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A Report on the Future of Electric Aviation

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SUSTAINABLE AVIATION SYMPOSIUM

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A Report on the Future of Electric Aviation

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Abstract

UC Berkeley has long been known as the home of important societal movements. In early October 2019, the electric aircraft movement came to UC Berkeley (UCB) courtesy of UCB's Institute for Transportation Studies (ITS) and the College of Engineering. At what some have called the "Woodstock of Aviation"—the Sustainable Aviation Symposium (SAS) convened leaders of that movement from across the globe for two full days in UC's Pauley Ballroom to explore how to solve important societal-enviro-economic issues in transportation with breakthroughs and innovations in high-tech physics, chemistry and electrical engineering. Beyond Science, Technology, Engineering, Art and Mathematics (STEAM) topics, the faculty presentations spanned a broad spectrum of UC's graduate and undergraduate curriculum and included those by prominent UC faculty members, professors from other universities, leaders from NASA as well as several by experts in private industry. SAS 2019 was unique among conferences in focusing on how the future driverless, emission-free sky taxis of urban air mobility (UAM) could affordably transform transportation and neighborhoods at scale in metro regions and beyond. The socio-enviro-economic prospects for that transformation's potential for regional mass transit by air that could ease surface gridlock, untenable infrastructure costs and climate change, showed why SAS 2019 engaged for the first time the disciplines of urban and environmental planning and civil engineering. SAS 2019 resulted in a growing awareness of the pan-topic relevance of UAM and justified both the continuation of SAS at UC Berkeley as well as further activities of the Aviation Futures Lab at UCB.

Executive Summary

The 2019 Sustainable Aviation Symposium (SAS 2019) at the University of California at Berkeley was organized as a collaboration between the Sustainable Aviation Foundation, Inc., (SAF) a 501c3 non-profit organization, and the UC Berkeley Institute for Transportation Studies (ITS) and UC Berkeley College of Engineering (COE). The curated faculty of presenters at SAS 2019 embodied the remarkably diverse set of technologic, environmental and sociologic disciplines relevant to urban air mobility (UAM). SAF brought its extensive network of experts and constituents of the electric aircraft movement including those from industry, government and academia. Event Co-Chair Dr. Jasenka Rakas led the recruitment of faculty leaders from UC Berkeley's ITS and COE, and other program presenters were drawn from leading experts in emerging technological breakthroughs and promising new start-ups.

The result was a comprehensive program offering a condensed, graduate level examination of the evolving world of UAM and its integration into future transportation systems. Particularly valuable were this symposium's spirit of enthusiastic sharing of ideas and collaboration toward improving neighborhoods and transportation. This was in large part owing to the meeting's declared theme of responsibly exploring the *planning and societal integration* of UAM.

The SAS 2019 program filled two full days in UC's Pauley Ballroom providing a live audience with lecture, video and slide presentations about the "how" and the "why" of UAM. Some described breakthrough developments and innovations in high-tech physics, chemistry and electrical engineering that spanned a broad spectrum of UC's graduate and undergraduate engineering curricula. Additional presentations extended beyond engineering disciplines into city and regional planning issues, housing, social equity and quality of life. Each day's program provided attendees with extensive Q & A and networking opportunities during two coffee breaks and a mid-day buffet luncheon. An array of posters and hardware exhibits were placed by a number of the participating aerospace companies, including Jaunt, SLM Solutions, Sabrewing Aircraft, Gabriel DeVault, ASKA and the NASA AQUIFER project.

Day One's program began with NASA Langley Chief Scientist Dennis Bushnell delivering a virtual presentation about the emerging technological breakthroughs that can impel UAM into a real and sustainable transportation mode. The morning program topics were focused on short and vertical take-off technologies and the need for UAM to move cargo. The afternoon of Day One saw a wide variety of presentations about hydrogen fuel cell powertrains, autonomous flight technologic readiness, innovative landing facilities for UAM, a short history of eFlight developments, the importance of distributed UAM for real estate development and commute times, the system-wide ecology of UAM and its legal ramifications.

Day Two's morning program began with promising news about IBM's new high energy density battery, followed by presentations from 3 leading scientists at NASA, a revolutionary new type of solar energy collector, high torque motor design and 3D printing with metal powder. The afternoon session followed with presentations about the operational aspects of UAM, its costs, practicality, range limitations and then a panel about how UAM can be integrated with existing air traffic. The program then turned to airpark and vertiport design and siting for best city planning. The next presentation was the annual honorary Paul B. MacCready Lecture, delivered by Gabriel DeVault on "Doing More With Less, Right Now!", which described a low cost way to fly an electric powered aircraft with practical value. The concluding lecture was the 2019 PADA Trophy Award ceremony honoring Dr. John Langford's career and delivered by Aurora Flight Sciences CTO Tom Clancy.

SAS 2019 was roundly praised by its attendees and faculty and is known to have inspired many students toward UAM's future. In addition, contemporary developments in the UAM industry space clearly show the influence of SAS 2019 on industry thinking and directions.

