ARPA-E Electric Motor Workshop

Hybrid Electric Aircraft Design Space, Feasibility and Technical Challenges

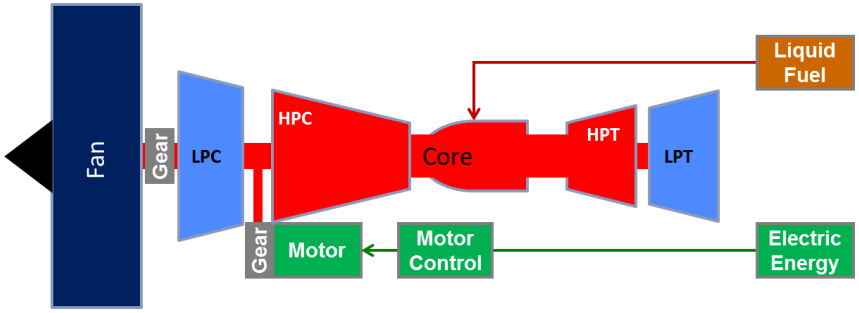
08 August 2019

Chuck Lents

Electrified Propulsion (EP) System Architectures

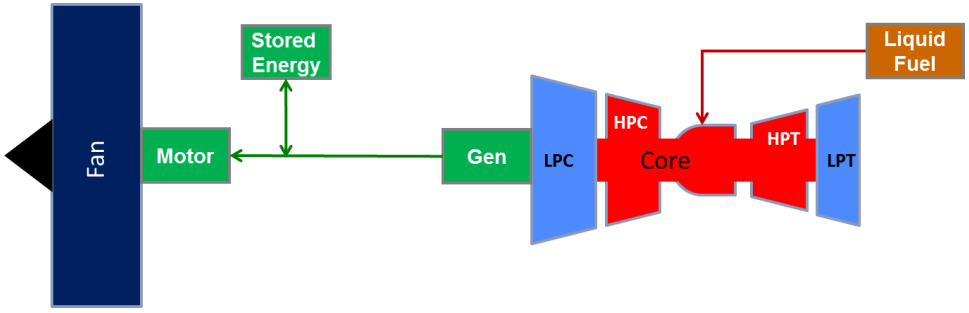
4 basic configurations

Parallel Gas-Electric Hybrid



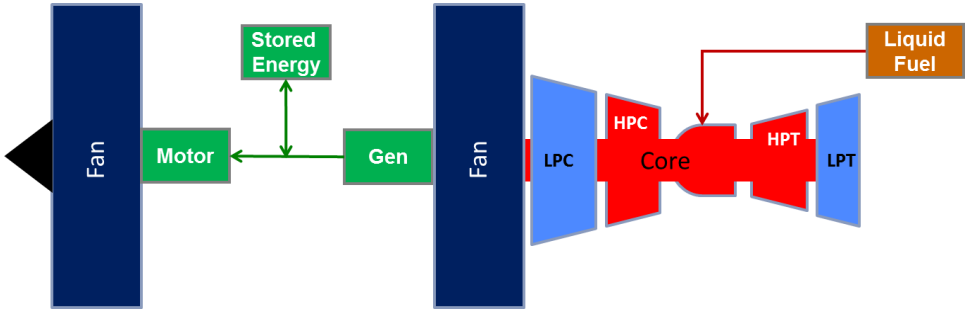
All thrust from main fans, fan power from liquid fuel through GT and battery though LS motor

Full Series Turboelectric Hybrid



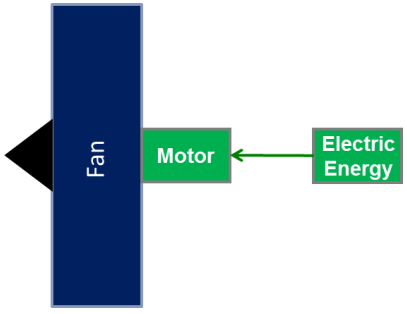
GT creates electric power from liquid fuel, electric power distributed to multiple electric fans for thrust, battery used load leveling

