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When AIAA Meets IEEE

Intelligent Aero-engine and Electric Aircraft

Springer

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Preface

The initial motivation of this book is an over-30-page long article submitted to AIAA Journal, the top administrative academic magazine of American Institute of Astronautic and Aeronautic association. Unlike a purely technical paper which just focuses on a specific research topic, the editor feels hard to choose proper reviewer since its content covers a broad scope of disciplines both in AIAA and in IEEE, and it is not easy to find any experts who master both of them. He shared his thought with me, and in the mean time, I received the letter from Springer to encourage me to write a book. Indeed, considering both the content and the scope, the best output mode of this long article is a book. It is the comment from editors in AIAA and Springer who inspire me to write this book, talking about the integration of IEEE and AIAA, the two biggest engineering organizations in the world.

The book title *When AIAA Meets IEEE* is inspired after joining the AIAA Meeting in 2018 in Cincinnati, USA, an interactive meeting that AIAA invited IEEE for a joint conference called EATS. It is the first interactive meeting that an AIAA invite IEEE for a joint project of electric aircraft technologies to combine the two teams' efforts together. The author was deeply engaged these years with AIAA people to develop smart sensors for intelligent gas turbine engines and accumulated a lot of real-time experience of IEEE/AIAA working together. And I do feel the strong need of coordination to integrate these two teams together to achieve an engineering target on electric aviation. The differentiation of the mindset and the focus of interest of these two teams shall be properly addressed for their most efficient cooperation. In general, IEEE people needs to adjust their focus to fit the need of AIAA, while the AIAA people need to adapt the most advanced achievements in IEEE, especially in building intelligent aero-system and powerful battery for electrified aero-engines. AIAA people should be able to ask the correct questions on their designated need in smartness, power, weight, and robustness when communicating with IEEE fellows. A professional integration team shall be suggested to aid the communications on both sides to coordinate their necessity and feasibility.

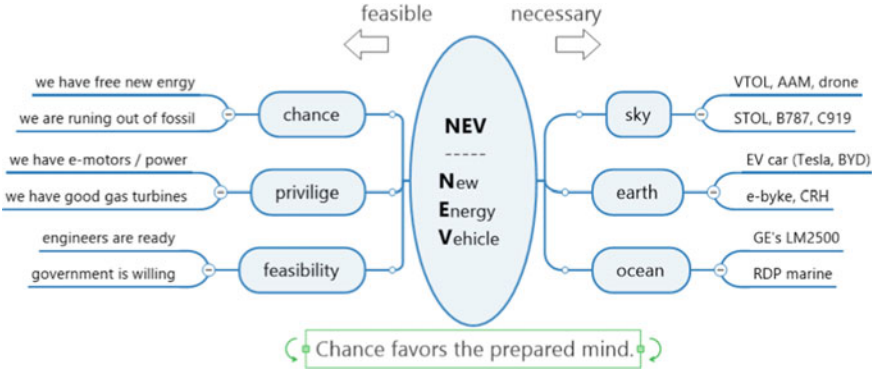
In the previous century, the key word of the AIAA is power; for the next century, the key word is smartness. Electric aero-engine and power are two crucial leading technologies, and both involve heavily the IEEE. The work-together of AIAA and IEEE people becomes a "MUST" in the future activities. While the first part of the book addresses IEEE people's working experience with AIAA, the second portion of the book explores the blueprint of electric aero-propulsion, involving two key technologies: rim-driven electric propulsion and mobile electric power grid. The privilege of this novel electric propulsion is investigated in comparison of the old-fashion propeller and the existing fuel-based gas turbine engines. Rim-driven aero-engines are much smaller and lighter. Multiple engines can be integrated in an aircraft design with a flexible vertical/horizontal propulsion orientation. New theories/methodologies are proposed and explored with some initial efforts made. As to the electric power, three major sources: battery, supercapacitor, and turbine gas generator are analyzed regarding the needs on power, energy, thrust from AIAA's angle and the power/energy density, efficiency, capability, price/maturity in IEEE's perspective.

When I start to write on the book, I feel a big challenge. The first challenge is the scope and the multi-disciplines involved since the AIAA and IEEE belong to totally two different categories of physics and cover so broad knowledge. Not only one needs to learn more knowledge but also needs to express it in more understandable manner. We try to use the verbal language other than the formal language to describe the technical terms whenever possible, and to use the glossary/index is to explain the specific technical jargons. Since the AA and EE cover two separate different physics categories, I most often use the first principles of physics to explain the technology/project from the root, like we did in Chap. 9 that electric motor is an origin of both electric generator and electric engine. The book is intending to lessen the burden of the readers of the intensive knowledge in vast fields by using the oral English rather than the official English.

