

混合动力飞行器关键技术研究及探讨

Research and Investigation on Key Technologies of Hybrid Aircrafts

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提纲 Contents

■ 动力革命与交通发展

Transport Development with Power Revolution

■ 混动飞行器关键技术

Key Technologies of Hybrid Aircrafts

■ 清华混合电推进研究

Hybrid Propulsion Research at Tsinghua

大众化个体交通发展历程

Evolution of Popular Personal Transport



步行 Walking



马车 By carriages



传统汽车 By fuel vehicles



电动汽车 By electric vehicles

经历了步行、马车、汽车阶段，跨入电动汽车时期。

Gone past walking, by carriage and car phase. Currently entering e-vehicle phase.

个体飞行发展历程

Progress of Personal Flight



滑翔机 By gliders



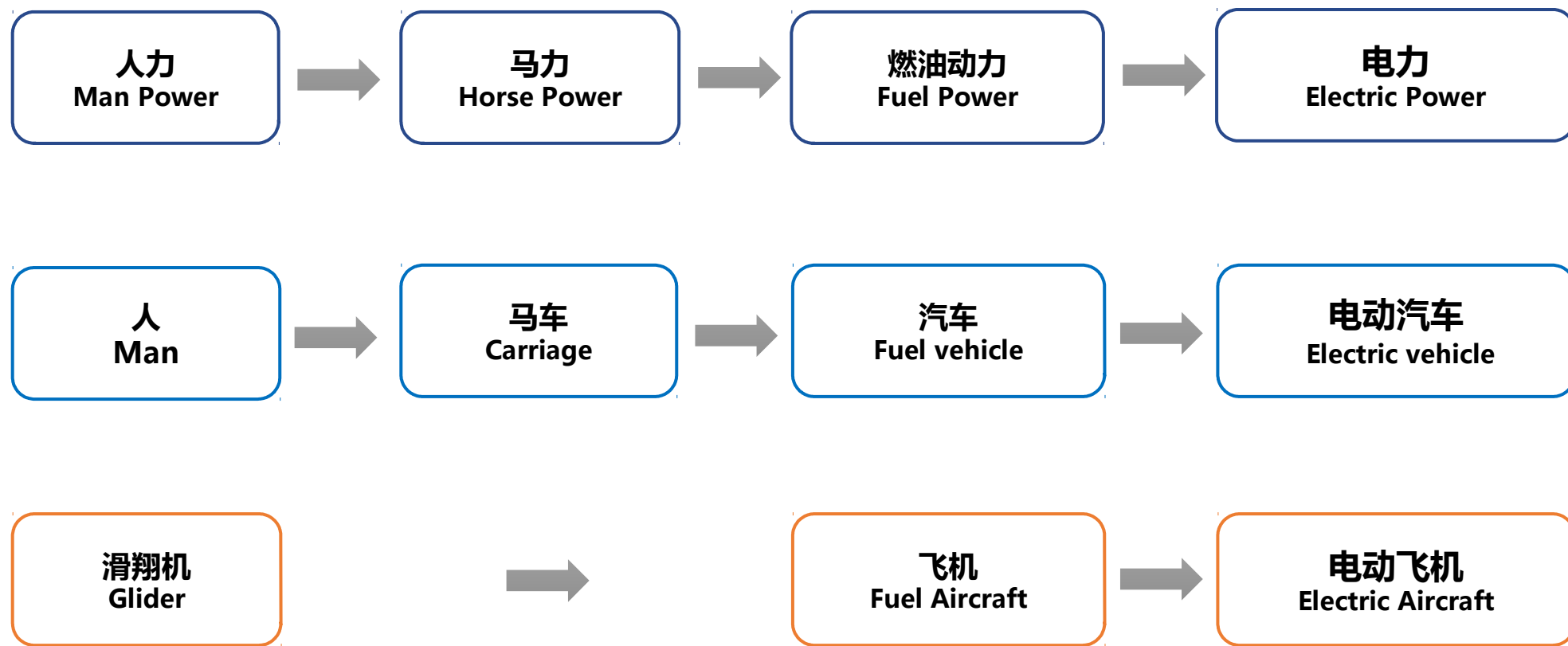
动力飞行 By powered aircrafts



经历了人力滑翔机和动力飞机阶段，正在迈向电动飞机新阶段。
Advanced gliders and powered aircrafts are evolving towards electric propulsion.

动力革命与交通发展

Transport Development with Power Revolution



动力是交通发展的主导因素之一，一个电动化的交通时代正在走来。

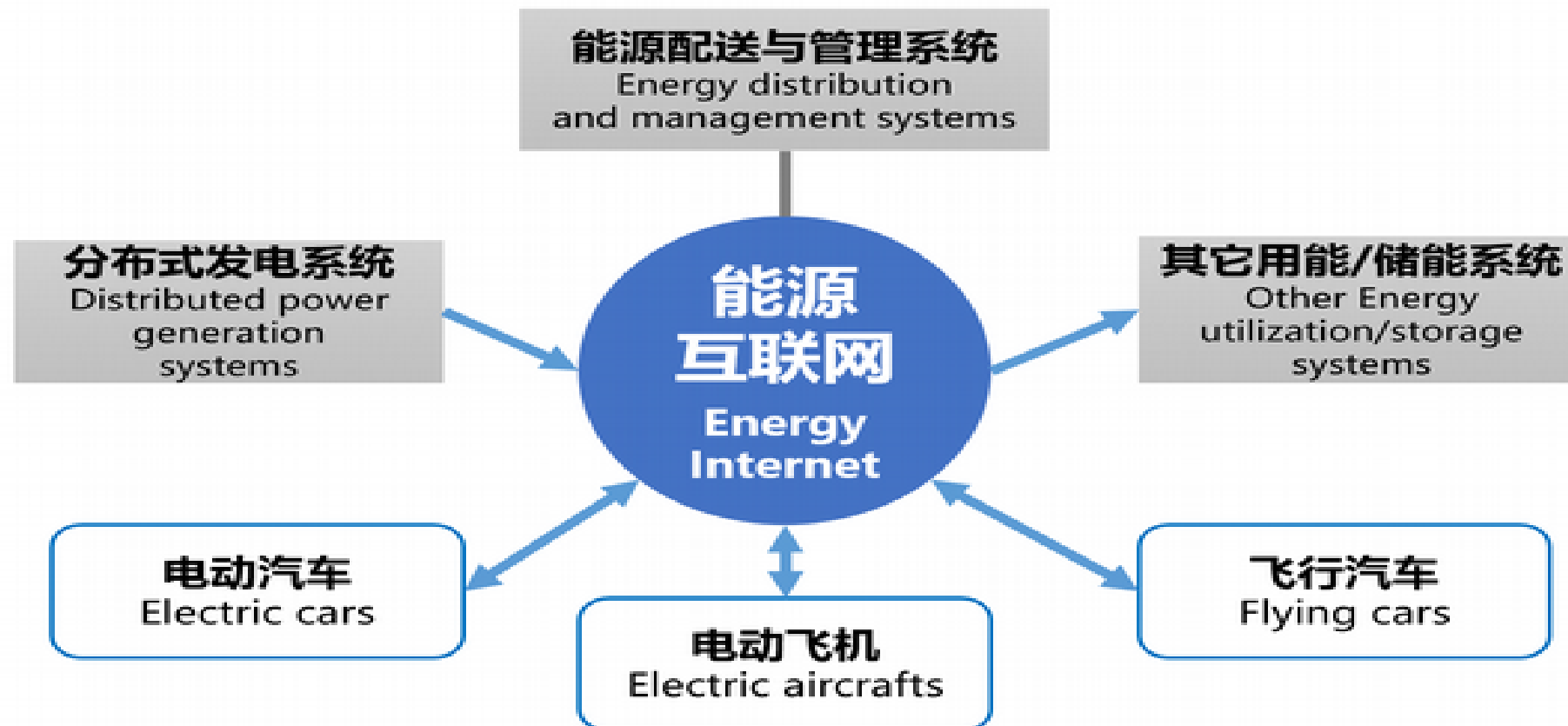
Engine power is a key factor in transport development, and a new era of electric transportation is coming.

