

# Future Aircraft Power Systems Integration Challenges

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced in Scientific and technical aerospace reports (STAR) and International aerospace abstracts (IAA) Green Aviation is the first authoritative overview of both engineering and operational measures to mitigate the environmental impact of aviation. It addresses the current status of measures to reduce the environmental impact of air travel. The chapters cover such items as:

- Engineering and technology-related subjects (aerodynamics, engines, fuels, structures, etc.),
- Operations (air traffic management and infrastructure)
- Policy and regulatory aspects regarding atmospheric and noise pollution.

With contributions from leading experts, this volume is intended to be a valuable addition, and useful resource, for aerospace manufacturers and suppliers, governmental and industrial aerospace research establishments, airline and aviation industries, university engineering and science departments, and industry analysts, consultants, and researchers.

The objective of this contract effort was to define the functionality and evaluate the propulsion and power system benefits derived from a Solid Oxide Fuel Cell (SOFC) based Auxiliary Power Unit (APU) for a future long range commercial aircraft, and to define the technology gaps to enable such a system. The study

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employed technologies commensurate with Entry into Service (EIS) in 2015. United Technologies Corporation (UTC) Integrated Total Aircraft Power System (ITAPS) methodologies were used to evaluate system concepts to a conceptual level of fidelity. The technology benefits were captured as reductions of the mission fuel burn and emissions. The baseline aircraft considered was the Boeing 777-200ER airframe with more electric subsystems, Ultra Efficient Engine Technology (UEET) engines, and an advanced APU with ceramics for increased efficiency. In addition to the baseline architecture, four architectures using an SOFC system to replace the conventional APU were investigated. The mission fuel burn savings for Architecture-A, which has minimal system integration, is 0.16 percent. Architecture-B and Architecture-C employ greater system integration and obtain fuel burn benefits of 0.44 and 0.70 percent, respectively. Architecture-D represents the highest level of integration and obtains a benefit of 0.77

percent. Srinivasan, Hari and Yamanis, Jean and Welch, Rick and Tulyani, Sonia and Hardin, Larry Glenn  
Research Center  
AUXILIARY POWER SOURCES;  
SOLID OXIDE FUEL CELLS; BOEING 777 AIRCRAFT;  
CERAMICS; AIRFRAMES; SYSTEMS INTEGRATION;  
PROPULSION; FEASIBILITY

This thesis proposes new power converter topologies suitable for aircraft systems. It also proposes both AC-DC and DC-DC types of converters for different electrical loads to improve the performance these systems. To increase fuel efficiency and reduce environmental impacts, less efficient non-electrical aircraft systems are

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being replaced by electrical systems. However, more electrical systems requires more electrical power to be generated in the aircraft. The increased consumption of electrical power in both civil and military aircrafts has necessitated the use of more efficient electrical power conversion technologies. This book presents a comprehensive mathematical analysis and the design and digital simulation of the power converters. Subsequently it discusses the construction of the hardware prototypes of each converter and the experimental tests carried out to verify the benefits of the proposed solutions in comparison to the existing solutions.

The primary human activities that release carbon dioxide (CO<sub>2</sub>) into the atmosphere are the combustion of fossil fuels (coal, natural gas, and oil) to generate electricity, the provision of energy for transportation, and as a consequence of some industrial processes. Although aviation CO<sub>2</sub> emissions only make up approximately 2.0 to 2.5 percent of total global annual CO<sub>2</sub> emissions, research to reduce CO<sub>2</sub> emissions is urgent because (1) such reductions may be legislated even as commercial air travel grows, (2) because it takes new technology a long time to propagate into and through the aviation fleet, and (3) because of the ongoing impact of global CO<sub>2</sub> emissions. Commercial Aircraft Propulsion and Energy Systems Research develops a national research agenda for reducing CO<sub>2</sub> emissions from commercial aviation. This report focuses on propulsion and energy technologies for reducing carbon emissions from large, commercial aircraft—single-aisle and twin-aisle aircraft

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that carry 100 or more passengersâ€"because such aircraft account for more than 90 percent of global emissions from commercial aircraft. Moreover, while smaller aircraft also emit CO<sub>2</sub>, they make only a minor contribution to global emissions, and many technologies that reduce CO<sub>2</sub> emissions for large aircraft also apply to smaller aircraft. As commercial aviation continues to grow in terms of revenue-passenger miles and cargo ton miles, CO<sub>2</sub> emissions are expected to increase. To reduce the contribution of aviation to climate change, it is essential to improve the effectiveness of ongoing efforts to reduce emissions and initiate research into new approaches.

