages to manned systems

- Enhance situational awareness – ISR
 - “Eyes of the Army”
- Reduce human workload
- Improve mission performance
 - Persistence, versatility, survivability
 - Ideal for dull, dirty or dangerous missions
- Minimize overall risk to human life
- Reduce cost



Selected UAS Application Areas



rescue



filming



agriculture



Fire fighting



Border control

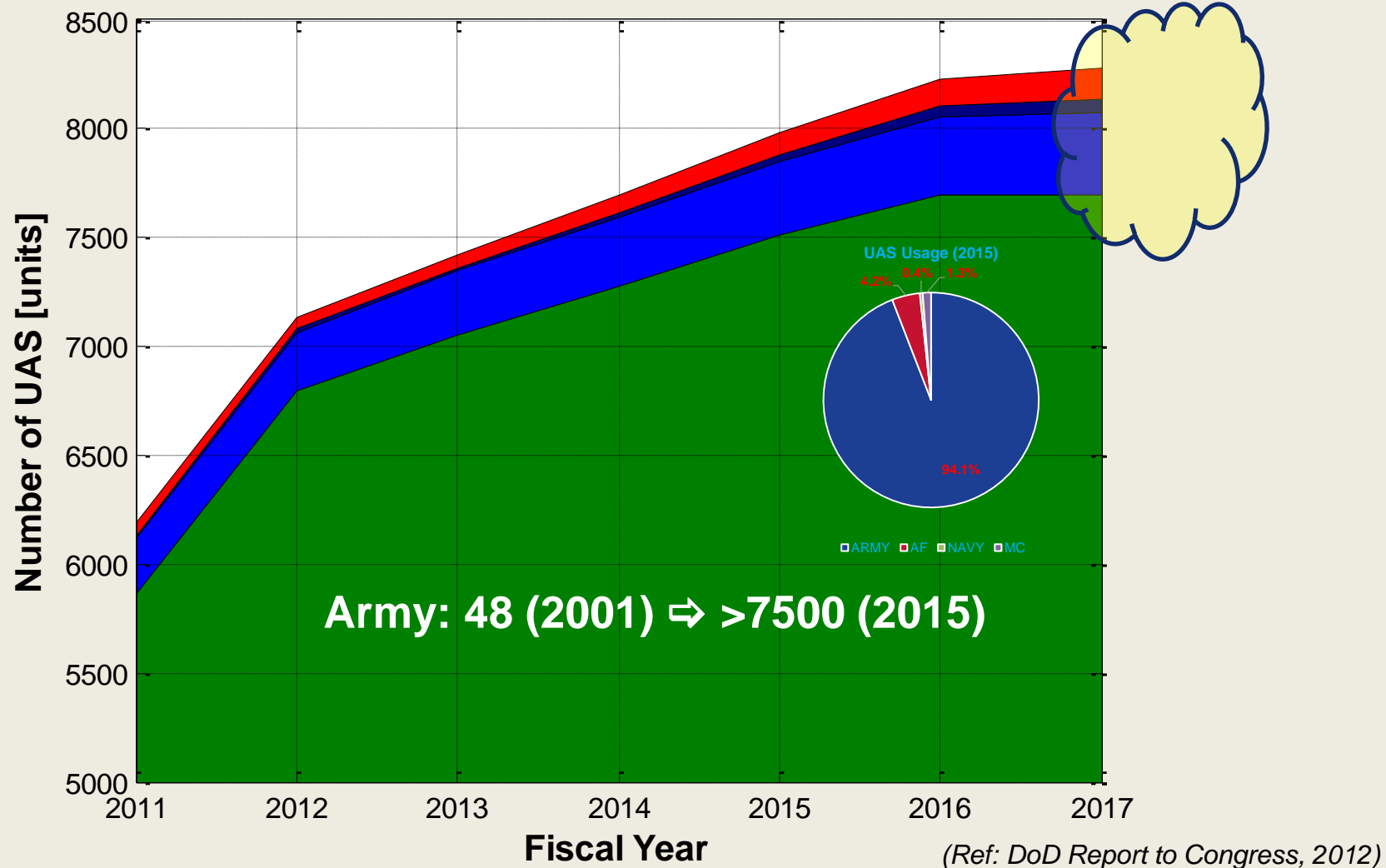


military



U.S. DoD UAS Inventory

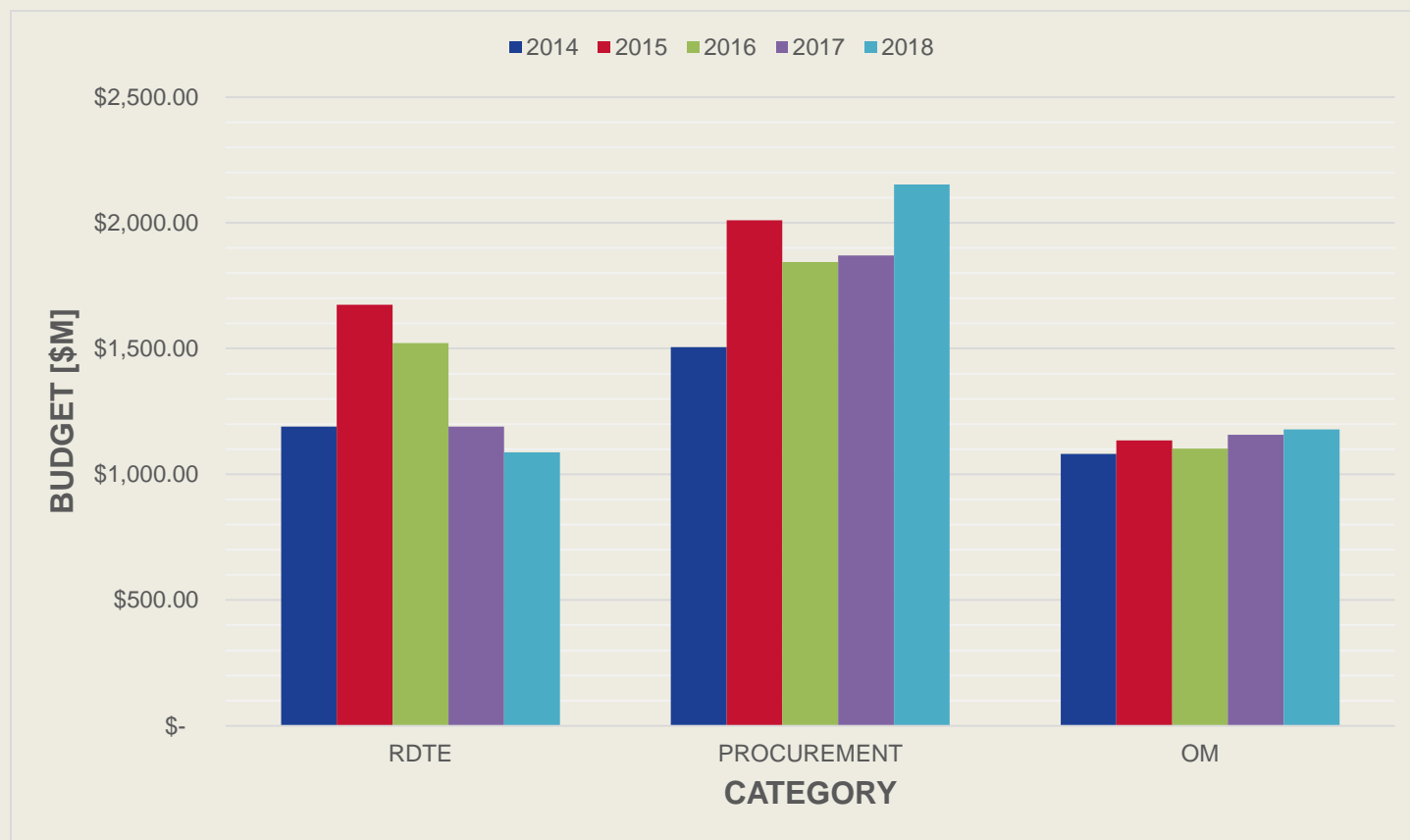
Dramatic increase over the last 15 years





UAS Presidential Budget (PB14)

Decreased budget trend for DoD UAS RDTE but global UAS spending may double over the next decade (prediction)