电动化交通与能源互联网

Energy Internet and Electric Transportation

电动汽车、电动飞机等，将是未来能源互联网的有机组成部分。

E-cars and e-aircrafts, etc., will be an intrinsic element of the energy internet.



电动航空将非常具有发展应用前景。

Electric aviation will have great development and application prospect.



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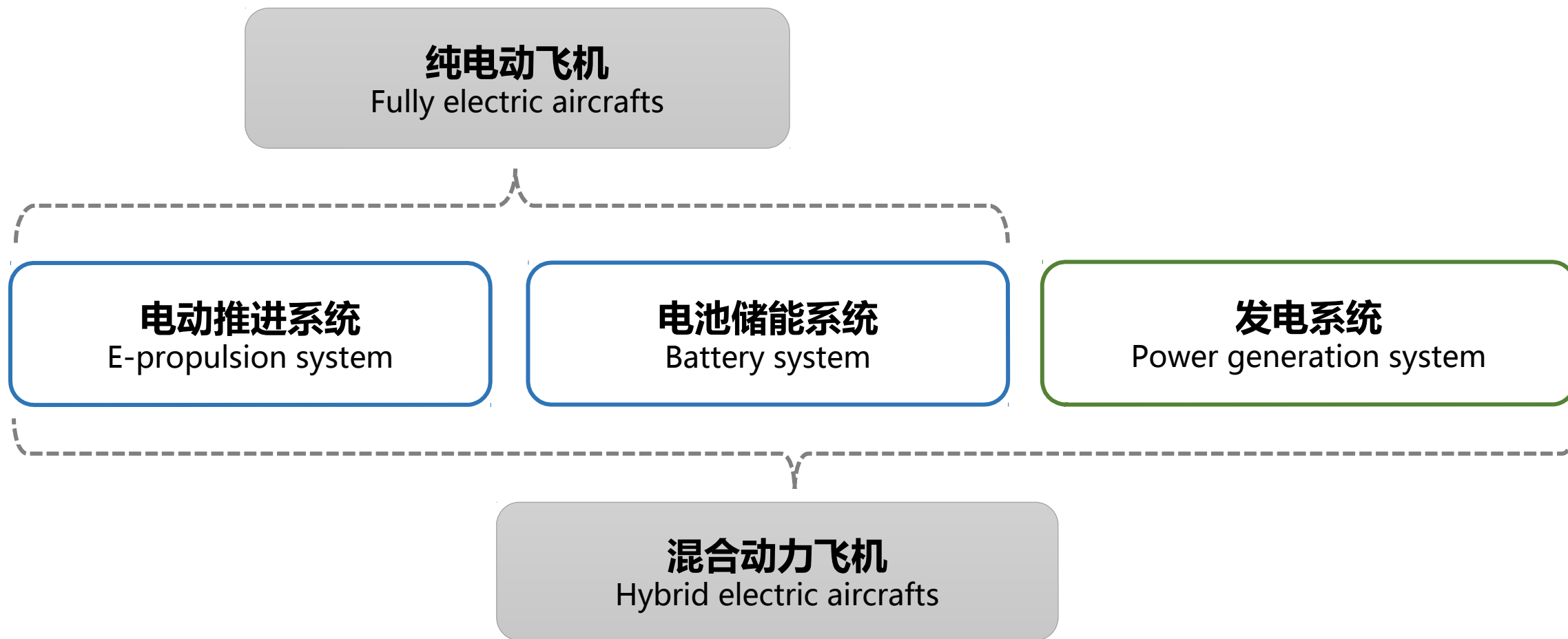
Key Technologies of Hybrid Aircrafts