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1. Introduction

1.1 Background

The electric aircraft movement began in Spring of 2007, when Cal graduate Brien Seeley, organized and chaired the first-ever electric aircraft symposium in San Francisco. This became an annual event that attracted greater interest each year until 2015, when annual symposium chair Seeley assembled a team of experts comprised of Tyler MacCready, Wayne Cook and Damon Seeley to inaugurate the all-volunteer, non-profit Sustainable Aviation Foundation (SAF). The SAF team had long been enthusiasts and builders of small, efficient experimental aircraft. Together, they organized an annual symposium dedicated to electric aircraft technologies. Each year, their Sustainable Aviation Symposium (SAS) attracted leaders in cutting edge technologies around electric flight to come to the Bay Area from their posts at Boeing, NASA, FAA and across the globe. UC Berkeley faculty Dr. Jasenka Rakas joined the SAS faculty in 2017 and recognized its leading role in the electric aircraft movement. As a renowned expert and educator in airport design and aviation, she saw the potential for SAS to bring together each year at UCB the leaders in the burgeoning frontier of urban air mobility to provide inspiration to graduate students in a broad range of engineering disciplines. Dr. Rakas joined the SAF team and led the effort to bring SAS to Berkeley by connecting the Sustainable Aviation Foundation with the UCB ITS and curating its 2019 program.

1.2 Discussion

SAS 2019 provided an important discussion for the engineering, environmental, city and regional planning communities about how concurrent advances in the several core sciences and technologies that enable electric flight will substantially change their world.

This awakening extended not only to the faculty, students, attendees and media members who witnessed SAS 2019, but also, to several of the most prominent agency policymakers, elected officials, and leaders of both the Environmental and New Urbanism movements by the efforts of the SAF team through invitation, networking, outreach and shared video recordings of the SAS proceedings.

This necessary coupling of science and engineering with the commonwealth domains of community planning, environmental protection, social equity and resource management comprises an ideal fit at the comprehensive public university that is UC Berkeley. The Sustainable Aviation Foundation has demonstrated with SAS 2019 that it can be a valuable partner with the UCB ITS in bringing such coordinated programs to UCB.

The world of UAM faces many challenges, but fortunately the main ones are regulatory, and those can be solved by engendering the necessary collective will. As occurred with the adoption of recycling, a concerted and transparent program of public education, planning and collaboration will be necessary.

1.3 Conclusions

The UCB Institute for Transportation Studies' SAS 2019 clarified on a public university stage the electric aircraft movement's encompassing scope and importance to all. Its attendees expressed consistently strong praise for the quality and content of the program. The main conclusions evidenced by its proceedings were the following:

Highly distributed, emission-free mass transit by air (MTBA) is already eminently achievable technologically, with clear evidence that future technologic advances will improve its speed, safety, range, capacity and affordability. MTBA will include mass transport of both people and goods and will be deployed across the globe in both developed nations and poor ones whose infrastructure is still under-developed. Even in those nations that are challenged by political unrest, high mountainous terrain, dense jungle, extreme weather and resource scarcity, the many valuable benefits of electric aircraft will drive its adoption.

Compared to all other forms of transportation, MTBA could provide the safest, fastest and, apart from walking and bicycling, the most affordable. Not if, but when a fully built-out MTBA system is operational across the world's metro mega-regions, its benefits will include substantial reductions in surface gridlock, reductions in infrastructure costs, carbon and particulate matter emissions, reductions in lost productivity and traffic deaths. With future driverless vehicles, MTBA could help make having a driver's license unnecessary. Those who, due to age, poor vision or infirmity are unable to drive, could still travel safely and conveniently using MTBA. MTBA could enable many to live without the costs of owning a car, in housing without the costs of driveways and garages. It could thereby help make communities more resilient and self-contained, which could allow them to maintain urban growth boundaries and perimeter greenbelts. The ultimate effect of MTBA on suburban sprawl is, however, uncertain at this time and asks for greater involvement of community planning experts. In the event of natural disasters and states of emergency, MTBA could be vitally helpful for both evacuation and relief efforts.

2. Details of the Proceedings and their Relevance

The Dean of UC Berkeley College of Engineering, Professor Tsu-Jae King Liu, kicked off the meeting with a welcoming message describing the history of SAS and how Dr. Jasenka Rakas of the ITS had brought it to UC Berkeley. Dr. King Liu pointed out that, befitting a major university, SAS 2019 would converge experts in the following disciplines:

- Civil Engineering
- Environmental Engineering
- Mechanical Engineering
- Aeronautical Engineering
- Urban, Regional and City Planning
- Electrical and Computer science
- AI and Robotics
- Materials Science and Engineering
- Industrial Engineering and Operations Research
- Bioengineering
- Environmental Economics and Policy
- School of Business
- Public Policy and Administration
- Sociology

Dr. King Liu expressed her belief that UC Berkeley can provide an important and valuable civic-minded voice in this new UAM domain, a voice that will complement those of industry, policymakers and city planners.

Dr. Daniel Rodriguez, Associate Director of the UCB ITS, then officially welcomed the Sustainable Aviation Foundation as co-developer with ITS of SAS 2019, and affirmed the university's intention to embrace and support the development of urban air mobility as an important part of aviation's future.

A large number of UC Berkeley students from several different disciplines were able to attend SAS 2019, thanks to support from the UC College of Engineering. Faculty presenters, industry professionals and students all engaged in a buzz of stimulated conversations during the coffee breaks and luncheons both days.