Partial Series Turboelectric Hybrid



Full Series Turboelectric Hybrid, with addition of thrust from GT LS fan

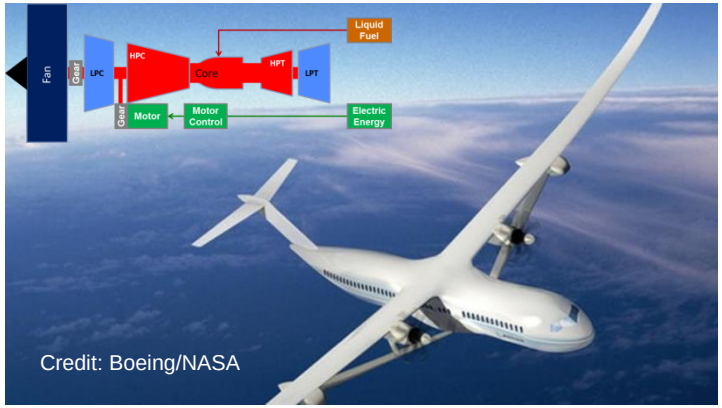
All Electric (not a Hybrid)



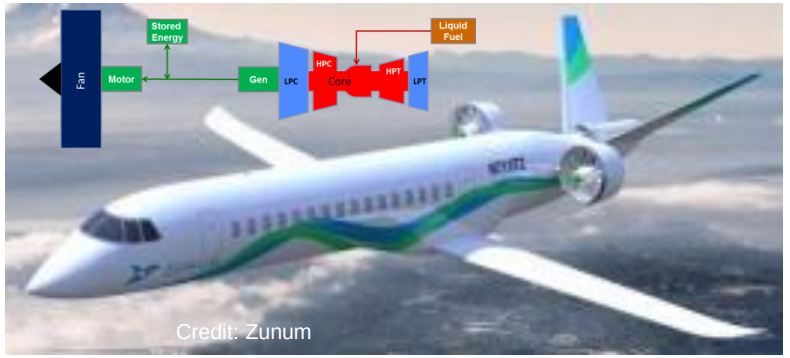
Electric power from battery distributed to multiple electric fans for thrust