The Encyclopedia of Electrochemical Power Sources is a truly interdisciplinary reference for those working with batteries, fuel cells, electrolyzers, supercapacitors, and photo-electrochemical cells. With a focus on the environmental and economic impact of electrochemical power sources, this five-volume work consolidates coverage of the field and serves as an entry point to the literature for professionals and students alike. Covers the main types of power sources, including their operating principles, systems, materials, and applications Serves as a primary source of information for electrochemists, materials scientists, energy technologists, and engineers Incorporates nearly 350 articles, with timely coverage of such topics as environmental and sustainability considerations Provides a significant update to the definitive book

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on aircraft system design This book is written for anyone who wants to understand how industry develops the customer requirement for aircraft into a fully integrated, tested, and qualified product that is safe to fly and fit for purpose. The new edition of Design and Development of Aircraft Systems fully expands its already comprehensive coverage to include both conventional and unmanned systems. It also updates all chapters to bring them in line with current design practice and technologies taught in courses at Cranfield, Bristol, and Loughborough universities in the UK. Design and Development of Aircraft Systems, 3rd Edition begins with an introduction to the subject. It then introduces readers to the aircraft systems (airframe, vehicle, avionic, mission, and ground systems). Following that comes a chapter on the design and development process. Other chapters look at design drivers, systems architectures, systems integration, verification of system requirements, practical considerations, and configuration control. The book finishes with sections that discuss the potential impact of complexity on flight safety, key characteristics of aircraft systems, and more. Provides a holistic view of aircraft system design, describing the interactions among subsystems such as fuel, navigation, flight control, and more Substantially updated coverage of systems engineering, design drivers, systems architectures, systems integration, modelling of

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systems, practical considerations, and systems examples Incorporates essential new material on the regulatory environment for both manned and unmanned systems Discussion of trends towards complex systems, automation, integration and the potential for an impact on flight safety Design and Development of Aircraft Systems, 3rd Edition is an excellent book for aerospace engineers, researchers, and graduate students involved in the field.

This book focuses on the interaction between different energy vectors, that is, between electrical, thermal, gas, and transportation systems, with the purpose of optimizing the planning and operation of future energy systems. More and more renewable energy is integrated into the electrical system, and to optimize its usage and ensure that its full production can be hosted and utilized, the power system has to be controlled in a more flexible manner. In order not to overload the electrical distribution grids, the new large loads have to be controlled using demand response, perchance through a hierarchical control set-up where some controls are dependent on price signals from the spot and balancing markets. In addition, by performing local real-time control and coordination based on local voltage or system frequency measurements, the grid hosting limits are not violated.

Integrating renewable energy and other distributed

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energysources into smart grids, often via power inverters, is arguablythe largest “new frontier” for smart grid advancements. Inverters should be controlled properly so that their integrationdoes not jeopardize the stability and performance of power systemsand a solid technical backbone is formed to facilitate otherfunctions and services of smart grids. This unique reference offers systematic treatment of importantcontrol problems in power inverters, and different generalconverter theories. Starting at a basic level, it presentsconventional power conversion methodologies and then ‘non-conventional’ methods, with a highly accessiblesummary of the latest developments in power inverters as well asinsight into the grid connection of renewable power. Consisting of four parts – Power Quality Control, NeutralLine Provision, Power Flow Control, and Synchronisation –this book fully demonstrates the integration of control and powerelectronics. Key features include: the fundamentals of power processing and hardware design innovative control strategies to systematically treat thecontrol of power inverters extensive experimental results for most of the controlstrategies presented the pioneering work on “synchronverters” which hasgained IET Highly Commended Innovation Award Engineers working on inverter design and those at power systemutilities can learn how advanced control strategies could improvesystem

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performance and work in practice. The book is a useful reference for researchers who are interested in the area of control engineering, power electronics, renewable energy and distributed generation, smart grids, flexible AC transmission systems, and power systems for more-electric aircraft and all-electric ships. This is also a handy text for graduate students and university professors in the areas of electrical power engineering, advanced control engineering, power electronics, renewable energy and smart grid integration.