■ 清华混合电推进研究

Hybrid Propulsion Research at Tsinghua

电动飞机类型

Categories of Electric Aircrafts



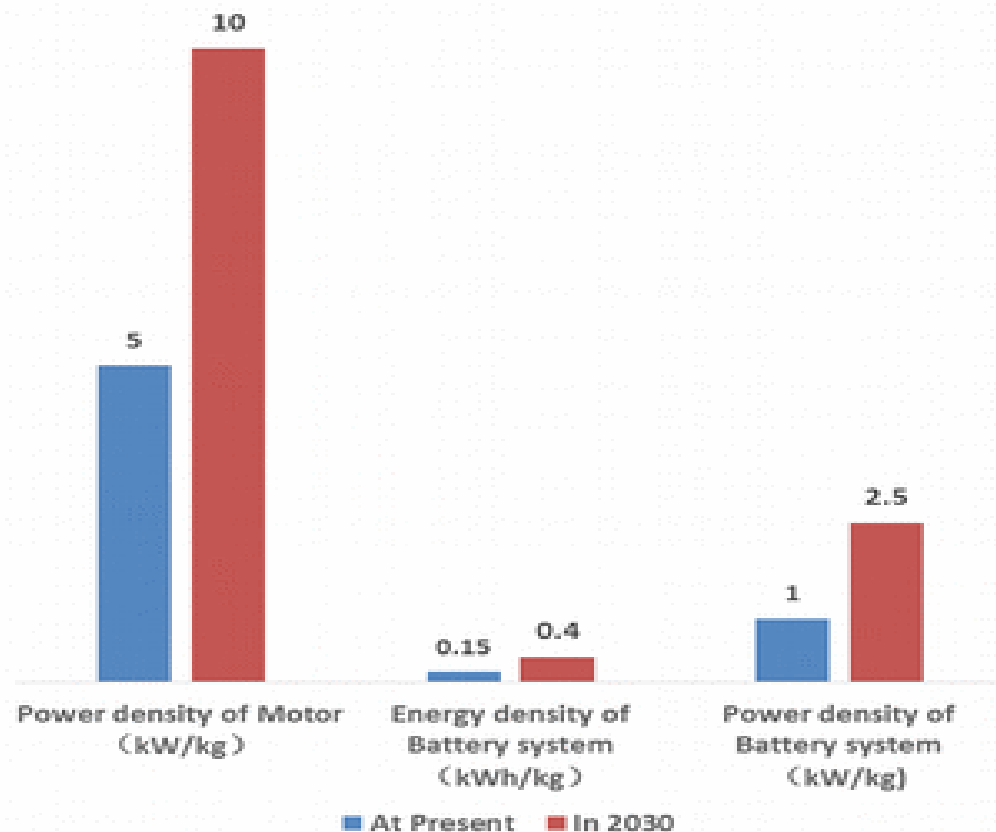
混合动力飞机技术，涵盖了纯电动飞机的相关技术。

The system of a hybrid aircraft includes the technology of a fully electric one.

飞机电动化的有效途径

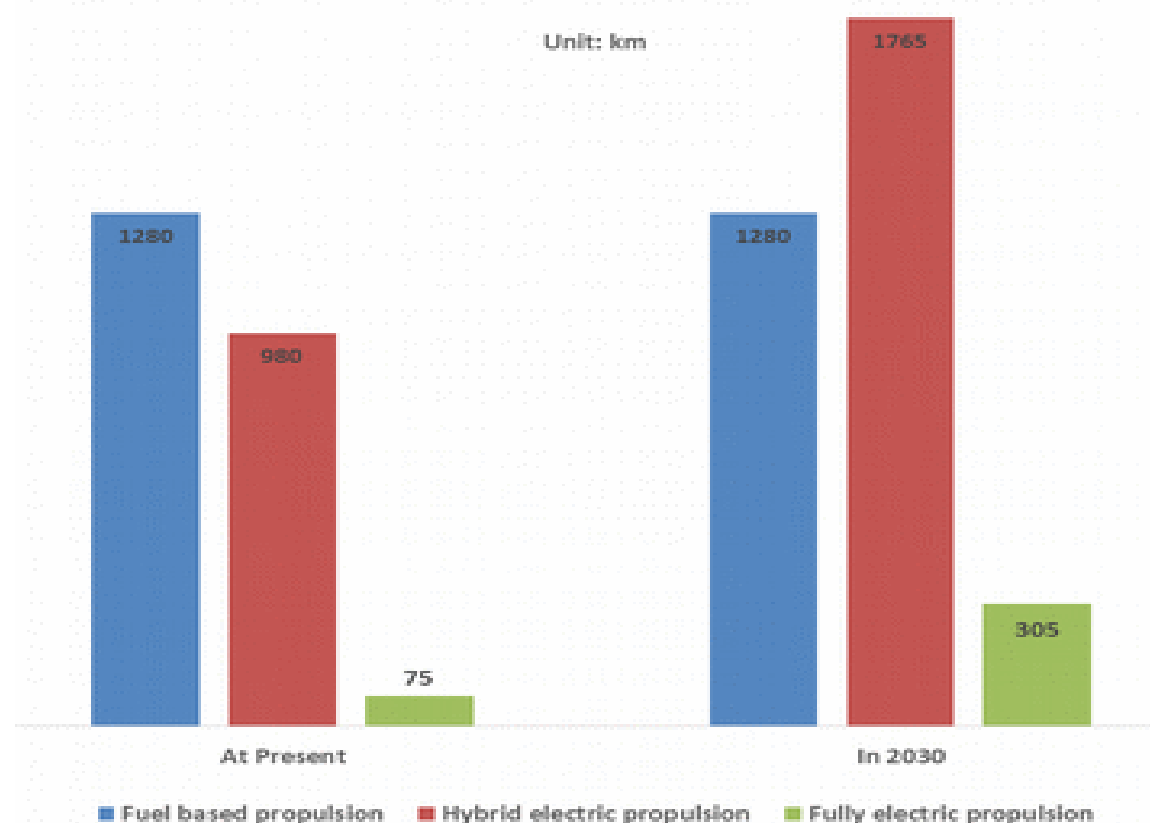
Effective Path to Aircraft Electrification

Components Performance Comparison



Cruising Capability Comparison of General Aircraft (4 Seats)