The second challenge is to walk out from your own comfort zone which may make fool of yourself for the insufficient knowledge outside your profession. Besides, some readers may also feel uneasy when finding themselves outside the comfort zone at some point. The author, therefore, asks the pardon of the readers for some stupid naïves occurred occasionally in the book and offers you the courage you to engage into the new land like me. In fact, the author is intending to use this book to inspire you instead of using it as a textbook. The author was originally an IEEE fellow for nearly 20 years and then engaged in AIAA project in the past 10 years. The author appreciates the different mindsets of these two great minds from AIAA and IEEE people through these 30 years engagement on both sides. The author also feels the need for the effective and efficient integration of these two teams of people if they got to work together for a common goal. From necessity point of view, the intelligent aero-engine needs smart sensors, the electrified propulsion makes the aviation more efficient and sustainable. From feasibility point of view, advanced rim-driven brushless electric motor and advanced battery/supercapacitor achievements in electric automobiles shed the light for electrified niche aero-applications and smarter aviation scenarios such as short distance takeoff landing.

The author understands that some people may prefer to live in their comfortable zone instead of taking the challenge to step into another brand new career, just like most people prefer to park the car near the entrance of a shopping mall. It is the author's willingness to take the risk of making fool of himself, to make an initial effort to contribute some primitive thoughts for the integration of the two teams of people—the two world largest institutes of technology/engineering groups. The coordination of these two great minds, goals, and the ways of doing is highly necessary in order to make an efficient multi-disciplinary project such as the exemplified cases in this book—the IoT for intelligent aero-engine and electric propulsion for next generation electrified aviation, among the many others.

There are three main parts of this book. Part I explains the necessity and feasibility of the AIAA and IEEE cooperation. Part II discusses the use of smart sensor for an intelligent aero-engine. Among the Part II, Chap. 2 mainly explores the specific meanings of AI and how the sensors play an indispensable rules for intelligent AIAA. Then, we use Chaps. 3–5 to illustrate how to use the smarter methods to build the smart sensors to achieve the smarter gas turbine machines. Chapter 3 deals with the scenarios that the TFTC sensor can be used. Chapter 4 discusses the various methods to build them, and Chap. 5 discusses the specific tests that IEEE and AIAA people need to go through before the smart sensors being used infield. It is the author's motivation to use the true experience between the AIAA and IEEE people working together to encourage and to serve as a reference for the future IEEE/AIAA cooperation on electrified aviation engineering. As an intermission between Part II and Part III, Chap. 6 is an intermediate chapter to connect the AIAA and IEEE cooperation from previous to future, i.e., to use our six years' true experience of IEEE people with AIAA colleagues to explain the integrated process between the two groups of professionals, serving as a reference point for the future bigger cooperation. Electric propulsion and associated aviation electric power in Part III are much more challenging and more promising and may bring a more revolution to the whole aviation enterprise. In Part III, we discussed the smarter and the green aviation by the innovative design from e-engines, e-power to e-planes. Although electricity provides power for the e-aviation, the electricity is just a medium but not the final energy resource. The ultimate human energy comes from the solar, wind, tidal, and other green and sustainable natures. New energy vehicle offers new generation of human transportations from ground, ocean to sky with chance, privilege, and feasibility as shown in chart below—a blueprint of the feasibility (the left) versus necessities (the right) of future NEV.



Specifically in Chap. 7, we discuss the e-aviation from the first principle of physics, i.e., how to achieve a clever and smarter aviation, the significance of the greener takeoff and landing, and how to achieve this by vertical e-propulsion. Vertical thrust from e-engines leverages the weight of an airplane either to achieve a VTOL or STOL. Vertical takeoff and landing offer the vast scope of aviation mobility. Short takeoff and landing for larger airliners save lot of airport resources and reduce the airport pollution both from noise and from the hostile gases. Chapter 8 compares the few generations of the aero-engines from propeller to jet, gas turbine, and gas turbine fan, as well as the evolution of the electric motors from the DC brush to AC brushless. From these previous technologies, we are intending to extract the useful experience and lessons for the future development of advanced electric propulsion. In Chap. 9, we introduce a new e-propulsion called rim-driven fan (RDF) jet, a lightweight and small yet more efficient electric propulsion unit as the future electric aero-engine. Chapter 10 discusses the electric power grid suitable to provide enough electricity to drive the RDF jets such as battery, supercapacitor, and lightweight gas generator. Chapter 11 discusses the integrated design of the e-engines and e-airplanes, i.e., how to integrate the multi-electric engines into an aircraft. The key technology is the vertical and horizontal thrust transformation by rotatable wings to keep the optimal performance for both vertical thrust and horizontal propulsion.