The U.S. air transportation system is very important for our economic well-being and national security. The nation is also the global leader in civil and military aeronautics, a position that needs to be maintained to help assure a strong future for the domestic and international air transportation system. Strong action is needed, however, to ensure that leadership role continues. To that end, the Congress and NASA requested the NRC to undertake a decadal survey of civil aeronautics research and technology (R&T) priorities that would help NASA fulfill its responsibility to preserve U.S. leadership in aeronautics technology. This report presents a set of strategic objectives for the next decade of R&T. It provides a set of high-priority R&T challenges—characterized by five common themes—for both NASA and non-NASA researchers, and an analysis of key barriers that



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must be overcome to reach the strategic objectives. The report also notes the importance of synergies between civil aeronautics R&T objectives and those of national security.

Electricity, supplied reliably and affordably, is foundational to the U.S. economy and is utterly indispensable to modern society. However, emissions resulting from many forms of electricity generation create environmental risks that could have significant negative economic, security, and human health consequences. Large-scale installation of cleaner power generation has been generally hampered because greener technologies are more expensive than the technologies that currently produce most of our power. Rather than trade affordability and reliability for low emissions, is there a way to balance all three? The Power of Change: Innovation for Development and Deployment of Increasingly Clean Energy Technologies considers how to speed up innovations that would dramatically improve the performance and lower the cost of currently available technologies while also developing new advanced cleaner energy technologies. According to this report, there is an opportunity for the United States to continue to lead in the pursuit of increasingly clean, more efficient electricity through innovation in advanced technologies. The Power of Change: Innovation for Development and Deployment of Increasingly Clean Energy Technologies makes the case that America's advantages—world-class universities and national laboratories, a vibrant private sector, and innovative states, cities, and regions that are free to experiment with a variety of public policy

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approachesâ€"position the United States to create and lead a new clean energy revolution. This study focuses on five paths to accelerate the market adoption of increasing clean energy and efficiency technologies: (1) expanding the portfolio of cleaner energy technology options; (2) leveraging the advantages of energy efficiency; (3) facilitating the development of increasing clean technologies, including renewables, nuclear, and cleaner fossil; (4) improving the existing technologies, systems, and infrastructure; and (5) leveling the playing field for cleaner energy technologies. The Power of Change: Innovation for Development and Deployment of Increasingly Clean Energy Technologies is a call for leadership to transform the United States energy sector in order to both mitigate the risks of greenhouse gas and other pollutants and to spur future economic growth. This study's focus on science, technology, and economic policy makes it a valuable resource to guide support that produces innovation to meet energy challenges now and for the future.

Test Techniques for Flight Control Systems of Large Transport Aircraft offers theory and practice of flight control system tests. It is a systematic and practical guide, providing insights to engineers in flight control, particularly those working on system integration and test validation. Ten chapters cover an introduction to flight control system tests, equipment tests and validation, software tests and validation, flight control law and flying qualities evaluation, tests of flight control subsystems, integration and validation based on the iron bird, ground-based test, flight-tests, airworthiness tests and validation,

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and finally, the current status and prospects for flight control tests and evaluation. Presents flight control system integration tests and validation for large transport aircraft Includes the most advanced methods and technologies available Details the latest research and its applications Offers theoretical and practical guidance that engineers can use Considers the state-of-the-art and looks to the future of flight control system tests