MTOW-1543kg LOAD-360kg
ICE(Fuel)-187kg ICE(Hybrid)-144kg

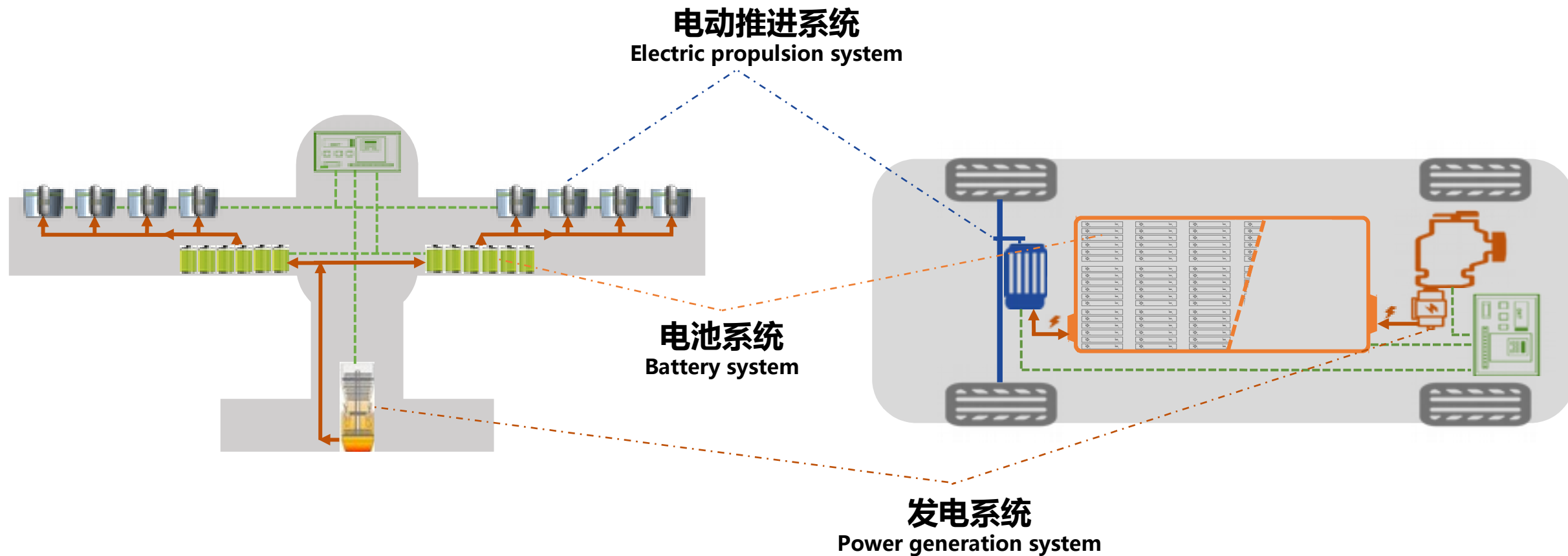


混合电推进，是实现长航时飞机电动化的有效且现实的途径。

Hybrid electric propulsion, an effective and realistic path to long endurance aircraft electrification.

混合动力飞机的关键技术

Key Technologies of Hybrid Electric Aircrafts



发展电动汽车的关键技术，同时也是发展电动飞机的关键技术。
These key technologies for electric vehicles, are also for electric aircrafts.

电动汽车走向电动飞机

Developing Electric Aircraft from Electric Vehicle Technology

飞机混合电推进技术及产业化基础

Technological and industrial foundation of aircraft hybrid e-propulsion

	电动推进系统 Electric propulsion system		电池系统 Battery system	发电系统 Power generation system		
	电机 Motor	推进系统 Propulsion system		内燃机 ICE	涡轮机 Gas Turbine	燃料 电池 Fuel cells
汽车工业 Automotive industry	✓		✓	✓		✓
航空工业 Aeronautical industry		✓			✓	

依托汽车工业的电动化基础，将有效促进飞机的电动化发展。
Electric aircrafts can be developed with technological foundation of e-vehicles.



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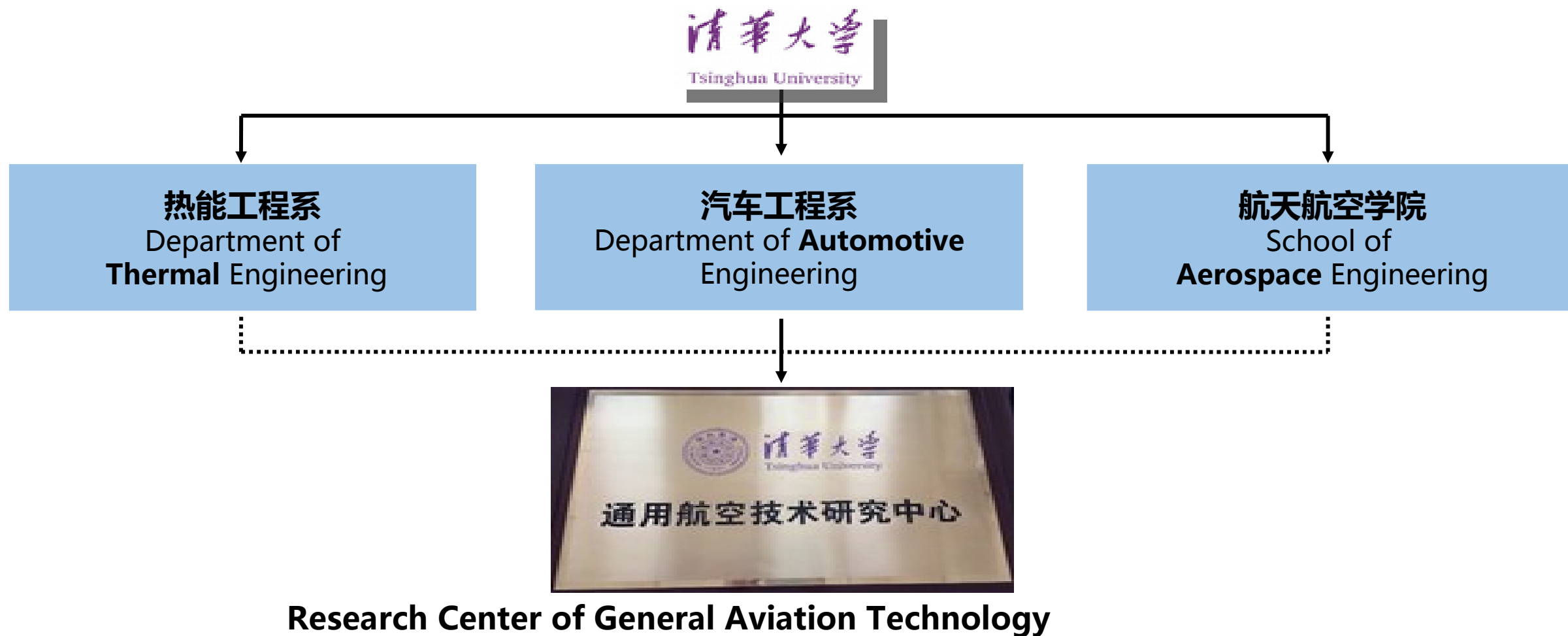
Key Technologies of Hybrid Aircrafts

■ 清华混合电推进研究

Hybrid Propulsion Research at Tsinghua

清华大学通用航空技术研究中心

Research Center of General Aviation Technology , Tsinghua University



基于电动汽车的研究基础，进行航空电推进系统研究。

Developing aircraft electric power and propulsion systems from electric vehicle technologies.