The author deeply appreciates the academic and research platform provided by Shanghai Jiaotong University over the past 10 years, especially the cooperation and support of the team. Specifically, the author thanks Prof. Ding Guifu, Zhang Yafei, Han Tao, Fu Xuecheng, Cheng Xiulan, Wang Ying, and other teachers in these years. The author also thanks the other cooperative supports on all levels, such as Li Jibao, Li Jie, Hong Zhiliang, Qian Lingyi, Zheng Fangfang, Shao Jing, Wu Shaohui, Zhang Baowen, Tian Shuqing, and other comrades in AECC. The author also thanks the other colleagues outside the school such as Lin Yuzhen, Cao Xueqiang, Zou Binglin, Wang Ruijun, in Beihang University Wuhan Polytechnic University and

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Shanghai, China Franklin Li Duan

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当航空航天与电力电子相遇

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Afterword

The motivation of this book is to apply the AI to AIAA in order to make it smarter and more intelligent—it is the basic relationship between IEEE and AIAA. It should be pointed out that although IEEE plays a main role in AI, there are many other contributors. IEEE resembles human brain who masters the other actions from other disciplines such as like ASME and MRS. The brain itself is not enough, we also requires the muscles and limbs. We must integrate electric/electrical engineering with other disciplines such as materials science, such as machinery/dynamics/material science, in order to achieve the ultimate goal of an intelligent AIAA. In this interaction, a leader—a dream keeper, is needed who can persistently coordinate the whole cooperative progress without deviating the original target. Not only this leader have the executive power and perseverance, but also has the authority to execute the key AIAA/IEEE actions/plans.

From the technologies perspectives, we have presented two distinct spots in this book which can be invested upon immediately, the two points of interests to make AIAA smarter, one is to use electronics, the other is to use electricity.

(1) The three levels by using electronic technology to make AIAA more intelligent are sensors, data processing and reactions/actuation.

The three steps of AI

Among the three steps, sensor technology is the most basic foundation. It is the most essential part especially right now both from its necessity and the feasibility. Sensors are like the bases of a skyscraper, although we see it is tall and glorious. we should at first lay down a solid foundation. Before we cook a delicious meal, at least we need to get the rice ready. We should collect enough

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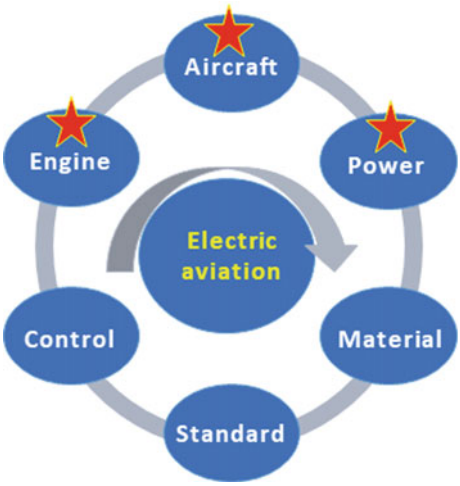
sensing data in all dimensions and then we can do the data mining and algorithms to process them to make the right judgment and then the correct reaction. The building the sensor is the first step and at currently time is still very lacking especially in the AIAA area. The difference between aero-sensors and others lies in that it's relatively more difficult to make and also these sensors work in a relatively tougher environment such as high temperatures up to a 1000 °C. Smart method such as MEMS and AM are two basic approaches to fit the purpose. MEMS is good at build multiple sensors in batch, AM is good at making the sensor onsite and on tough locations. The curved surface patterning and the tough working environment are the two main challenges to for AIAA's sensors.