Power systems worldwide are going through a paradigm shift from centralized generation to distributed generation. This book presents the SYNDEM (i.e., synchronized and democratized) grid architecture and its technical routes to harmonize the integration of renewable energy sources, electric vehicles, storage systems, and flexible loads, with the synchronization mechanism of synchronous machines, to enable autonomous operation of power systems, and to promote energy freedom. This is a game changer for the grid. It is the sort of breakthrough — like the touch screen in smart phones — that helps to push an industry from one era to the next, as reported by Keith Schneider, a New York Times correspondent since 1982. This book contains an introductory chapter and additional 24 chapters in five parts: Theoretical Framework, First-Generation VSM (virtual synchronous machines), Second-Generation VSM, Third-Generation VSM, and Case Studies. Most of the chapters include experimental results. As the first book of its kind for power electronics-enabled autonomous power systems, it • introduces a holistic architecture applicable to both large and small power systems, including aircraft power systems, ship power

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systems, microgrids, and supergrids • provides latest research to address the unprecedented challenges faced by power systems and to enhance grid stability, reliability, security, resiliency, and sustainability • demonstrates how future power systems achieve harmonious interaction, prevent local faults from cascading into wide-area blackouts, and operate autonomously with minimized cyber-attacks • highlights the significance of the SYNDEM concept for power systems and beyond Power Electronics-Enabled Autonomous Power Systems is an excellent book for researchers, engineers, and students involved in energy and power systems, electrical and control engineering, and power electronics. The SYNDEM theoretical framework chapter is also suitable for policy makers, legislators, entrepreneurs, commissioners of utility commissions, energy and environmental agency staff, utility personnel, investors, consultants, and attorneys. The Handbook of Clean Energy Systems brings together an international team of experts to present a comprehensive overview of the latest research, developments and practical applications throughout all areas of clean energy systems. Consolidating information which is currently scattered across a wide variety of literature sources, the handbook covers a broad range of topics in this interdisciplinary research field including both fossil and renewable energy systems. The development of intelligent energy systems for efficient energy processes and mitigation technologies for the reduction of environmental pollutants is explored in depth, and environmental, social and economic

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impacts are also addressed. Topics covered include:

Volume 1 - Renewable Energy: Biomass resources and biofuel production; Bioenergy Utilization; Solar Energy; Wind Energy; Geothermal Energy; Tidal Energy. Volume 2 - Clean Energy Conversion Technologies: Steam/Vapor Power Generation; Gas Turbines Power Generation; Reciprocating Engines; Fuel Cells; Cogeneration and Polygeneration. Volume 3 - Mitigation Technologies: Carbon Capture; Negative Emissions System; Carbon Transportation; Carbon Storage; Emission Mitigation Technologies; Efficiency Improvements and Waste Management; Waste to Energy. Volume 4 - Intelligent Energy Systems: Future Electricity Markets; Diagnostic and Control of Energy Systems; New Electric Transmission Systems; Smart Grid and Modern Electrical Systems; Energy Efficiency of Municipal Energy Systems; Energy Efficiency of Industrial Energy Systems; Consumer Behaviors; Load Control and Management; Electric Car and Hybrid Car; Energy Efficiency Improvement. Volume 5 - Energy Storage: Thermal Energy Storage; Chemical Storage; Mechanical Storage; Electrochemical Storage; Integrated Storage Systems. Volume 6 - Sustainability of Energy Systems: Sustainability Indicators, Evaluation Criteria, and Reporting; Regulation and Policy; Finance and Investment; Emission Trading; Modeling and Analysis of Energy Systems; Energy vs. Development; Low Carbon Economy; Energy Efficiencies and Emission Reduction.

Key features: Comprising over 3,500 pages in 6 volumes, HCES presents a comprehensive overview of the latest research, developments and practical

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applications throughout all areas of clean energy systems, consolidating a wealth of information which is currently scattered across a wide variety of literature sources. In addition to renewable energy systems, HCES also covers processes for the efficient and clean conversion of traditional fuels such as coal, oil and gas, energy storage systems, mitigation technologies for the reduction of environmental pollutants, and the development of intelligent energy systems.