混合电推进技术研究

Investigation of Hybrid E-propulsion Technology

混合电推进技术 Hybrid electric propulsion technology

电动推进系统

Electric propulsion system

电池系统

Battery system

发电系统

Power generation system

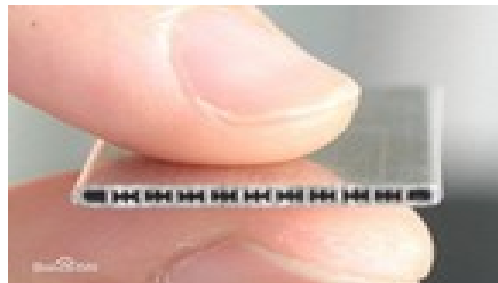
1 电动风扇推进技术

Electric-fan propulsion technology



2 轻量化电池技术

Light-weight battery technology



3 涡轮复合发电技术

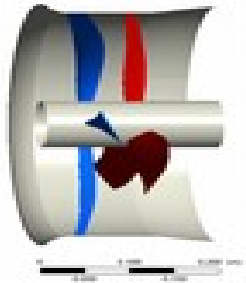
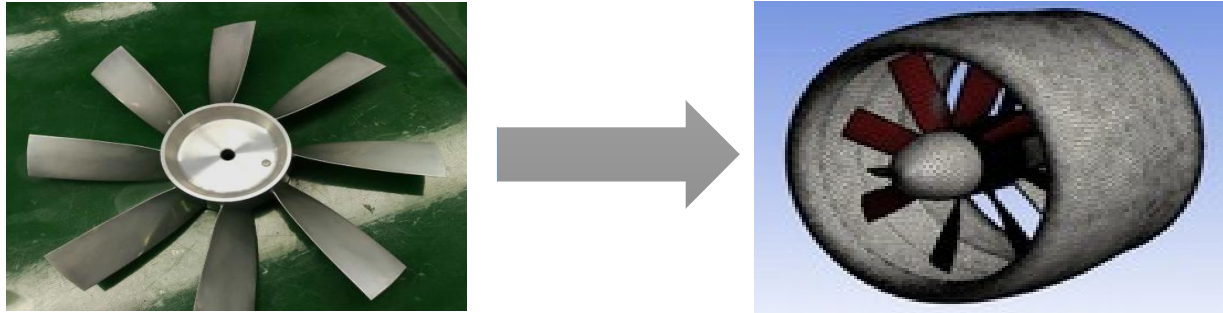
Turbo-compound power technology



1 电动风扇推进技术

E-fan Propulsion Technology

高通流涵道风扇设计 High through flow duct fan design

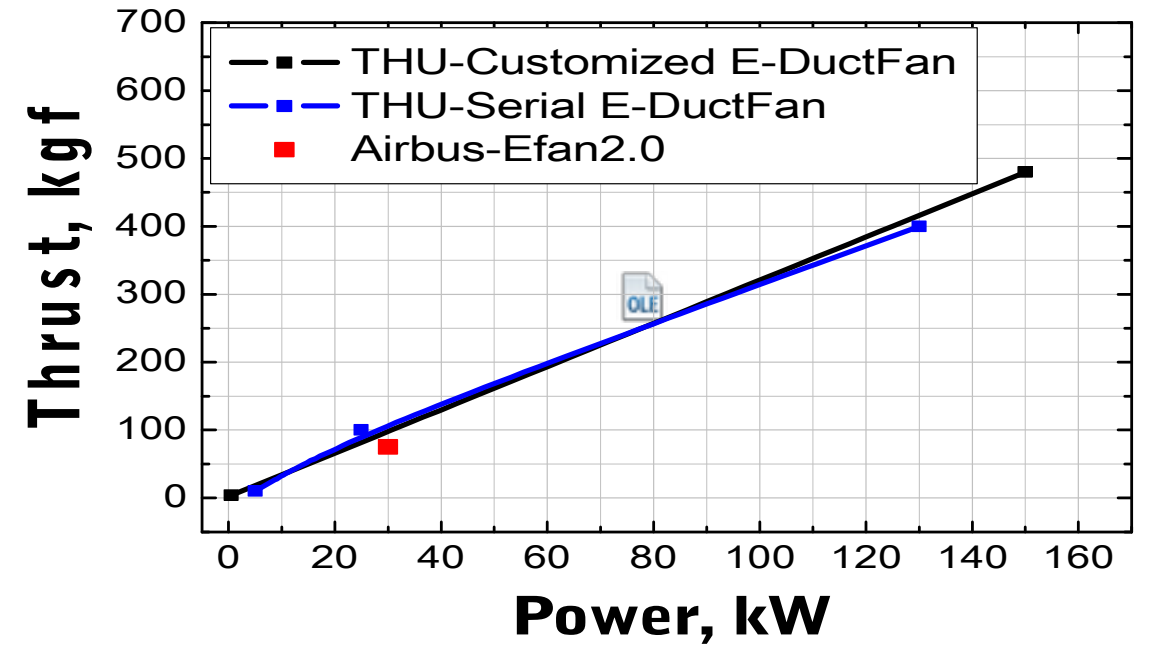


CR-4kgf/ 0.5kW
RS-10kgf/ 4kW

RS-100kgf/ 25kW

RS-400kgf/ 130kW

CR-480kgf/ 150kW



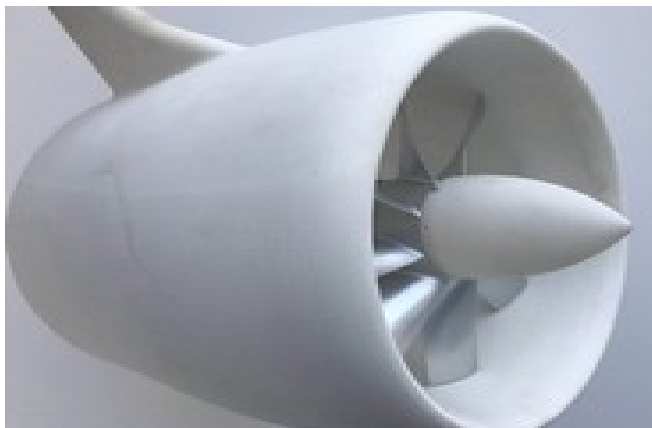
基于航空发动机风扇设计技术，有效提高涵道风扇的性能。

Improving duct fan performance by using turbo engine fan design technology.