(2) Electrified aviation is another way for a smarter AIAA by the aid of IEEE. There are three main cleverness. One is the smart electric engine / propulsion. The other is the integrated design of the e-airplane with multiple e-engines. The third one is the mobile electric power grid incorporating the most advanced achievements in electric power including battery, supercapacitor and lightweight gas generator. There are six major areas of the electrification on aviation as shown in the chart:



The composition of e-aviation

Typically, these six compositions basically cover all the aspects of e-eviation, where at the current moment the three star areas are the key technologies which need to be paid more attention to. The engine, power and aircraft are the three main topics in this book from Chaps. 9, 10 and11. We present the RDF jet as a new type of e-engine which is most suitable for e-propulsion with high thrust yet light weight/compact size. To provide this amount of propulsion, more effective electric power is needed. Therefore we present the hybrid electric power supplier for both long term navigation range and VTOL operation by lightweight gas turbine generator plus the 3D high K super capacitor. For the most efficient

aero-dynamic performance we design a Δ shaped streamlined airplane which equipped multiple electric engines with rotatable wings. For the rest of the remaining three parts, they are either fairly mature technologies or belong to the various international FAA organizations/managements which are not covered in this book.

With the obvious advantage of green electricity from the new sustainable energy, from the Sun, the Wind and the Water, it is already expected that the electrical cars will be the mainstream transportation toys on the street within the next 5 years, although fossil thermal engines viehcles will still remain as a legendary human achievement on the road. Likewise, driven by the strong needs of smarter and greener AIAA and pushed by the great achievements of the twenty-first century on both AIAA and IEEE, we also anticipate the e-airplane will dominate on the air traffic in 10 years, either as a flying car or a car copter, the same as e-cars as the main road viehcles with the two incoming advancements of AI- and e-aviation technologies.

Glossary

3A Refer to three automations: industrial automation, office automation, home automation, but different from the meaning of AI, the artificial intelligence. AI has much more complex thinking and judgment based on the multiple sensors and sensor fusion.

3D HK SC A three dimensional high dielectric super capacitor Which is suitable for the to provide the high energy density as well as the high power density for the electric engine and electric aviation, made by the MEMS Micro fabrication technique together with a super high dielectric constant (50,000) material.

3D printing An equivalent term to additive manufacturing which constructs a three-dimensional object from a CAD model or a digital 3D model by a variety of processes in which material is deposited, joined or solidified under computer control.

3D thinking The three-dimensional quadrants (urgency, significance and the good timing) in a task management of a project. To get the something done, one needs to control the proper balance of the three factors. The Chinese call it chance, privilege, feasibility that a good deed shall happen at a specific time and a specific place with specific people. If such timing is not yet ready, you may either wait or manage to create that opportunity. Trying to do it forcibly may just get things even worse.

AAM The abbreviation of advanced air mobility, also called advanced aerial mobility, refers to the "adoption of electric and hybrid propulsion aid an aircraft for versatile air operations."Advancing aerial mobility involves the emergence of transformative and disruptive new airborne technology to transport people and things to locations not traditionally served by current modes of air transportation, including both rural and the more challenging and complex urban environments.

Additive manufacturing The construction or manufacture of an 3D object by deposited, joined or solidified materials under computer control with material being added together (such as plastics, liquids or powder grains being fused), typically layer by layer.

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Aero-engines The power component of an aircraft propulsion system, also called aircraft engines. There are few typical types: piston engines, gas turbines and electric motors. In history, the airplane and aero engine are two independent units. Nowadays with the advent of the multi electric engines and rotatable wings, the integrated design of airplane with multiple engines becomes possible to achieve more advanced aerodynamic performance.

AI Artificial intelligence (AI) is originally defined as the intelligence demonstrated by machines as opposed to the natural intelligence displayed by humans. Initially AI is the simulation of human intelligence by machines that are programmed to think like humans and mimic their actions. Nowadays AI has the extended meanings of the smarter brain, the IoT and the intelligent activities/machines that do a more effective job or even replace humans to fulfil a task.

AIAA Refers to American Institute of Aeronautics and Astronautics. AIAA (pronounced A-I-double-A) the world's largest aerospace organization in the aerospace community for more than 80 years.

Amazon An American multi-national technology company that focuses on e-commerce and online shopping.

Battery An electric device which stores the electricity inside a cell or a system. Nowadays most often people refer the battery as rechargeable and portable electric storage unit such as Li battery and fuel cell battery which can be carried by a portable computer, iPhone, EV car or by an electric airplane.

Boeing 787 One of the world most advanced, American-built wide-body jet airliners developed and manufactured by Boeing Commercial Airplanes. The most distinguished features of the Boeing 787 is its most electrified components in the airplane, and also the lightweight composites materials to build the turbo fan for the most fuel efficient aviation. The first B787 airplane was delivered in September 2011.