RDTE: Research, Development, Test, and Evaluation

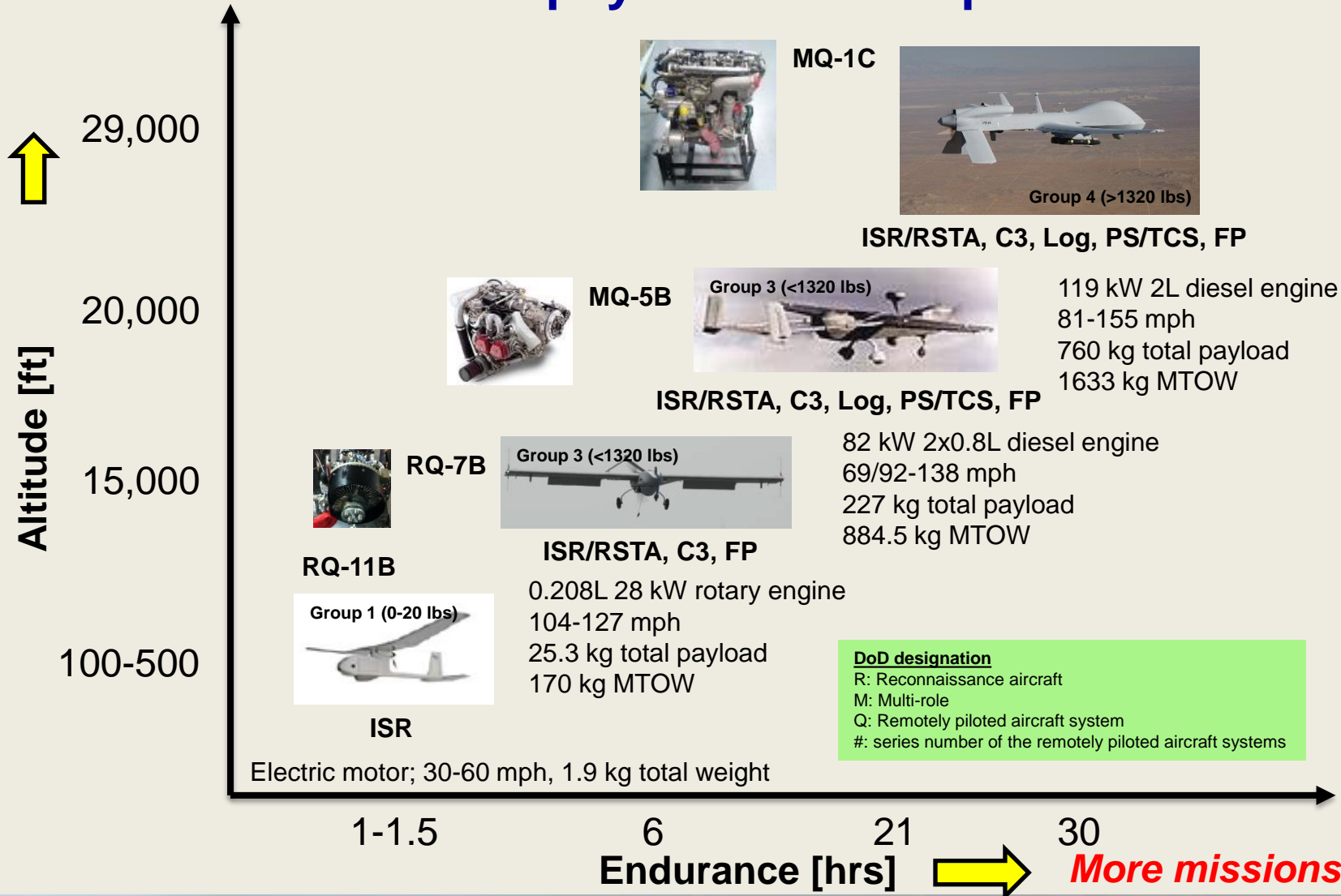
OM: Operations & Maintenance

(Ref: Unmanned Systems Integrated Roadmap FY2013-2038, 14-S-0553)



Current Major Army UAS

Increased payload ⇨ more power





UAS Future for the Army

Manned-UnManned Teaming (MUM-T) Technologies:

Merge air, ground, sea unmanned systems with unmanned and manned systems

Parameter	Unit	Apache AH-64E	Gray Eagle	Shadow
Speed	[mph]	165-177	81-155	104-127
Range	[mi]	295	249	68
Endurance	[hrs]	~3	30	6
Max altitude	[ft]	21,000	29,000	15,000



Teaming among Apache,
Gray Eagle, and Shadow

Increased mobility with small more agile
manned-unmanned systems

Needs:

- *Runway independent* ⇒ *vertical takeoff*
- *Easy to takeoff*
- *Longer endurance*
- *Equivalent speed to Apache*



Needs:

- *Interoperability*

UAV Swarms



Mechanical failures & Operator mistakes

Hit



Crashes



⇒ What should we do?