1 电动风扇推进技术

E-fan Propulsion Technology

电动无人机 Electric UAV



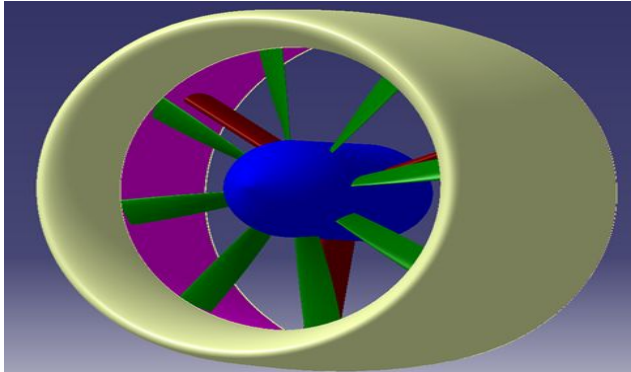
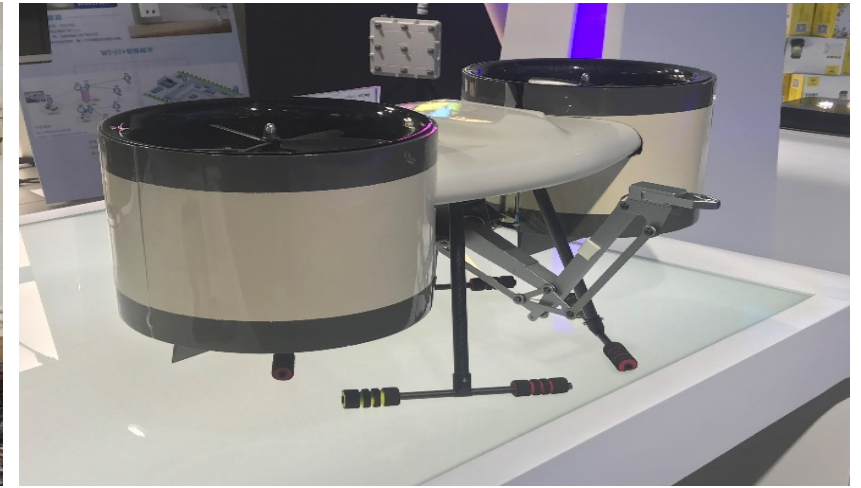
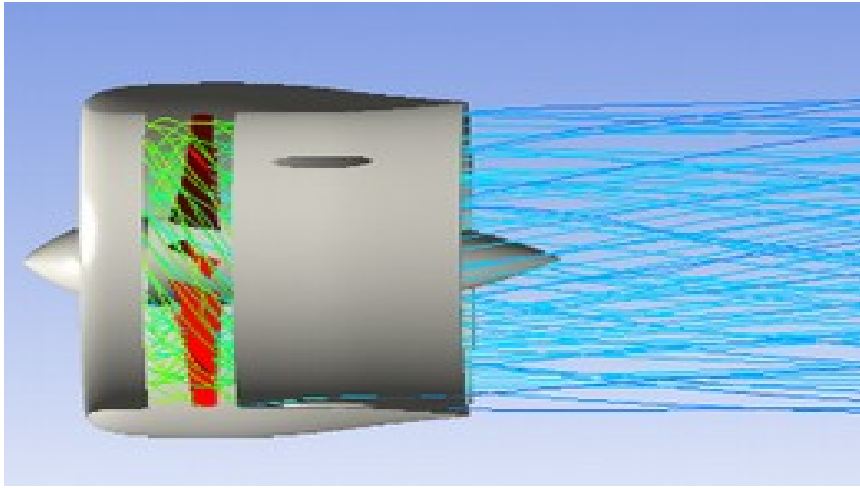
50kg 和 500kg 级电动无人机，巡航速度 150km/h，续航时间 1h。

50kg-500kg UAVs, cruising speed 150km/h, flight time 1h.

1 电动风扇推进技术

E-fan Propulsion Technology

垂直起降无人平台 VTOL unmanned platform



10kg 级和 80kg 级垂直起降无人平台，续航时间 1h。
10kg and 80kg VTOL platforms for UAVs, flight time 1h.

1 电动风扇推进技术

E-fan Propulsion Technology

电动涵道风扇飞行汽车 Electric duct fan flying vehicle



飞行汽车乘员 1 人，续航距离 100km，续航时间 1h，拟 2019 年试飞。

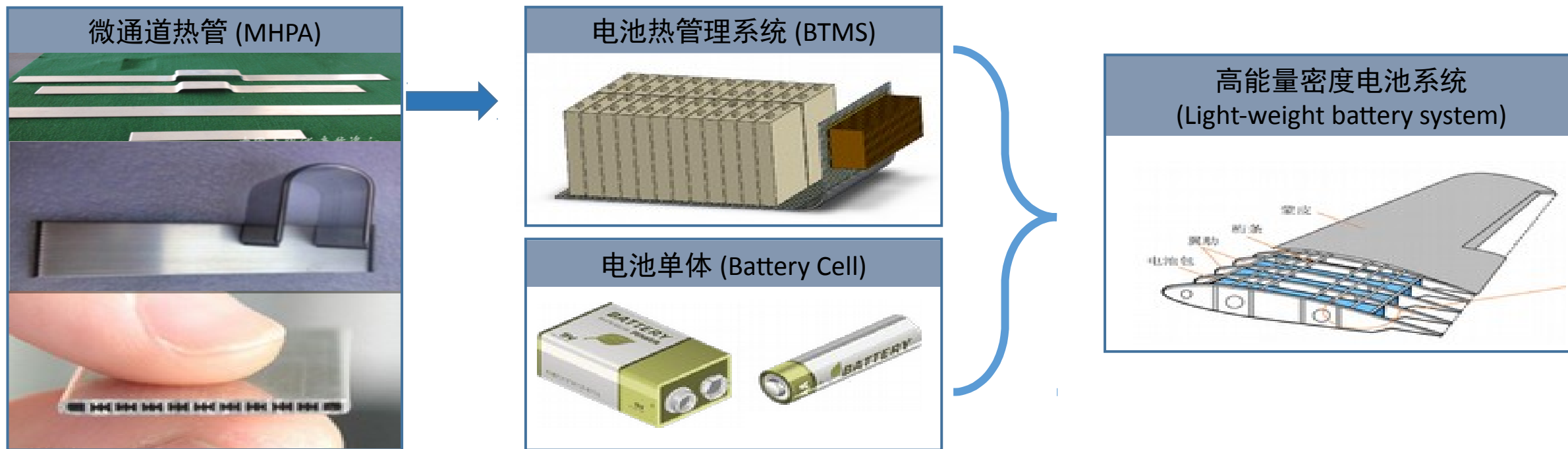
Flying car crew: 1, Flight distance: 100km; Flight time: 1h; Planned test flight: 2019.