BYD A major full-electric automobile and Li rechargeable batteries manufacturer in Shenzhen China. BYD Co. Ltd (Chinese: 比亚迪) is also called "Build Your Dreams".

CATL Contemporary Amperex Technology Co. Limited (Chinese: 宁德时代), abbreviated as CATL, is a Chinese battery manufacturer and technology company founded in 2011 that specializes in the manufacturing of lithium-ion batteries for electric vehicles and energy storage systems, as well as battery management systems. With a market share of 32.6% in 2021, CATL is the biggest lithium-ion battery manufacturer for EVs in the world.

COMSOL A finite element analysis, solver, and simulation software package for various physics/chemistry/biology and engineering applications, especially coupled phenomena and multiphysics.

Delivery drone An unmanned aerial vehicle used to transport packages, medical supplies, food, or other goods. Delivery drones are typically autonomous with robotics control. Delivery drones are the indispensable tools to transport the online shopping goods such as Amazon in US and Taobao in China.

Delta-shaped airplane An aircraft with a delta shaped wing in the form of a triangle. It is named for its similarity in shape to the Greek uppercase letter delta (Δ). The

delta form has unique aerodynamic characteristics and structural advantages such as more space occupancy and more lift-to-drag ratio. Δ-shaped is most suitable shape for the multi-electric propulsion aircraft with rotatable wing both for vertical take off and horizontal navigation.

DEP A distributed electric propulsion with an arrangement in which the propulsive and related air flows are distributed over the aerodynamic surfaces of an aircraft. The purpose is to improve the craft's aerodynamic, propulsive and/or structural efficiency over an equivalent conventional design. Anticipated benefits include improved fuel efficiency, emissions, noise, landing field length and handling. DEP comprises multiple small fans or propellers driven by electric motors. Typically, each individual thruster is direct driven by its own relatively small and lightweight electric motor. The electrical power may be provided by any suitable source.

DJI A Chinese technology company headquartered in Shenzhen, Guangdong (Chinese: 大疆) who manufactures commercial unmanned aerial vehicles (drones) for aerial photography and videography. It's revolutionary coaxial twin rotor design of T40 agricultural unmanned aircraft brings 40 kg spraying and 50 kg seeding load. It is equipped with dual atomization spraying system, smart map system, active phased array radar and binocular visual perception system, integrating flight defense and aerial survey, which can easily lead you to precision agriculture. One T40 costs ~ CMY4000 (year 2022).

E-aviation Electrified aviation including the VTOLer and STOL

E-engine An electrical machine that converts electrical energy into mechanical energy. e-engine is a derivative from an electric motor, which operates through the interaction between the motor's magnetic field and electric current in a wire winding to generate force in the form of torque applied on the motor's shaft. In this book, a new electric engine is proposed which is rim driven instead of the shaft-driven with its distinctive advantage of the bigger torque.

E-motor An electrical machine that converts electrical energy into mechanical energy or vice versa. Electric engine and electric generator are two derivatives from an electric motor, which operate through the interaction between the motor's magnetic field and electric current in a wire winding to generate force in the form of torque applied on the motor's shaft. An electric generator is mechanically identical to an electric engine, but operates with a reversed flow of power, converting mechanical energy into electrical energy. Electric engines can be powered by direct current (DC) sources, such as from batteries, or rectifiers, or by alternating current (AC) sources, such as a power grid, inverters or electrical generators. Most of the electric generators are either the diesel generator of the gas turbine generator.

Energy density The amount of energy stored in a given media per unit volume or per unit weight. The synonyms are volumetric energy density, energy per unit mass, specific energy, gravimetric energy density. There are different types of reactions to release different types of energies in the media, which can be a super capacitor, battery, fossil fuel, kerosene, hydrogen tank. The types of reactions can be: nuclear, chemical, electrochemical, and electrical.

Engineering man The word "engineering" does not just mean "to build a skyscraper". Engineering = "science, life and dream", which is the cross combination of science, technology and sociology. Engineering = IQ + EQ, including team and responsibility chain, which is the great difference between pure artists/sientists / craft masters. We need a smart man, we also need the united power. Together we can make a difference. The core concept of Engineering is IPO (Input → Process → Output): ① O - A feasible and necessary right question; ② P - the right theory or method; ③ I - input variables and which variable is the key factor, and how to optimize the combination of variables.