Environmental, social and economic impacts of energy systems are also addressed in depth. Published in full colour throughout. Fully indexed with cross referencing within and between all six volumes. Edited by leading researchers from academia and industry who are internationally renowned and active in their respective fields. Published in print and online. The online version is a single publication (i.e. no updates), available for one-time purchase or through annual subscription.

Analysis and Design of Power Converter Topologies for Application in Future More Electric Aircraft Springer Renamed to reflect the increased role of digital electronics in modern flight control systems, Cary Spitzer's industry-standard Digital Avionics Handbook, Second Edition is available in two comprehensive volumes designed to provide focused coverage for specialists working in different areas of avionics development. The first installment, Avionics: Elements, Software, and Functions covers the building blocks and enabling technologies behind modern avionics systems. It discusses data buses, displays, human factors, standards, and flight systems in detail and includes new

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chapters on the Time-Triggered Protocol (TTP), ARINC specification 653, communications, and vehicle health management systems.

This third edition of Aircraft Systems represents a timely update of the Aerospace Series' successful and widely acclaimed flagship title. Moir and Seabridge present an in-depth study of the general systems of an aircraft – electronics, hydraulics, pneumatics, emergency systems and flight control to name but a few - that transform an aircraft shell into a living, functioning and communicating flying machine. Advances in systems technology continue to alloy systems and avionics, with aircraft support and flight systems increasingly controlled and monitored by electronics; the authors handle the complexities of these overlaps and interactions in a straightforward and accessible manner that also enhances synergy with the book's two sister volumes, Civil Avionics Systems and Military Avionics Systems. Aircraft Systems, 3rd Edition is thoroughly revised and expanded from the last edition in 2001, reflecting the significant technological and procedural changes that have occurred in the interim – new aircraft types, increased electronic implementation, developing markets, increased environmental pressures and the emergence of UAVs. Every chapter is updated, and the latest technologies depicted. It offers an essential reference tool for aerospace industry researchers and practitioners such as aircraft designers, fuel specialists, engine specialists, and ground crew maintenance providers, as well as a textbook for senior undergraduate and postgraduate students in systems engineering,

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aerospace and engineering avionics.

A comprehensive review of the science and engineering behind future propulsion systems and energy sources in sustainable aviation *Future Propulsion Systems and Energy Sources: in sustainable aviation* is a comprehensive reference that offers a review of the science and engineering principles that underpin the concepts of propulsion systems and energy sources in sustainable air transportation. The author – a noted expert in the field – examines the impact of air transportation on the environment and reviews alternative jet fuels, hybrid-electric and nuclear propulsion and power. He also explores modern propulsion for transonic and supersonic-hypersonic aircraft and the impact of propulsion on aircraft design. Climate change is the main driver for the new technology development in sustainable air transportation. The book contains critical review of gas turbine propulsion and aircraft aerodynamics; followed by an insightful presentation of the aviation impact on environment. Future fuels and energy sources are introduced in a separate chapter. Promising technologies in propulsion and energy sources are identified leading to pathways to sustainable aviation. To facilitate the utility of the subject, the book is accompanied by a website that contains illustrations, and equation files. This important book:

- Contains a comprehensive reference to the science and engineering behind propulsion and power in sustainable air transportation
- Examines the impact of air transportation on the environment
- Covers alternative jet fuels and hybrid-electric propulsion and power
- Discusses



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modern propulsion for transonic, supersonic and hypersonic aircraft Examines the impact of propulsion system integration on aircraft design Written for engineers, graduate and senior undergraduate students in mechanical and aerospace engineering, Future Propulsion Systems and Energy Sources: in sustainable aviation explores the future of aviation with a guide to sustainable air transportation that includes alternative jet fuels, hybrid-electric propulsion, all-electric and nuclear propulsion.