Areas for Improvements in Propulsion & Power

- Reliability - #1 priority - survivability
 - Reliable components / software
- Increased power - #2 priority - survivability
 - Payload is being increased for electronic devices and weapons
- Longer endurance
 - Needs to perform more missions
- Multi heavy fuel capability
 - Reduce the logistic cost
 - Engine technologies to operate on heavy fuels: F-24, JP-8, alt Jet fuels
- Reduced signature - susceptibility
 - IR, noise, and smoke
 - Signature detection and reduction technologies
- Increased speed
 - To team with faster rotorcrafts such as Apache

Must be affordable!!!



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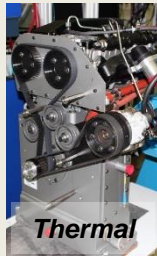
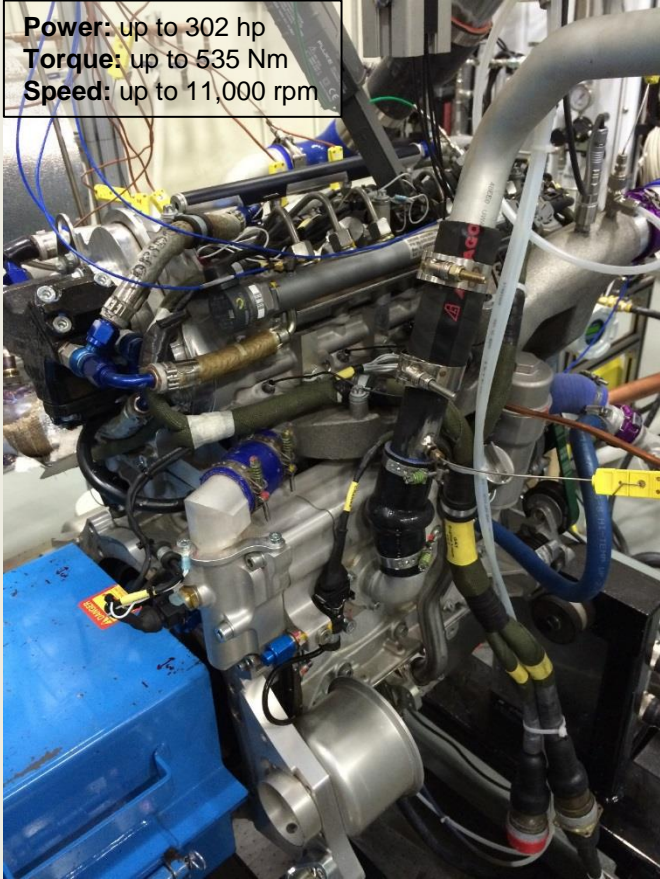
Small Engine Research Facilities

DoD Unique Small Engine Altitude Research Facility

Fuel → Spray → Atomization → Vaporization → **Mixing → Combustion → Power/Efficiency**