2 轻量化电池技术

Light-weight Battery Technology

电池热管理轻量化设计 Light-weight design of BTMS

- 研发先进的电池微通道热管散热系统，满足 $>2c$ 放电需求，大幅度降低电池重量。
Develop advanced micro heat pipe array (MHPA) for BTMS to improve battery performance and reduce the system weight.



采用微通道热管系统代替电池液冷系统，可使电池能量密度提升 50% 以上。
MHPA based energy density is 50% higher than when using liquid cooling system.

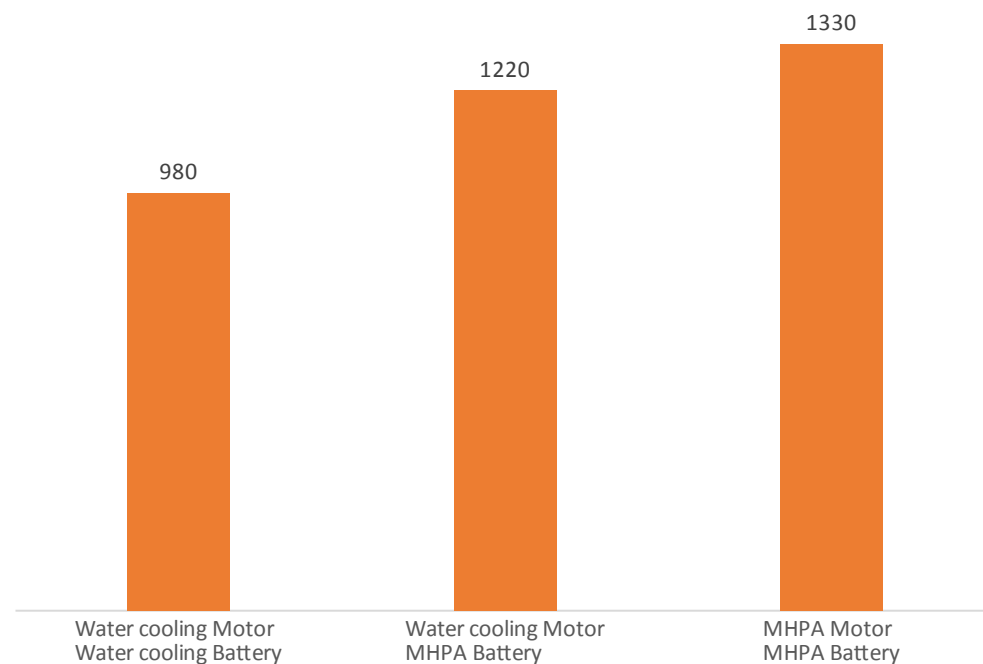
2 轻量化电池技术

Light-weight Battery Technology

西锐飞机混合电推进设计 Hybrid propulsion design for Cirrus



Influence of light weight design of BTMS on Cruising Range
Unit: km

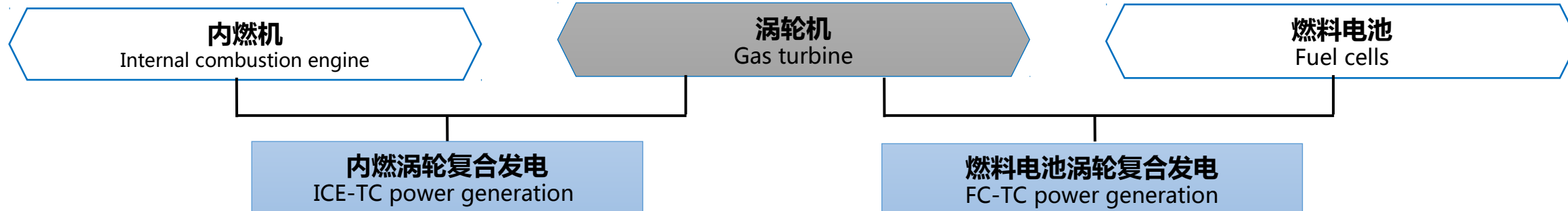
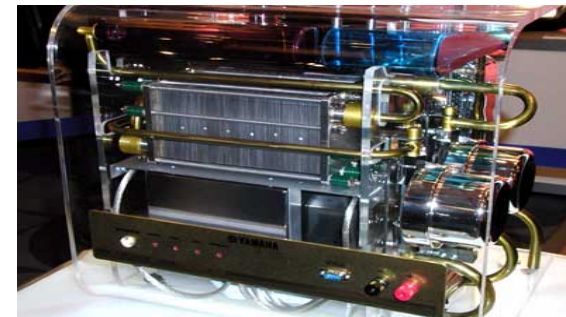
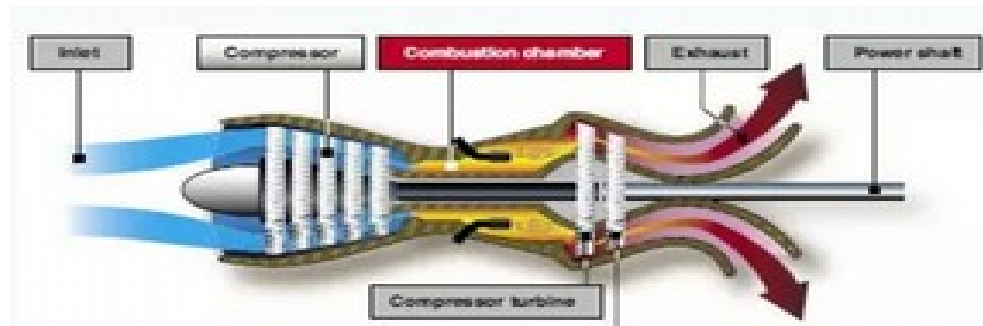


电池热管理轻量化设计，可有效提升飞机混电推进性能，增加续航里程 >35%。
MPHA could improve Cirrus aircraft performance greatly, distance increasing >35%.