E-plane An electric airplane which is driven by the electric engine either to the propeller or to the duct fan. The electric power to drive this electric engine could come from the battery super capacitors or the generators, that is, an e-airplane can be either pure electric or hybrid.

E-power An equivalent term as electric power. e-power is from either /all electric generators, batteries, and super capacitors. Specifically for the aviation need, electric power is also called mobile electric power which requires the three resources possess both the higher power for VTOL capability and higher energy density for longer range.

EV An electric car, battery electric car, or all-electric car, is an automobile that is propelled by one or more electric motors, using only energy stored in batteries. Compared to internal combustion engine (ICE) vehicles, electric cars are quieter, have no exhaust emissions, and lower emissions overall. Many countries have established government incentives for plug-in electric vehicles, tax credits, subsidies, and other non-monetary incentives while several countries have legislated to phase-out sales of fossil fuel cars, to reduce air pollution and limit climate change. Tesla and BYD are world's two popular brands of the EV cars.

Gas turbine Also called a combustion turbine, is a type of continuous flow internal combustion engine in which burning of an air–fuel mixture produces hot gases that spin a turbine to produce power. The three main parts (the core) in the direction of flow include a rotating gas compressor, a combustor, and a compressor-driving turbine.

GEnX An advanced dual rotor, axial flow, high-bypass turbofan jet engine in production by GE Aviation for the Boeing 787. GEnX adopted the most advanced technology including lightweight composite materials, big BPR ratio, and overall superior aerodynamic and aircraft propulsion performance.

Green Also referred to as environmentally friendly, eco-friendly, nature-friendly. Green is a sustainability and marketing term referring to the good deeds (machines, energies, activities, associations) on reducing the CO_2 and other harmful gases emissions and using more sustainable energy resources other than the fossil fuels or coals.

IEEE Institute of Electrical and Electronics Engineers. IEEE (pronounced I-triple-E) is a professional association for electronic engineering and electrical engineering (and associated disciplines). As of 2018, it is the world's largest association of technical professionals with more than 423,000 members in over 160 countries around the world. Its objectives are the educational and technical advancement of electrical and electronic engineering, telecommunications, computer engineering and similar disciplines.

IGBT Insulated Gate Bipolar Transistor, a power semiconductor device of energy conversion and transmission, an indispensable device which is used in the electric vehicles connecting the electric power to the electric engines, to transfer and to control the electric power output from batteries/hybrid generators towards the e-engines.

IoT The Internet of things, which may consist of two meanings: (1) the internet info + things, i.e., The physical things can be exchanged via the internet. With aid of the text, video and audio message from internet, the physical object can be exchanged via the drones deliveries like Amazon in US and Taobao in China. (2) describes physical objects with sensors, processing ability, software, and other technologies that connect and exchange data with other devices and systems over the Internet or other communications networks.

IPO IPO = Input – Process – Output, IPO is the technical route to fulfil a project, a topic and a task. I, P and O are the three major components of a project, which is to set the specific goal ("O", the output), then determine the input variable "I" that affects the output "O", by going through a process "P", which is the proper mechanism/model such as simulation or experiment. IPO forms the direction of an engineering endeavor, i.e., from Input → Process → Output. Although "O" is the last in the sequence and the final result of the whole engineering process, it may be initiated first, that is, what we call "being able to ask the right question is half the solution". The ability to define problem, and to ask executable question is a very important ability. To determine a specific target "O" is to ask the right question. This "O" is not only necessary but also feasible. To some extent, this "O" is the innovation, the new idea, the core of IPO. The right "O" initiates and directs the development flow of a project, a scientific topic or as task.

Jingdong JD.com, Inc. is a Chinese e-commerce company headquartered in Beijing

Li battery Most of the time is equivalent term of Li-ion battery. Strictly speaking, Li battery include Li-ion battery, LiS and other lithium-based batteries.

lift-to-drag ratio The amount of lift generated by a wing or airfoil compared to its drag. The lift/drag ratio (L/D) is determined by dividing the lift coefficient by the drag coefficient, CL/CD. A ratio of L/D indicates airfoil efficiency.

Li-ion battery Or lithium-ion battery, a rechargeable battery composed of cells in which lithium ions move back and forth from negative to positive electrodes during the discharging and charging process.

LTG Lightweight turbine generator, which is an advanced electric generator using the gas turbine principle with lightweight material with moderate weight (less than 1 ton) and high power output (500 k to 10 MW), compact size (diameter < 0.5 m, length < 1.5 m).