Small Engine Comb Res Lab

Power: up to 302 hp
Torque: up to 535 Nm
Speed: up to 11,000 rpm



Thermal



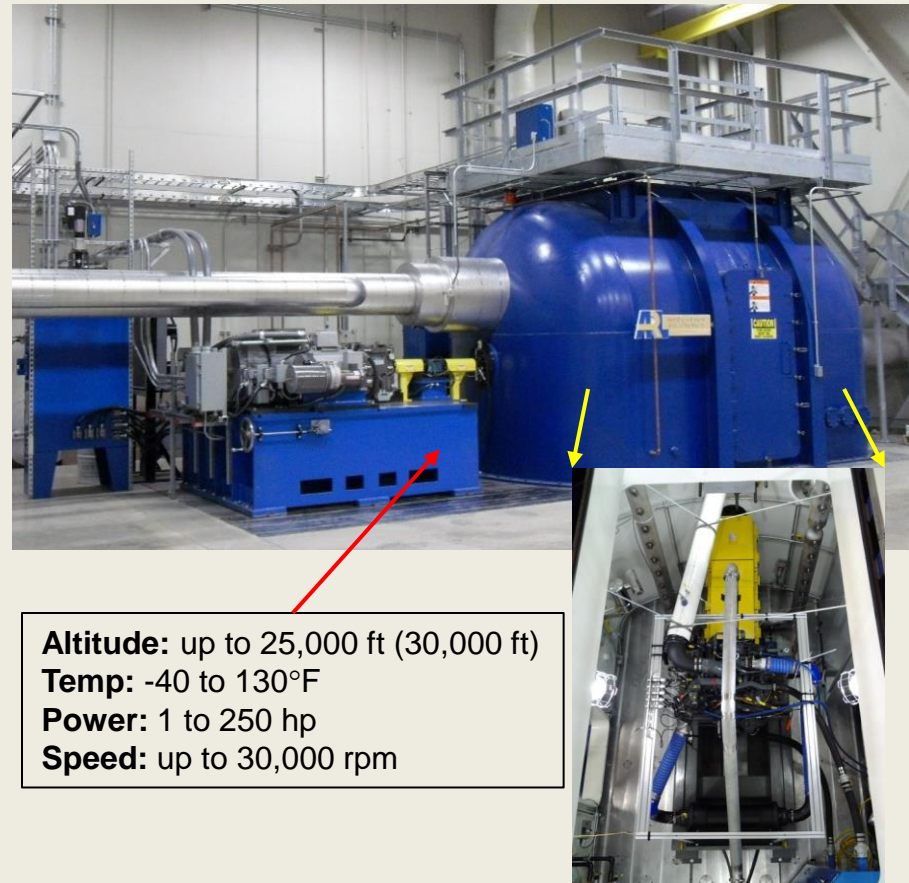
Optical

Single-cylinder research engine

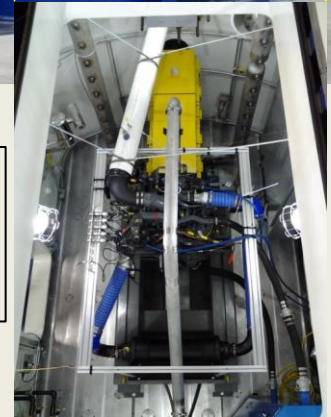


Opposed piston engine

Small Engine Altitude Res Facility



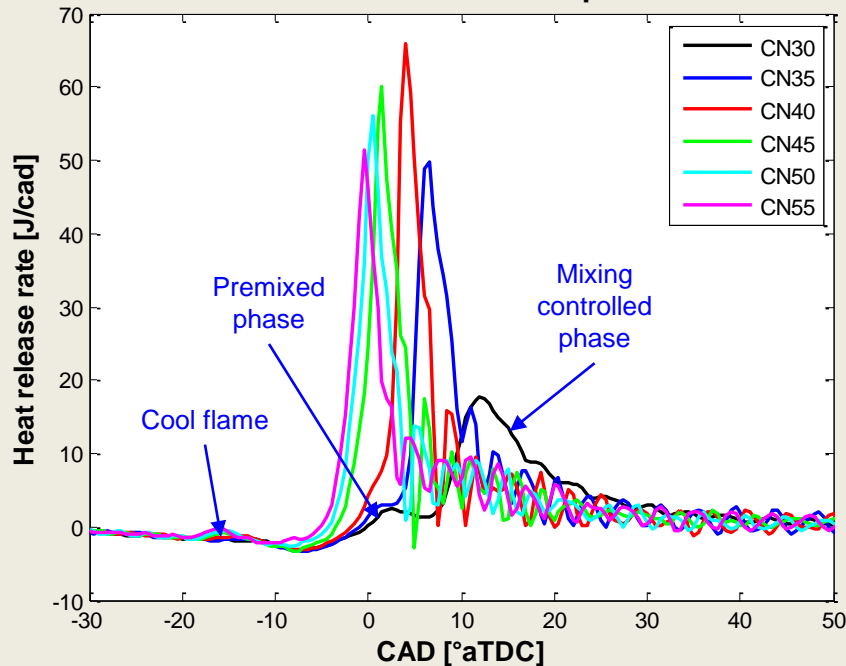
Altitude: up to 25,000 ft (30,000 ft)
Temp: -40 to 130°F
Power: 1 to 250 hp
Speed: up to 30,000 rpm