3 涡轮复合发电系统

Turbo-compound (TC) power systems

混合电推进的发电系统 Power system of hybrid propulsion



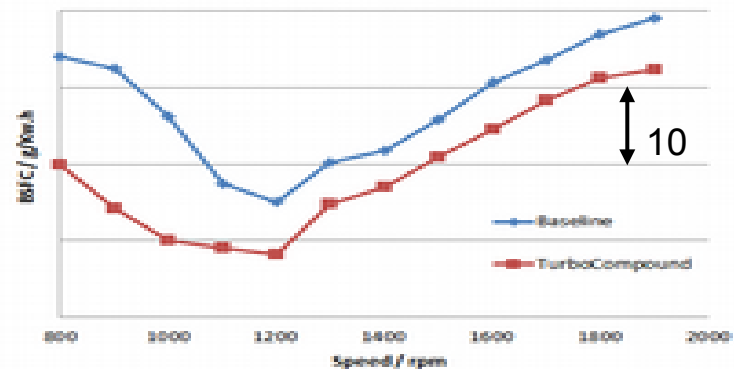
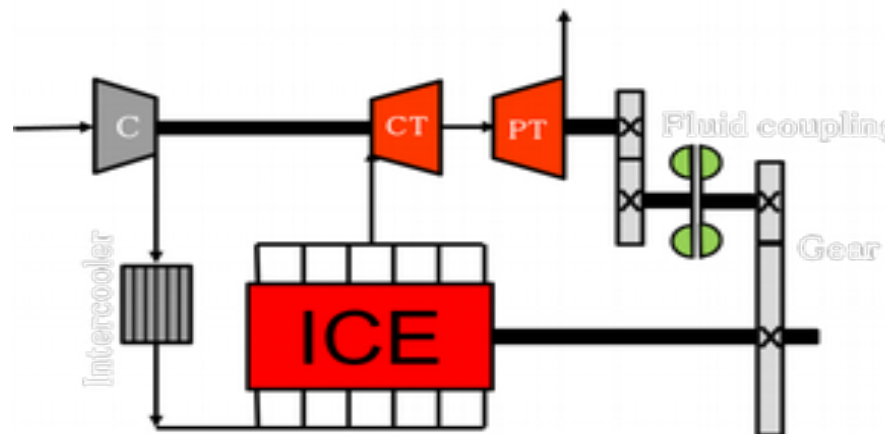
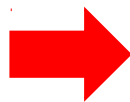
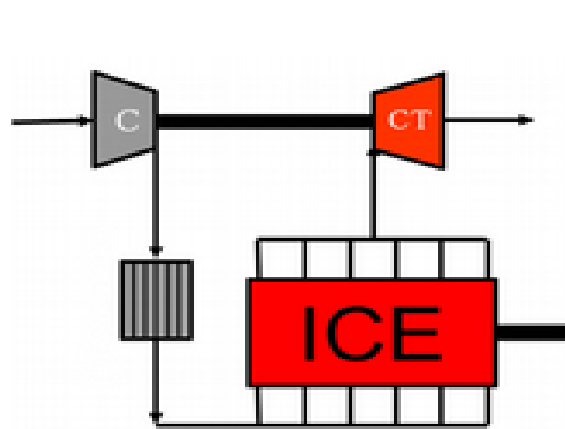
涡轮复合发电系统，为涡轮机与内燃机或燃料电池的联合循环。

TC power generation system: a gas turbine based combined cycle with ICE or fuel cells.

3 涡轮复合发电系统

Turbo-compound (TC) power systems

内燃涡轮复合 ICE-TC system

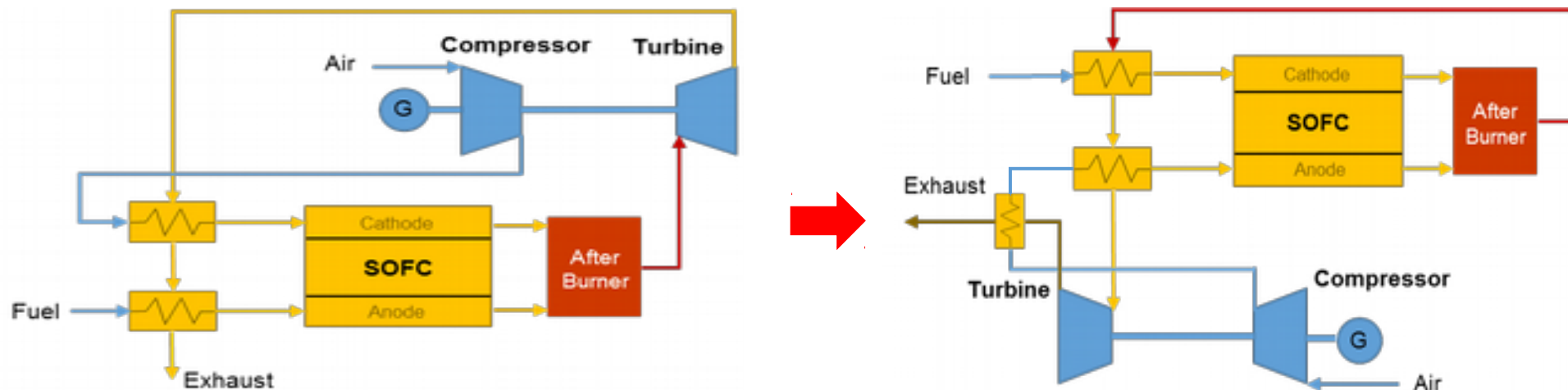


内燃涡轮复合发电效率 >45% , 相对于增压内燃机效率提升 >5% 。
ICE-TC system efficiency: >45%, >5% increased compared to turbocharged ICE.

3 涡轮复合发电系统

Turbo-compound (TC) Power Systems

燃料电池涡轮复合 FC-TC (turbo-compound) system



	TIT	Speed	Efficiency	Cost
SOFC-TC	$\leq 700^{\circ}\text{C}$	$\leq 80 \text{ kr/min}$	$\geq 60\%$	\$1200/kW
SOFC-GT	$\geq 1000^{\circ}\text{C}$	$\geq 100 \text{ kr/min}$	$\geq 62\%$	\$1400/kW

燃料电池涡轮复合发电效率 $> 60\%$, 极具发展和应用前景。
FC-TC system efficiency: $> 60\%$, wide application prospects.



结束语

Concluding Remarks

- ❑ 电动航空非常具有发展前景，将是能源互联网的有机组成。

Electric aviation will have great development and application prospect , and it will be an essential part of the energy internet.

- ❑ 电动化为发展电动汽车与电动飞机的共性关键技术，依托汽车电动化基础，可有效促进飞机电动化的发展。

Key technologies for electric vehicles are also for electric aircrafts. Development of electric aircraft can be accelerated by employing existing advanced technologies used in e-vehicles.

- ❑ 清华的混合电推进研究，在电动风扇推进、电池轻量化设计和高效涡轮复合发电技术等方面取得了一定进展。

Regarding hybrid propulsion research at Tsinghua, progress has been made in E-fan propulsion, light-weight battery and turbo-compound power generation technologies.