3. Day One Speakers

The opening presentation at SAS 2019 was by NASA Langley Chief Scientist Dennis Bushnell, titled *Enabling a Sustainable Unmanned Aircraft Systems (UAS)/On-demand Mobility (ODM)/Urban Air Mobility (UAM)/Personal Air Vehicles (PAV) Industry*, or shortly *Enabling a UAS/ODM/UAM/PAV Industry*. He described the key breakthroughs that were emerging concurrently in the relevant disciplines of aeronautics, materials science, renewable energy, battery chemistry, propulsion, 3D printing, nano-composites, tele-travel, population de-densification, autonomous air traffic management, machine intelligence and driverless vehicle safety. Bushnell forecasts UAM in the USA to become a one trillion dollar per year market when fully developed, and cites this as a not if but when scenario involving de-carbonization of electrical generation, the emergence of lithium/oxygen class battery energy densities, future aircraft that are 3D-printed, reliable, quiet, inexpensive, across all speed ranges, with advanced configurations and materials, and fully autonomous operation.

Dr. David Ullman, Emeritus Professor from Oregon State University, made his presentation of the *Ultra-Short Takeoff and Landing (STOL) Electric Aircraft* that he is developing from a Jabiru small aircraft. He resurrected the high-lift concepts demonstrated by the Custer Channel-Wing. Using his own wind-tunnel, he described the projected and measured gains in ultra-high lift coefficients that were enabled by using several miniature ducted fans blowing spanwise along the leading edge of a wing. These mini-fans create high velocity airflow over the wing to enhance its lift and enable extremely short takeoff and landing capabilities.

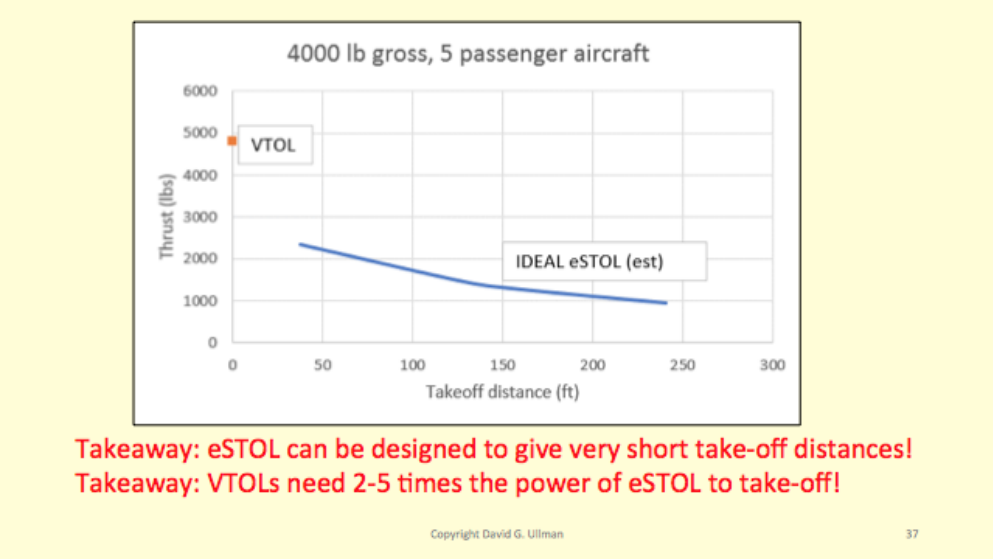

Figure 2. Takeoff Distance vs Thrust for eSTOL and VTOL Air Vehicles

Dr.Gecheng Zha, Professor and Director of the Aerodynamic and Computational Fluid Dynamics (CFC) Lab at the University of Miami presented *a High Efficiency Low Noise VTOL/ESTOL Concept Using CoFLow Jet* (SFJ). This technology promises to make possible extremely short takeoff and landing (ESTOL) aircraft that have much reduced wing and wetted area and thereby achieve much higher cruise speeds than previous ESTOL designs that have had to rely upon lower wing loadings.

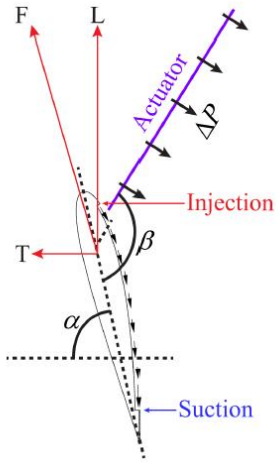

Figure 3. Schematic Plot of a Typical CoFlow Jet Airfoil in VTOL/ESTOL Conditions

Guy Kaplinsky, Chairman and Co-Founder of New Future Transportation (NFT), a joint US-Israel start-up, then presented *How Drive and Fly Will Impact the Future of Gen Z*. This presentation included ASKA's plans for a driverless flying car whose guidance system will be extensible to other aircraft designs. The principal aim of NFT is to develop UAM that does not need additional infrastructure such as vertiports or small airparks. The goal is that of a flying car, as shown below.

Figure 4. ASKA's Flying Car

Martin Peryea, CTO of Jaunt Air Mobility LLC, presented on the topic of *A Safe, Ultra-Quiet eVTOL UAM Solution--The Next Evolution in Aviation*. The presentations discussed an all- eVTOL aircraft designed for the Urban Air Mobility (UAM) and On-Demand Mobility (ODM) markets. This eVTOL is a Reduced-rotor Operating Speed Aircraft (ROSA™) with core technologies that result in the quietest, safest, and most efficient hovering aircraft of any configuration currently being developed for UAM missions. The patented features include a 70% reduction in main rotor tip speed from hover to cruise flight, a high energy inertia rotor system and a high static thrust scimitar propeller design. In addition, Jaunt provides the safety of a fly-by-wire flight control system and the comfort of Jaunt's patented LevelFlyTM technology, a mast tilting capability which facilitates management of the aircraft attitude throughout its flight envelope and provides a generous center of gravity envelope.