Electrified Aircraft Propulsion (EAP) Concepts

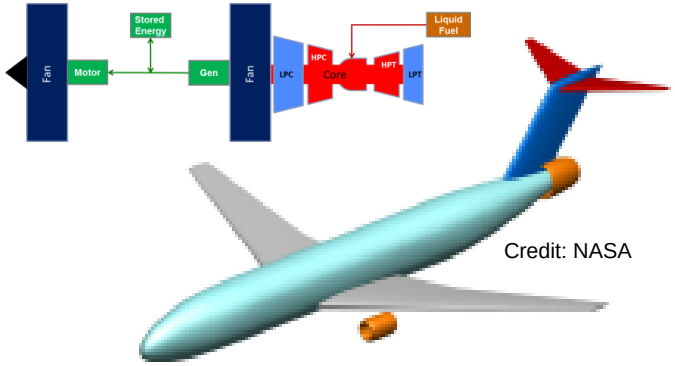
Example EP implementations



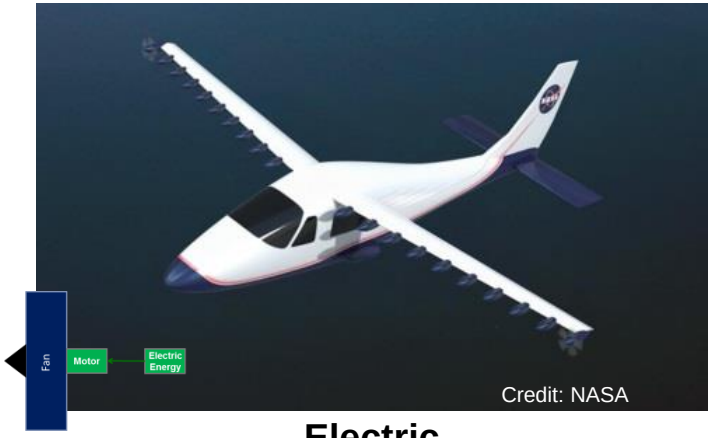
Parallel Gas-Electric Hybrid



Full Series Turboelectric Hybrid