MEMS Microelectromechanical systems, also written as micro-electro-mechanical systems constitute the technology of microscopic devices, made up of components between 1 μm to a millimeter in size. They usually consist of a central unit that processes data (an integrated circuit chip such as microprocessor) and several components that interact with the surroundings (such as micro sensors). Because of the large surface area to volume ratio of MEMS, forces produced by ambient electromagnetism (e.g., electrostatic charges and magnetic moments), and fluid dynamics (e.g., surface tension and viscosity) are more important design considerations than with larger scale mechanical devices. MEMS technology is distinguished from molecular nanotechnology or molecular electronics in that the latter two must also consider surface chemistry.

Micro/Nano The science, technology and engineering that belong to the range of 10^{-8} to 10^{-3} m

Mindset An established set of attitudes, esp. regarded as typical of a particular group's frame of mind, attitude, disposition. A firmly established mindset could create a powerful incentive to adopt or accept prior behaviors, choices, or tools, sometimes referred to as cognitive inertia, or "groupthink."

NEV A new word proposed as opposed to the EV (electric vehicles) since more and more electricity to drive the EVs (including EV cars, ships and airplanes) may not come purely from the fossil fuel but from the more sustainable energy resources like solar, windy and tidal, i.e., the new energies. The green resources are basically "free energy" which does not consume any natural sources.

Payload The carrying capacity of an aircraft in weight which may include cargo, passengers, flight crew, munitions, scientific instruments or experiments, or other equipment.

PI Also called a dream keeper, refers to the holder of an independent grant or the leader of a research for the grant project, usually in the sciences, technologies and engineering, such as a laboratory study, a clinical trial, or an VC-sponsored startup industrial entrepreneur. It is used widely for the person who makes final decisions and supervise funding and expenditures on a given research project.

Power density The amount of power (time rate of energy transfer) per unit volume or per unit weight, in energy transformers including power supply unit such as batteries, fuel cells, generators, and power users such as engines, motors, jets, thrusters, etc. Also called specific power, power-to-weight ratio, in the unit of W/kg, W/Liter.

Power-to-weight ratio The horsepower of the engine divided by the weight. Power-to-weight ratio (PWR, also called specific power, or power-to-mass ratio) is used to compare the performance of any engine or power source. It is also used as a measurement of performance of a vehicle as a whole, with the engine's power output being divided by the weight (or mass) of the vehicle. Power-to-weight is often quoted by manufacturers at the peak value, but the actual value may vary in use and variations will affect performance.

Pt-Dot-TC A unique insitu thermocouple device proposed in this book, which is very easy to fabricate and can be used for the onsite accurate temperature calibration and the measurement.

RDF jet A rim driven fan jet thruster for electric aircraft specially for VTOL feature. It is composed of a rim driven motor, the Taichi fan blade, and the duct jet. Among them, rim driven motor is good at larger torque, Taichi fan blade is good at more air intake, and duct and shrunken outlet is for higher jet speed. The RDF jet is a small, light and flexible rotatable e-propulsion engine for various aircrafts with VTOL/STOL features.

Rim-driven A novel type of electric magnetic drive unit that does not use a central hub for transmission of the driving torque. Conventional hub centric propellers typically use a shaft driven by a turbine, a diesel engine or an electric motor. The blades of the rim-driven thruster, by contrast, are mounted on an outer ring rather than a central hub. The ring constitutes the rotor of an electric motor and sits within a surrounding stator, which is also ring-shaped and creates the necessary torque.

Rotatable wing Refers to the wing capable of rotating from vertical to horizontal direction. Such wing attaches the multiple electric engines and since these e-engines are small, compact and light, it is relatively easier to rotate them with various angles with the rotatable wing. When rotating engines in various angles, the associated aircraft is capable to move from vertical to horizontal propulsions or vice versa.

SC Super capacitor, also called an ultra capacitor, is a high-capacity capacitor with a capacitance value (10–100 times more energy) much higher than conventional electrolytic capacitors. Unlike ordinary capacitor, the so-called super capacitor does not use the conventional solid dielectric, but rather, it involves electrochemical oxidation–reduction (redox) in the charging/discharging process, which possesses intrinsic limitation on the high specific power output density. But comparing with batteries, it can accept and deliver charge much faster and possesses much more charging/recharging cycles. In this book a new 3D high K dielectric super capacitor is invented which operates in different ways as the conventional SCs.