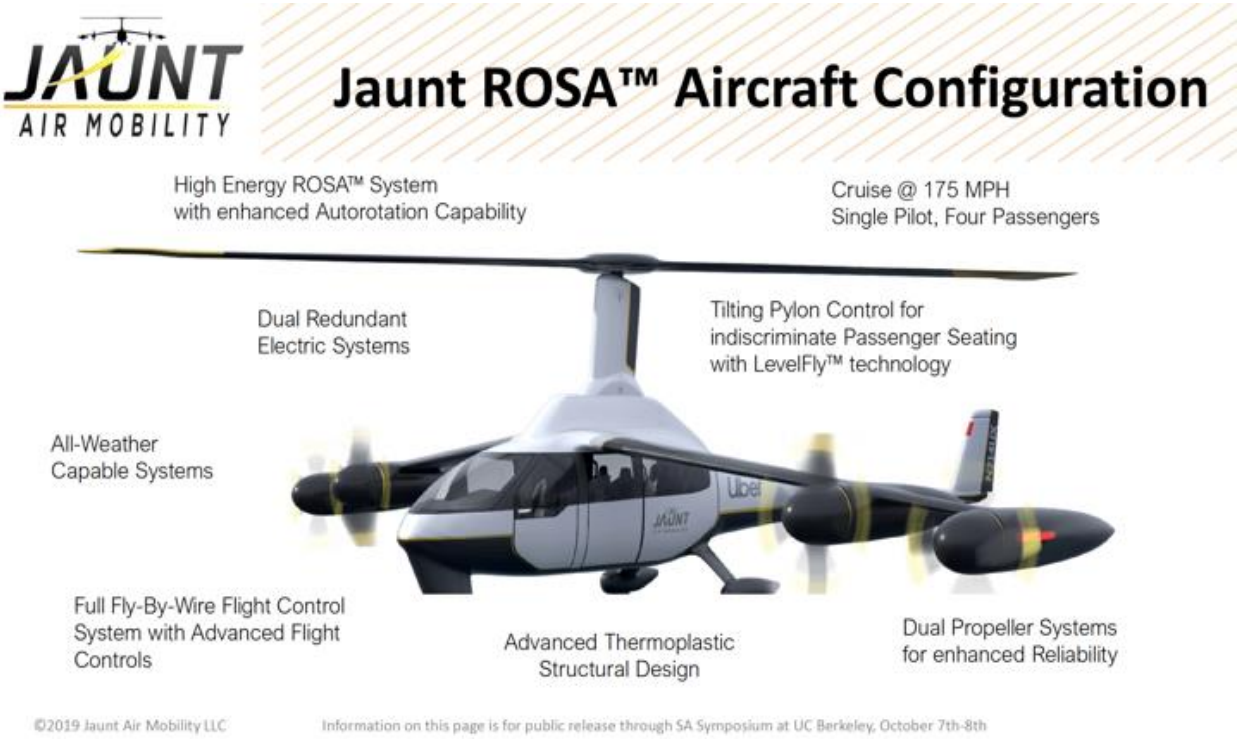

Figure 5. Jaunt ROSA Aircraft Configuration

Oliver Garrow, Co-Founder and CTO of Sabrewing Aircraft Company Inc., presented on the topic of *World's First Heavy-Lift VTOL Cargo UAV*. He described their hybrid-electric aircraft that could carry a 4400 lb. payload at 200 knots for a 600-mile range. Sabrewing has developed new solutions in the cargo delivery space, being both novel and more efficient. Overall efficiency is improved using the latest hybrid electric powerplant, with advanced printed and composites structures, twin-motor vectoring ducted fans, lifting and blended wing bodies (BWB), "programmable" landing gear and flexible take-off methods from conventional takeoff and landing (CTOL), to STOL to VTOL, translating to many benefits to cargo operators.