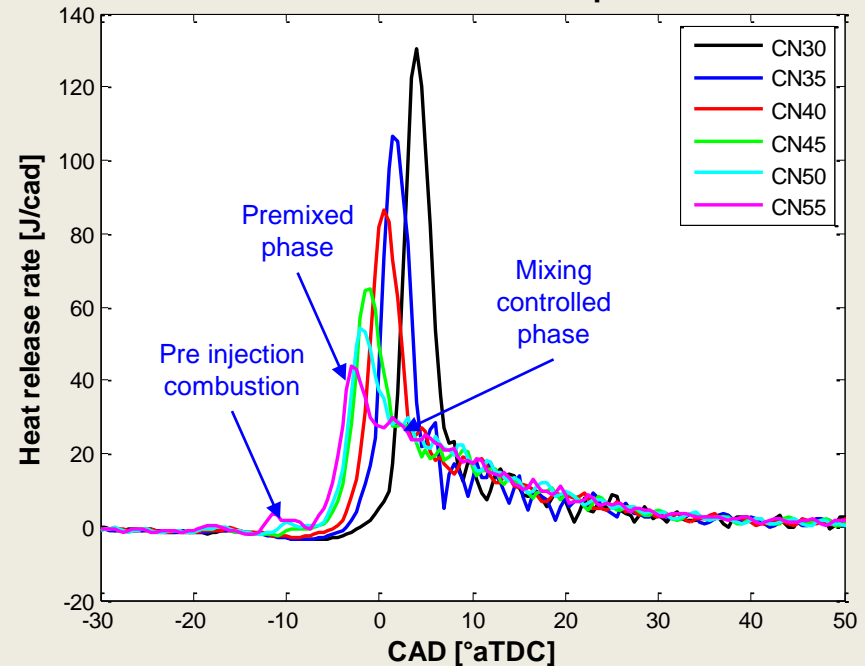


Combustion Dependence on Fuel Properties

Heat release rate: 3200 rpm/20%



Heat release rate: 3200 rpm/40%



- Extremely sensitive to fuel cetane number
 - Insensitive to engine power except for the low CN fuels
 - Knocking, noise, detonation ⇒ *reliability concerns*



Spray Combustion Research Facility

DoD Unique High-Pressure High-Temperature Chamber

Fuel → Spray → Atomization → Vaporization → Mixing → Combustion → Power/Efficiency