Partial Series Turboelectric Hybrid

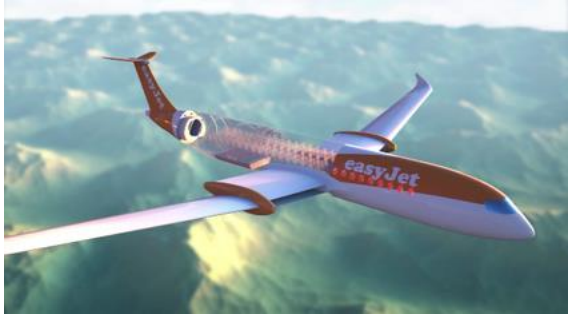


Electric

Why Hybrid Electric

Enables New Missions

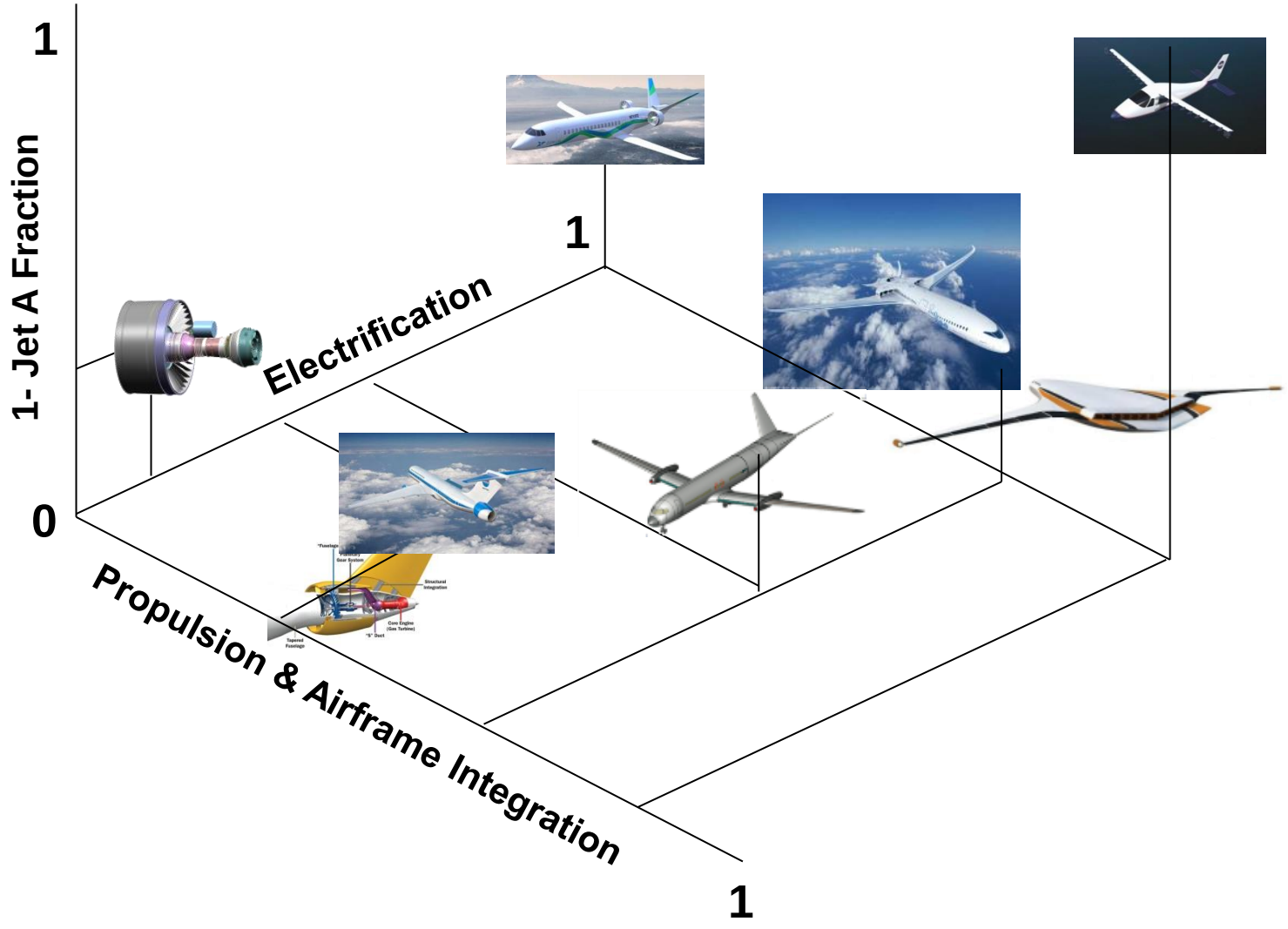
Enables New Business Models



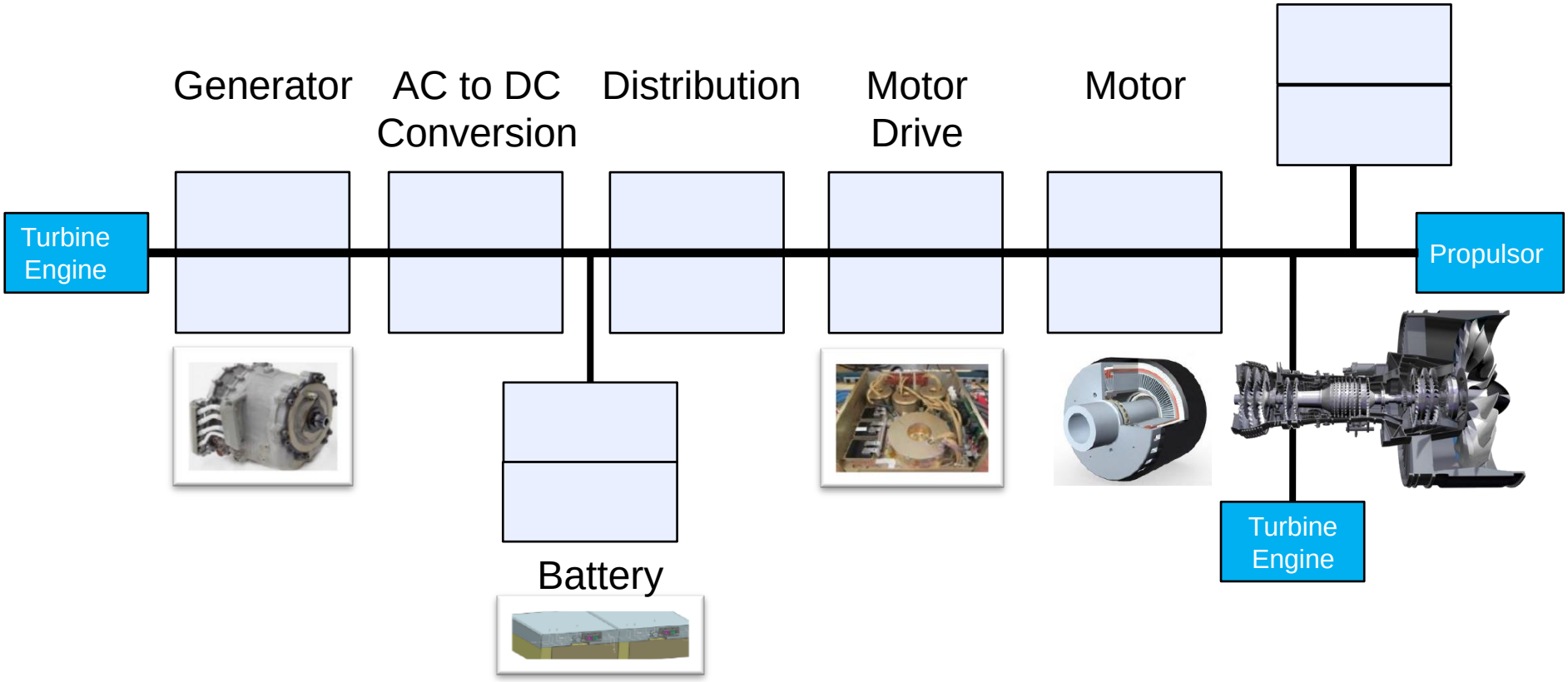