Figure 6. Exhaustive Engineering Tools at Sabrewing

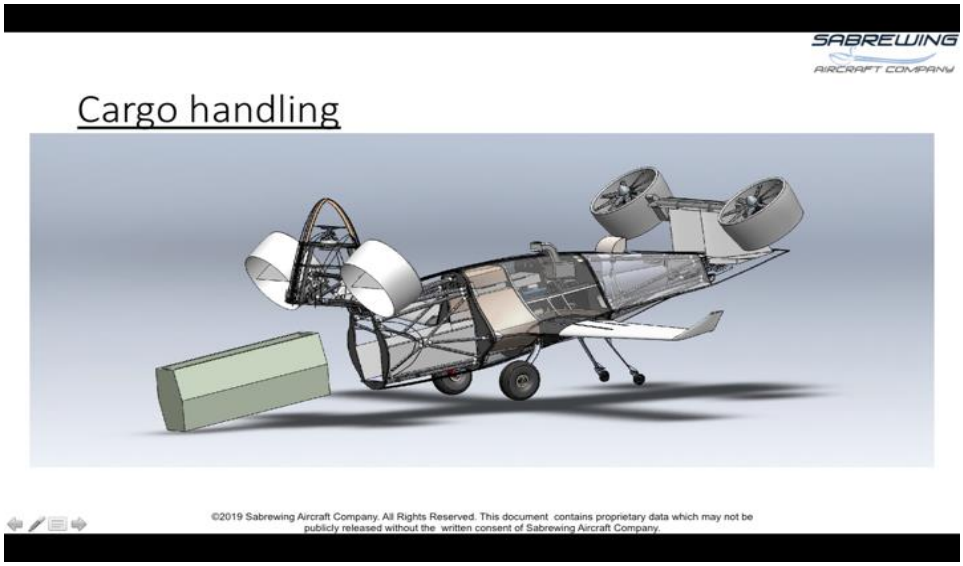

Figure 7. Cargo Handling of Sabrewing's Heavy-Lift VTOL Cargo UAV

Dr. Anita Sengupta, Co-Founder and CPO of Airspace Experience Technologies (ASX), presented on the topic of *Urban Air Mobility Evolution*. She discussed how space-age technology coupled to the VC-funded innovation environment are enabling a revolution in sustainable aviation. Then she reviewed how autonomous VTOL air taxis are an enabling technology for urban transport in smart cities of the future. In addition, she discussed the design and testing of the Mobi-One, an electric tilt-wing VTOL aircraft being developed at her new company, ASX. From the utilization of airspace, to infrastructure, to air traffic control, she presented on the Urban Air Mobility revolution and its arrival to cities.

Figure 8. Mobi-One Specifications

Valery Miftakhov, Founder and CEO of ZeroAvia, presented on the topic of *The First Practical Zero Emission Aviation Powertrain*. He described his company's application of a hydrogen fuel cell powertrain to a Piper M-Class GA airplane and its potential advantages over a battery-electric aircraft. The mission of ZeroAvia is to accelerate the world's transition to sustainable aviation in a cost-efficient manner, as flight-hour costs for its hydrogen-based powertrain will run around half of those of conventional turbine aircraft, taking account of lower fuel and maintenance costs, as well as better powertrain efficiency. He discussed the issues of battery aircraft, indicating that battery aircraft might be conceptually simpler, but would likely be limited to shorter range missions unless radical redesign of airframes occur. However, 500-mile range flights cover almost 50% of all trips worldwide, and introducing hydrogen-based powertrains on such routes will be realistic.

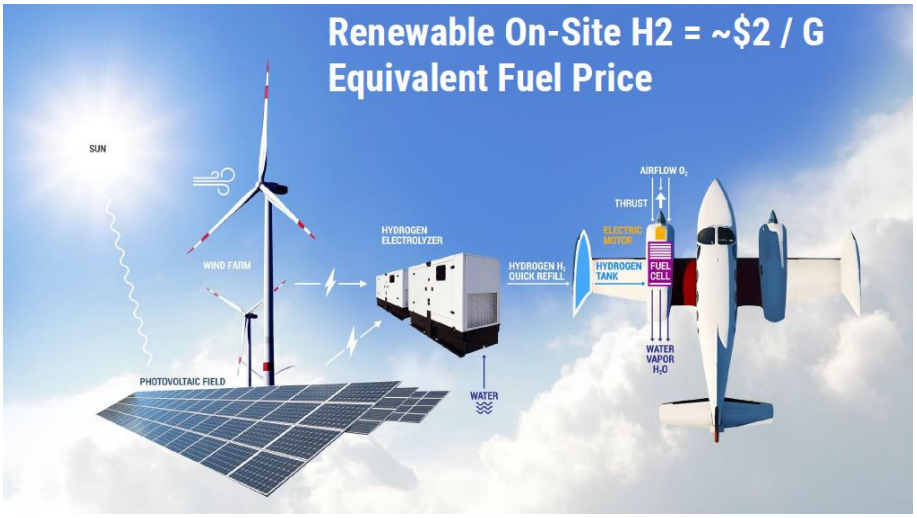

Figure 9. Renewable On-site Hydrogen Fuel Price

Dean Sigler, curator editor of SustainableSkies.org, presented on the topic of *Prophecies of Flight*, a summary of past and present efforts in electric aviation. He showed how the state of the art is advancing on all fronts and analyzed the various types of eVTOL aircraft that are emerging. The presentation summary asked the core questions related to the concept of UAM and our future: What are the benefits to humanity? Who will benefit? Will history judge this as an honest attempt to redeem our society's flaws, or just a selfish excuse for avarice? Why does this matter, and what are the long-term consequences?

Vectored Thrust	81
Lift + Cruise	29
Wingless (Multicopter)	47
Hover Bikes/Devices	40
Electric Rotorcraft	14
	211

Source: vfs.org

Figure 10. New eVTOL concepts for UAM

Susan Dell 'Osso, President of River Islands Development LLC, presented on the topic of *Planning Sustainable Communities for California's Future*. She cited the untenable commute times that affect people who work in the Bay Area but have to live in the Central Valley. Her map showed that just 3 small airparks could serve the entire 5000 acre community of River Islands near Tracy, California. She discussed how public-private partnerships between cities and development companies must work together to envision and underwrite large-scale innovation in master planned community development. In tying together the disparate topics of affordable housing, green building, air, water and energy conservation, quality neighborhood education, health and wellness, jobs creation and game-changing transportation innovation, the presentation demonstrated the need for planning as mega-regions, and the benefits of disruptive technology in transportation systems to tie large areas together.