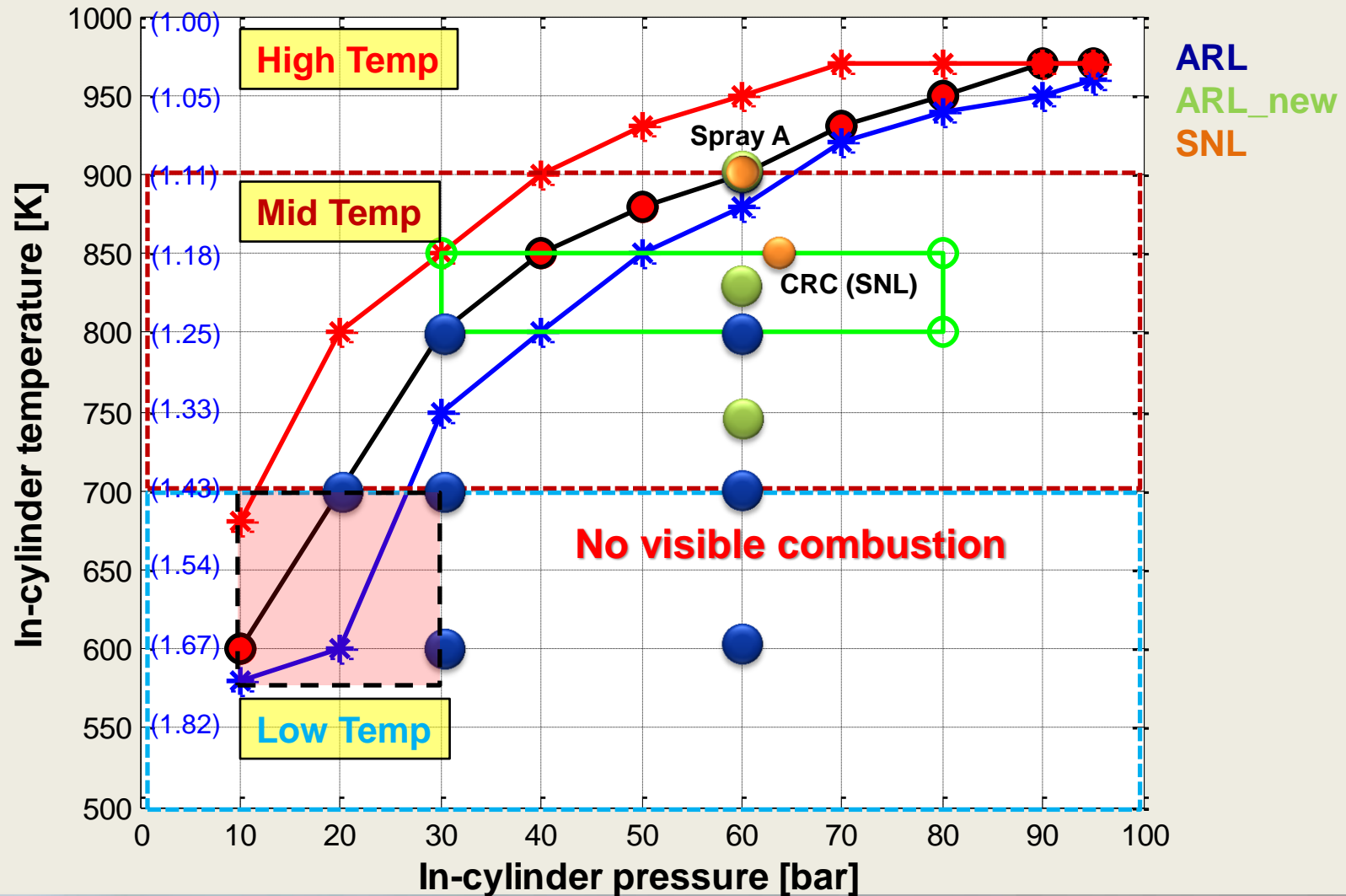


**P: amb to 150 bar
T: 300 to 1000 K
O₂ content: 0-21%**



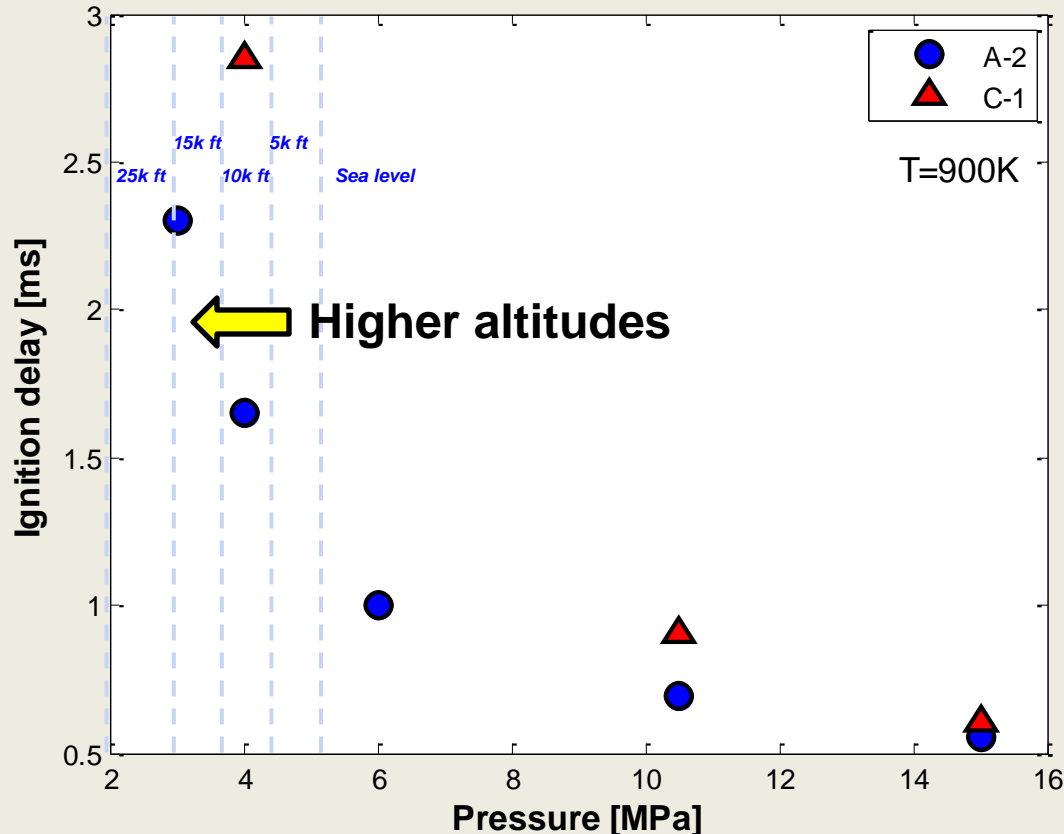
T & P at Fuel Injection

Measure Spray, Ignition and Combustion Processes





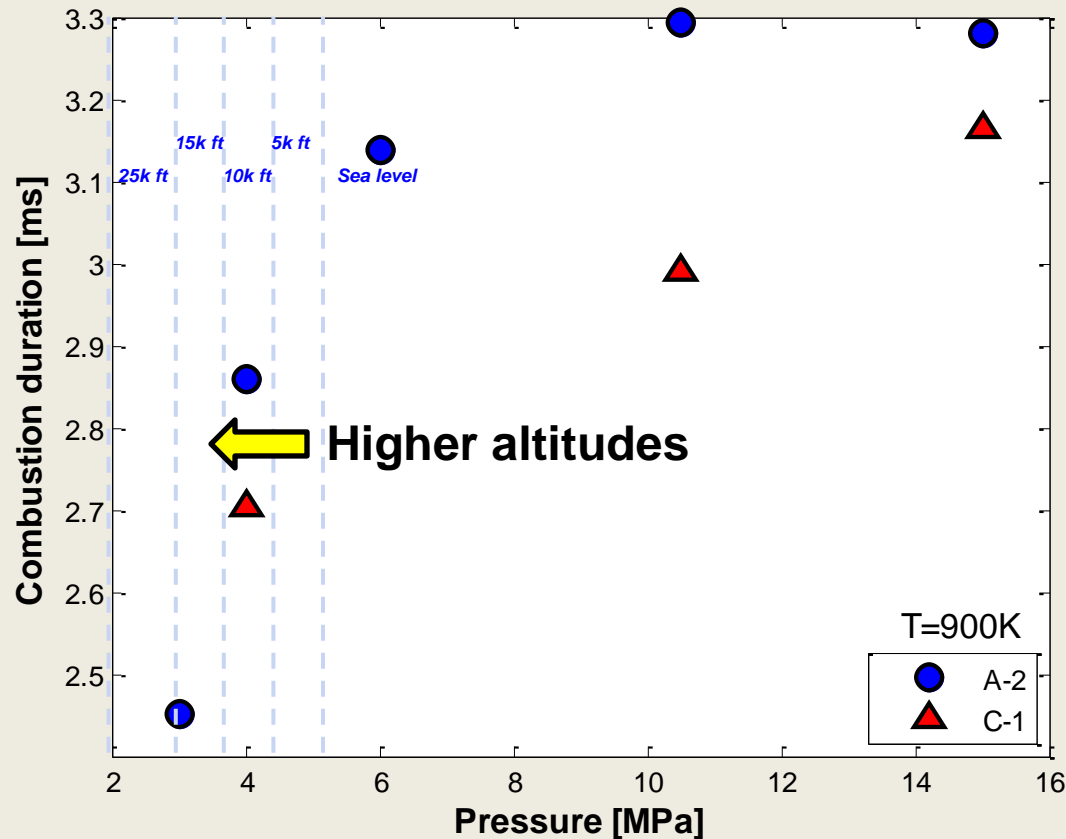
Ignition Delay Dependence on Pressure & Fuel Property



- Exponentially increased ID with decreasing pressure
- Lower CN fuel increases ID at lower pressures \Rightarrow increased CN impact at high altitudes



Combustion Duration Dependence on Pressure & Fuel Property



- CD gets shorter at lower pressure and CN \Rightarrow potentially higher EGT



Conclusions

- U.S. Army UAS dramatically increased over the last 15 years
- U.S. Army owns about 94% of all UAS aircrafts within the U.S. DoD
- Overall DoD RDTE budget is decreasing but the overall spending will gradually increase.
- Global UAS spending is predicted to dramatically increase over the next decade
- Current highest priorities include reliability, increased power, and longer endurance within affordability
- Uncontrolled fuel property poses significant reliability concerns
- Needs for optimal engine design and calibration for high altitude operation



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Acknowledgements

- **ARL-VTP**
 - Michael T. Szedlmayer and Michael J. Tess
- **AMRDEC AED**
 - Joseph Gibson, Ross H. Armstrong, Christopher A. Lindsey, Rik D. Meininger, Newman B. Jackson, and Bernard Acker
- **PM UAS**
 - Andrew V. Giddings, William G. Barnwell, Thomas P. Durgin, and Daniel F. Dittenber
- **General Atomics – Aeronautical Systems Inc**
 - Donald Sauder





Thank You!