Enables Fuel Burn & CO2 Reduction

Hybrid Electric Aircraft Design Space

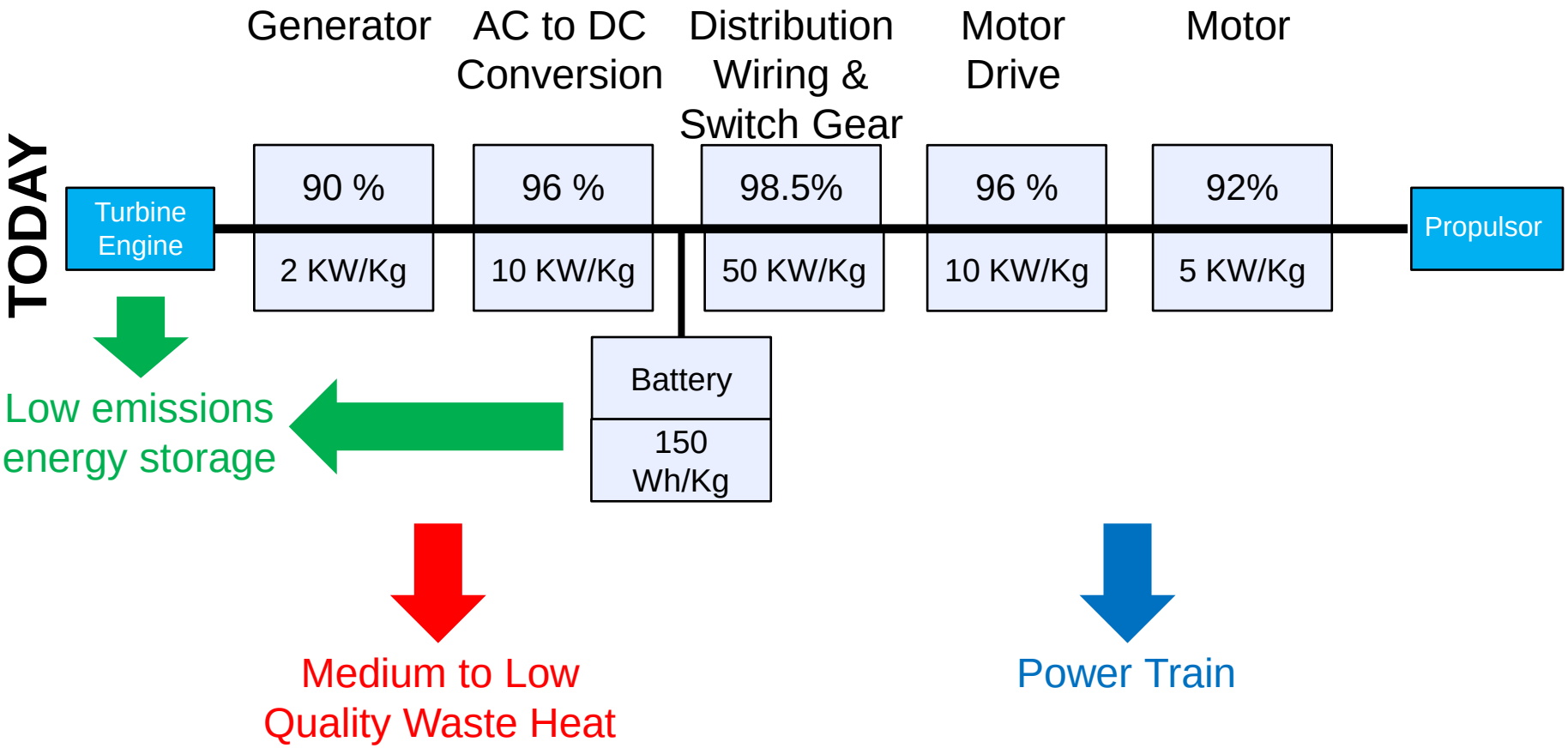
Point studies done in the design space



EAP Drive Train



Drive Train Challenges



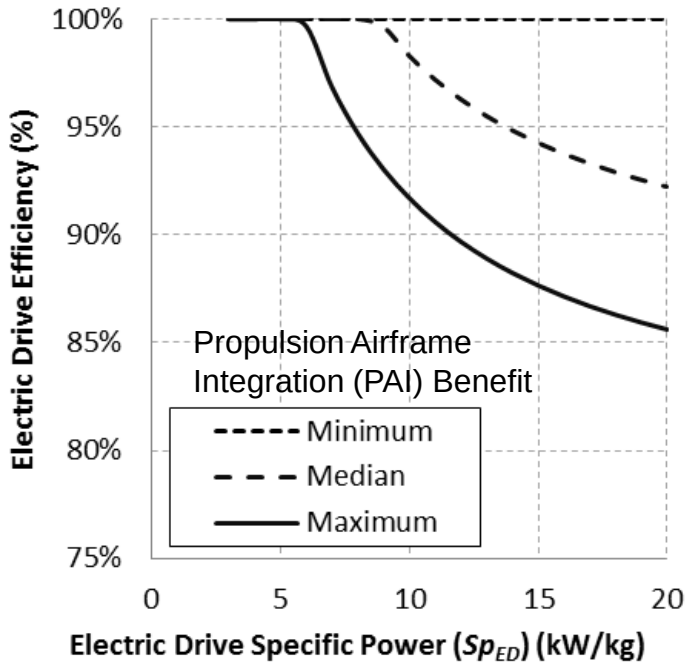
- Weight – Heat Exchangers, Ducts, Plumbing
- Ram Drag – Battery cooling
- Power – Pumps, Fans, VCS?

- Weight – EM Machines, PE & Distribution
- High voltage – switches and protection
- Power – Losses increase power and energy requirement, create heat