Figure 11. Potential Locations of Small Airparks

Darrel Swanson, Director of the Swanson Aviation Consultancy, presented on the topic of *Distributed Aviation*. He noted that there are more than 200 eVTOL concept aircraft that are under development for the UAM space. The presentation outlined how the development of electric aircraft will shift a proportion of passenger traffic away from our current hub-and-spoke aviation system to a sub-regional network of smaller airports and vertiports in our congested urban environments. A vertiport solution for London was presented, including a review of its operational characteristics. Additionally, a review of various proposed vertiport solutions was presented and compared against perceived requirements for North America vs Europe.

Figure 12. Distributed Electrical Propulsion VTOLs-eVTOLs for UAM

Dr. Ella Atkins, Professor and Associate Director of the Robotics Institute at the University of Michigan, Ann Arbor, presented on *Data to Decisions for Safe Flight*. She discussed three important topics in support of Safe Flying: advanced aerial mobility (AAM), airspace volume management, and autonomy for contingency management. She extensively discussed the core automation functions, piloted and pilotless pathways, and what can go wrong within each element of AAM. Then, she presented the concept of airspace geo-fencing as a method to separate air traffic for airspace volume management. Lastly, she discussed various objectives that have to be achieved for successful contingency planning, such as identifying and processing new data sources, developing and adapting metrics to fuse new data sources with traditional sensor data streams, etc. The presentation ended with videos illustrating recent work to experimentally validate the continuum deformation cooperative control strategy in the University of Michigan's new M-Air netted flight facility.

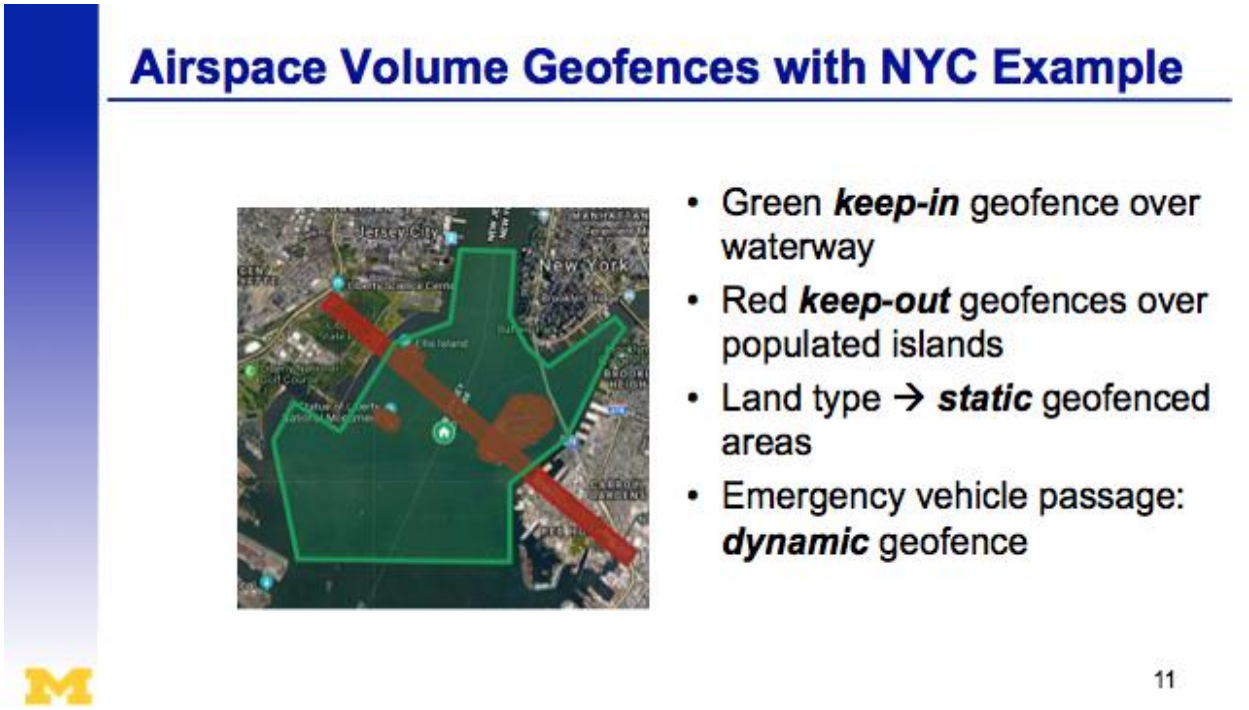

Figure 13. Airspace Volume Geofences with New York City Example

Dr. Jasenka Rakas, Co-Chair of SAS 2019, UC Berkeley CEE Faculty, and Board Member of the Sustainable Aviation Foundation presented on the topic of *Air Piers for Urban Air Mobility*. She began with a history of aviation transport and described previous UAM concepts and why they failed. Then she discussed air piers and the issues of capacity, building cost, size, airspace integration, turnaround time, taxi time, delays, weather, extreme weather and lightning strikes, facility siting, and airpark/vertiport design. She pointed out what lessons can be learned from the commercial air transportation sector, and what can be done to avoid potential mistakes when creating an efficient UAM system.