From the earliest days of aviation where the pilot would drop simple bombs by hand, to the highly agile, stealthy aircraft of today that can deliver smart ordnance with extreme accuracy, engineers have striven to develop the capability to deliver weapons against targets reliably, safely and with precision. Aircraft Systems Integration of Air-Launched Weapons introduces the various aspects of weapons integration, primarily from the aircraft systems integration viewpoint, but also considers key parts of the weapon and the desired interactions with the aircraft required for successful target engagement. Key features: Addresses the broad range of subjects that relate directly to the systems integration of air-launched weapons with aircraft, such as the integration process, system and subsystem architectures, the essential contribution that open, international standards have on improving interoperability and reducing integration costs and timescales Describes the recent history of how industry and bodies such as NATO have driven the need for greater interoperability between weapons and aircraft and worked to reduce the cost and timescales associated with

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the systems integration of complex air-launched weapons with aircraft Explores future initiatives and technologies relating to the reduction of systems integration costs and timescales The systems integration of air-launched weapons with aircraft requires a multi-disciplinary set of engineering capabilities. As a typical weapons integration life-cycle spans several years, new engineers have to learn the skills required by on-the-job training and working with experienced weapons integrators. Aircraft Systems Integration of Air-Launched Weapons augments hands-on experience, thereby enabling the development of subject matter expertise more quickly and in a broader context than would be achieved by working through the life-cycle on one specific project. This book also serves as a useful revision source for experienced engineers in the field.

Lists citations with abstracts for aerospace related reports obtained from world wide sources and announces documents that have recently been entered into the NASA Scientific and Technical Information Database.

After a decade of Eurosclerosis the EC is moving with renewed economic growth and increasing multinational investment toward a single European market under the heading "Project 1992". The creation of a single EC market creates dynamic adjustment needs and opens up new opportunities for international business in a period of intensified global competition and dramatic politico-economic changes. Since the mid-1980s Eastern Europe is undergoing a radical shift towards market-based economic systems - a difficult and fragile development so far which is further complicated by economic and political unification of Germany

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in central Europe. After the era of British and, later, U. S. leadership in multinational investment German and Japanese multinational companies are becoming more influential players worldwide. Firms from Germany play a special role because German unification of 1990 implies a bigger home market, but also the diversion of total investment activities towards the greater German home market. While the political divide of Europe has ceased to exist, the economic division is becoming more apparent, and it could indeed temporarily increase because the EC 1992 project primarily generates growth impulses in Western Europe, while systemic transformations in Eastern Europe reduce output growth in the short term.

The objective of this study is to define the functionality and evaluate the propulsion and power system benefits derived from a Solid Oxide Fuel Cell (SOFC) based Auxiliary Power Unit (APU) for a future short range commercial aircraft, and to define the technology gaps to enable such a system. United Technologies Corporation (UTC) Integrated Total Aircraft Power System (ITAPS) methodologies were used to evaluate a baseline aircraft and several SOFC architectures. The technology benefits were captured as reductions of the mission fuel burn, life cycle cost, noise and emissions. As a result of the study, it was recognized that system integration is critical to maximize benefits from the SOFC APU for aircraft application. The mission fuel burn savings for the two SOFC architectures ranged from 4.7 percent for a system with high integration to 6.7 percent for a highly integrated system with certain technological risks. The SOFC APU itself produced zero emissions. The reduction in engine fuel burn achieved with the SOFC systems also resulted in reduced emissions from the engines for both ground operations and in flight. The noise level of the baseline APU with a silencer is 78 dBA, while the SOFC APU produced a lower noise level. It is

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concluded that a high specific power SOFC system is needed to achieve the benefits identified in this study. Additional areas requiring further development are the processing of the fuel to remove sulfur, either on board or on the ground, and extending the heat sink capability of the fuel to allow greater waste heat recovery, resolve the transient electrical system integration issues, and identification of the impact of the location of the SOFC and its size on the aircraft. Gummalla, Mallika and Pandey, Arun and Braun, Robert and Carriere, Thierry and Yamanis, Jean and Vanderspurt, Thomas and Hardin, Larry and Welch, Rick Glenn Research Center SOLID OXIDE FUEL CELLS; AUXILIARY POWER SOURCES; WASTE ENERGY UTILIZATION; SYSTEMS INTEGRATION; WASTE

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