Sensor A device that detects events or changes in its environment for the purpose of sensing a physical phenomenon and convert it into electric signals to other electronics, frequently a computer processor. Sensor is one of three key e-devices i.e. the RLC (passive device of resistor, inductor and capacitor), the transistor (3-terminal active device) and sensor (converting device of other physical signals to electric signals). Sensors are always used with other electronics.

SFC Also called thrust-specific fuel consumption (TSFC), is the fuel efficiency of an engine with respect to thrust output. sfc (in the unit such as g/(s·kN)) is the fuel consumption per unit of thrust (kilonewtons, or kN) or per unit of Walt (kilowatts, or kW). It is thus thrust or power dependent, meaning that the src is dependable on the output thrust or power. In general, the higher thrust of power, the higher src.

Spitfire British single-seat fighter aircraft used by the Royal Air Force and other Allied countries before, during, and after World War II, which made a great contribution to win the War in many countries.

STOL Short takeoff or landing, which is mainly achieved by leveraging the weight of the aircraft. In general, the takeoff distance shorten X% with X% weight leverage.

Tai Chi The Tai Chi logo ☯ is an interactive chart of the positive (Yang((Chinese: 阳)) and negative (Yin(Chinese: 阴)) energy flows, where the Yin and Yang are both from the Tai Chi. Tai Chi (Chinese: 太极) also called taiji ("Supreme Ultimate") appears in both Taoist and Confucian philosophy. These two ancient Saints believe that everything in the world consists of two parts: Yin and Yang, such as positive and negative, good or bad, etc.. This Chinese philosophical theorem basically believe: (1) positive and negative energy flows coexist inside any item, (2) the Yin and Yang energy flows towards each other, (3) there is a Yin within the Yang, and there is a Yang energy inside the Yin. The constant positive and negative energy flows form the Life. The term taiji is a Chinese cosmological concept for the flux of Yin and Yang energy flow.

Taobao Taobao (Chinese: 淘宝) is a Chinese online shopping platform. It is headquartered in Hangzhou and is owned by Alibaba. It is one of the most-visited website globally in 2021 in China. Taobao.com was registered on April 21, 2003 by Alibaba Cloud Computing (Beijing) Co., Ltd and becomes popular since 2016 with over 1 billion product listings as of 2016 the combined transaction volume of 3 trillion CMY in 2017. Taobao provides a platform for small businesses and individual entrepreneurs to open online stores that mainly cater to consumers in Chinese-speaking regions (Mainland China, Hong Kong, Macau and Taiwan) and abroad, which is made payable by online accounts. Its stores usually offer an express delivery service. Sellers are able to post goods for sale either through a fixed price or an auction. Auctions make up a small percentage of transactions, whereas the majority of the products are new merchandise sold at fixed prices. Taobao users usually read feedback and compare items from multiple shops. Taobao's popular payment platform is Alibaba's Alipay.

Tesla An American multinational electric vehicle and clean energy company. Tesla, Inc. is one of a pioneering EV companies who bring the revolutionary leading automobile with the obvious advantages of quieter and no exhaust emission. EV car will phase-out the fossil fuel car eventually within a few years with government incentives for plug-in electric vehicles, tax credits, subsidies, and other non-monetary services.

TFTC Thin film thermocouple, an advanced temperature measuring sensor which can be attached to any surface of a machine part. Compared to conventional sensors, TFTC sensors are smarter which can be built with the MEMS process in small size and can be built in batch, together with many other advantages.

The 3rd way An innovative engineering approach to find the 3rd path which is neither yes nor no to avoid the dilemma but can cleverly resolve the issue. This term has different meaning as its political term.

UAS An unmanned aircraft system (UAS), which includes the UAV together with the ground-based controller and communications. The UAV is the key of UAS, which is an unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without any human pilot, crew, or passengers on board.

VAATE The Versatile Affordable Advanced Turbine Engines (VAATE) program provides the framework for addressing future turbine engine needs. VAATE is the first a AIAA plan which proposes the intelligence engine blue print.

VTOL Refers to vertical take-off and landing, an aircraft that can hover, take off and land vertically without relying on a runway. Specifically, the technology behind VTOL is the capability of a vertical thrust provided by the electric propulsion. Therefore, the VTOL is most often coined as eVTOL. An ideal VTOLer is an aircraft with multiple electric engines which is capable to provide the thrust for both the vertical takeoff and landing as well as the horizontal navigation with rotatable wings.

天时地利与人和 A Chinese proverb that says “favorable time and place together with the right people are the three basic elements of a success”.

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