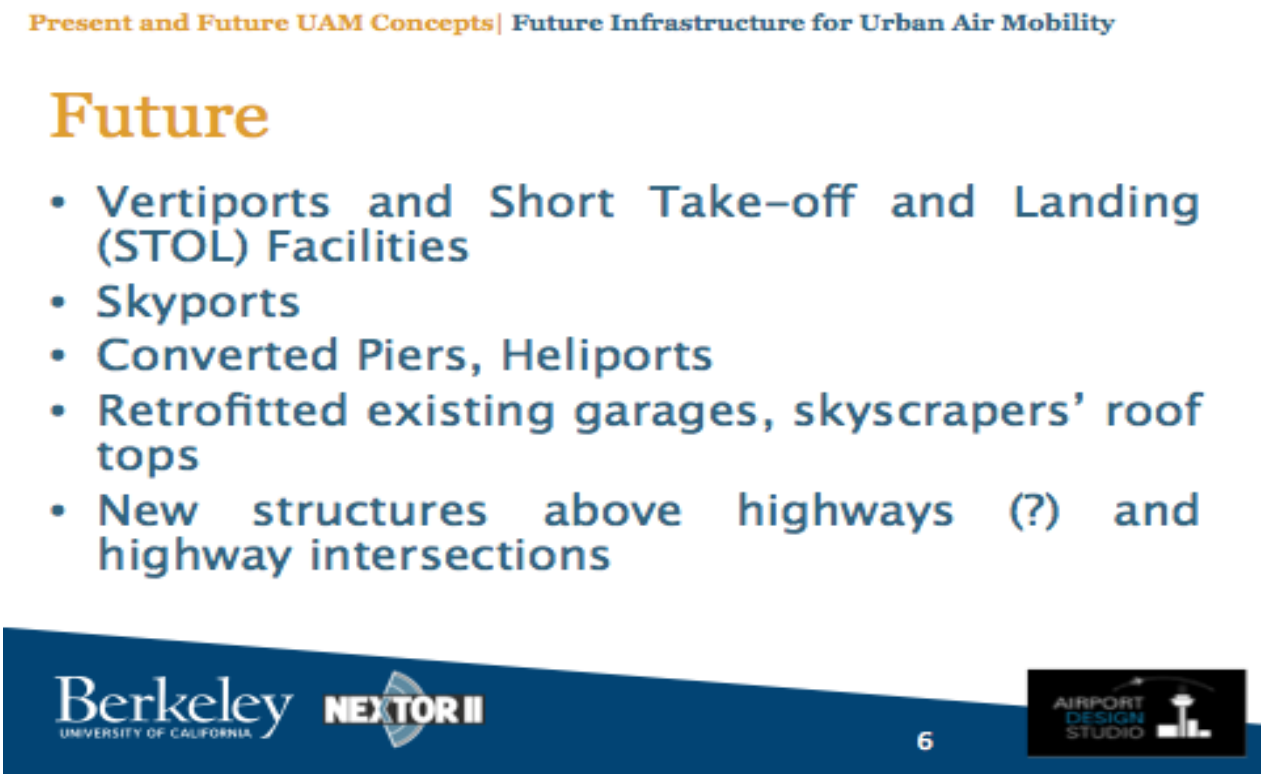

Figure 14. Future Infrastructure for Urban Air Mobility

Dr. Arpad Horvath, UC Berkeley CEE Professor and Co-Director of Transportation Sustainability Research Center, spoke on the life cycle analysis (LCA) of UAM and its dependency upon the type of energy being used to propel the sky taxis. He discussed the United Nations sustainable development goals, and the environmental metrics of common interest across different transportation modes. The LCA analysis and a comprehensive environmental inventorying of transportation was discussed across three types of vehicles (onroad, rail and air) for energy consumption, greenhouse gas (GHG) emissions (carbon dioxide), and non-GHG emissions (sulfur dioxide, nitrogen oxides and carbon monoxide). Lastly, a future comparison for the California corridor was discussed for new vehicle technologies (cars and aircraft) and for California high speed rail.