Series Turboelectric Hybrid

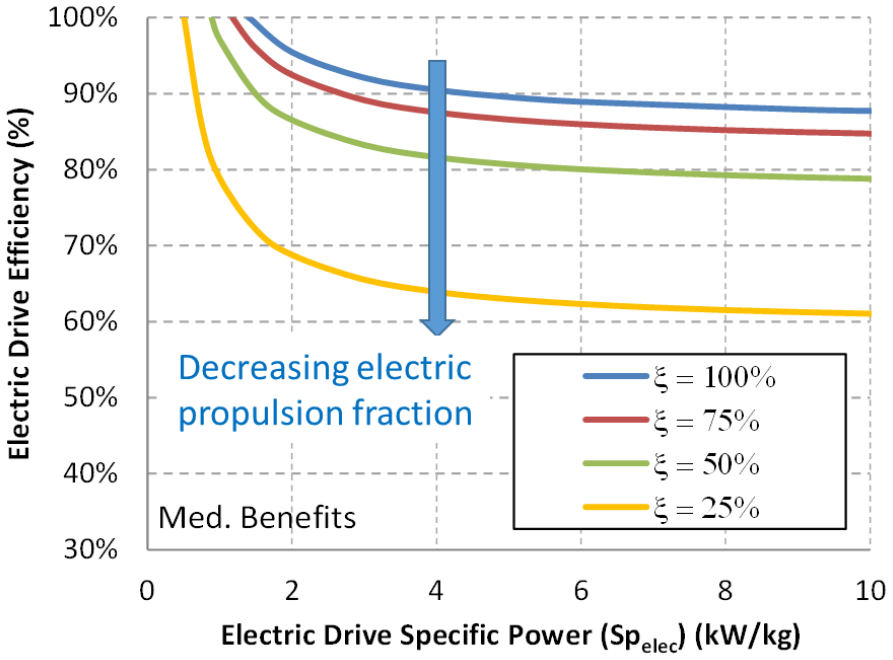
Series hybrids include an electric drive that must buy its way on the system

Series turbo-electric hybrid



Jansen, R. H., Brown, G. V., Felder, J. L., and Duffy, K. P., "Turboelectric Aircraft Drive Key Performance Parameters and Functional Requirements," AIAA Propulsion and Energy Forum, AIAA 2015-3890, Orlando FL, 2015.

Partial series turbo-electric hvbrid



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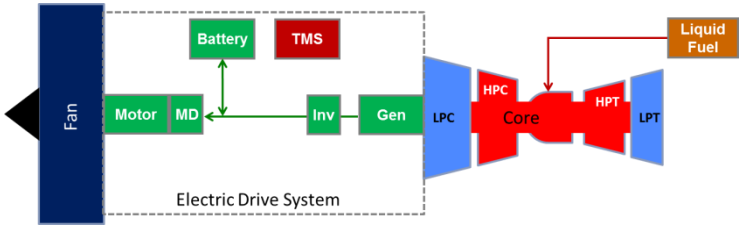
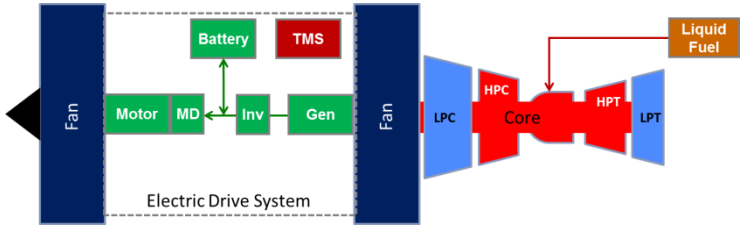




Electric Drive Train (EDT) Performance

Current development progressing toward 2.1 kW/kg @ 86%

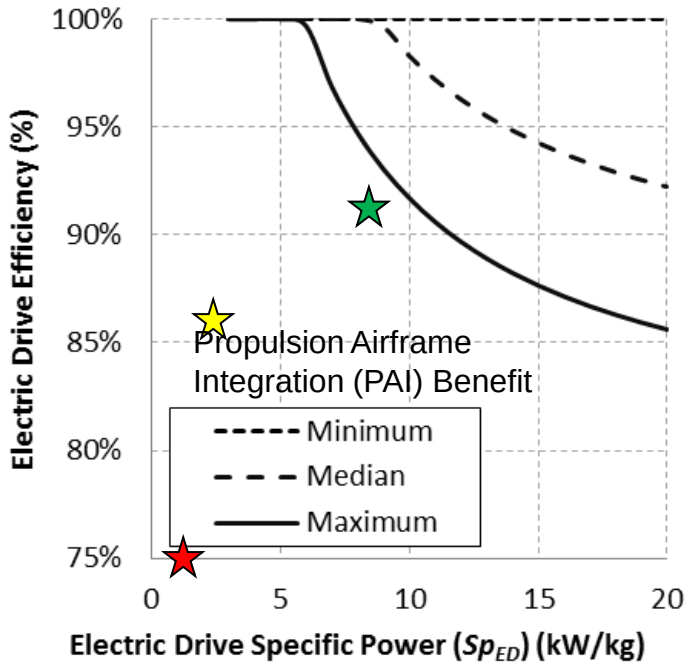
Today	Current Progress	Future Targets
0.9 kW/kg, 75%	2.1 kW/kg, 86%	8.4 kW/kg, 91%

	Today		Near Term Current Programs		Future Investment	
	Efficiency	Power Density	Efficiency	Power Density	Efficiency	Power Density
Components		kW/kg		kW/kg		kW/kg
Generator	90.0%	2	94.0%	4	96.0%	40
Rectifier	96.0%	10	98.0%	20	99.0%	40
Distribution	98.0%	50	98.5%	50	99.0%	100
Motor Drive	96.0%	10	98.0%	20	99.0%	40
Motor	92.0%	5	97.0%	13	98.0%	40
Thermal		1		4		10
Total	**75%**	**0.9**	**86%**	**2.1**	**91%**	**8.4**

Benefit of Improved EDT Performance

Future EDT improvements can enable PAI benefit

Series turbo-electric hybrid



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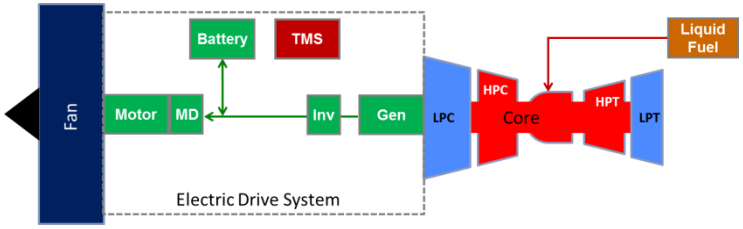

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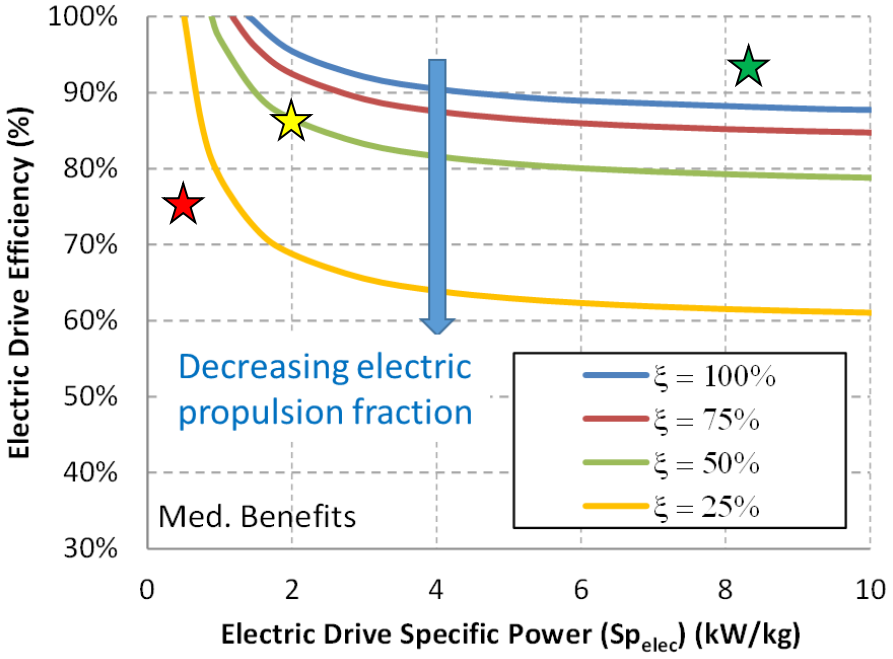

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