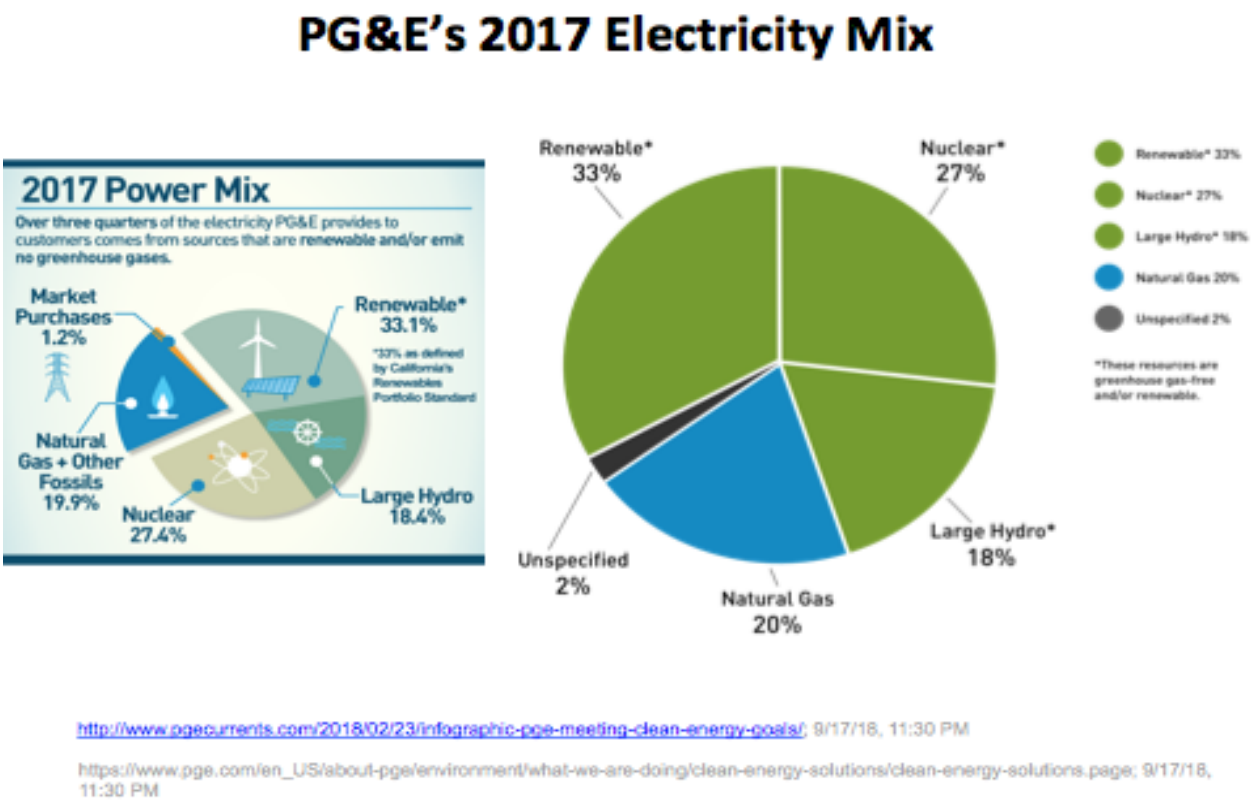

Figure 15. PG&E Electricity Mix for Different Power Sources

Jordan Jaffe, partner at Quinn Emmanuel law firm, and leader of the autonomous vehicle practice, presented on the topic of legal issues in UAM. He discussed two important questions: (1) who is liable for robot aircraft, and (2) how is intellectual property defined for UAM and artificial intelligence. Answers to the first question were provided by differentiating the present and the future law definitions for accidents. At present, accidents with human pilots are governed by negligence law, and accidents based on product malfunction are largely governed by product liability law. Mr. Jaffe stated that, in the future, the widespread adoption of autonomous vehicles could produce a shift from a compensation regime for conventional pilot error that is largely premised on negligence to a compensation regime for automated driving that increasingly implicates product liability. Regarding the second (i.e. the intellectual property) issue, he cited a very large upswing in the number of patents being filed in this domain.

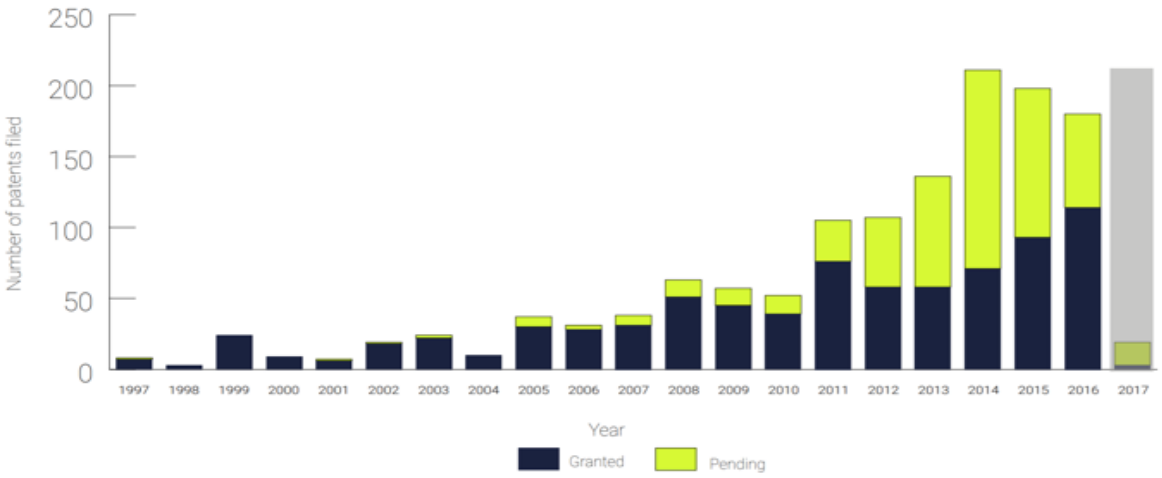

Figure 3. A patent filing timeline showing the number of live patents filed per year since 1997. Lapsed patents have been removed.

Figure 16. The Annual Number of Patents Filed since 1997

4. Day Two Speakers

Dr. van Bibber opened the second day of the symposium by providing the following comments:

“Today’s morning program will feature several expert presentations on breakthroughs in technologies that are strongly rooted in fundamental physics and chemistry. For those of us who teach and research these fields here at UC Berkeley, it is a pleasure to see how keenly relevant is their application to future urban air mobility. We will see how progress depends upon understanding at the sub-atomic scale and molecular level and from there grows into valuable, comprehensive gains in physical structures, energy storage and conversion and finally into full vehicles and their use in transportation systems. That will lead us into today's afternoon sessions where the program turns to the sustainable, civic-minded implementation of urban air mobility both on the ground and in the air. We’ll finish today’s program with the Personal Aircraft Design Academy (PADA) which will feature the Paul B. MacCready Honorary Lecture and the Presentation of the beautiful PADA Trophy, with a fascinating look at the career of its honoree, Dr. John Langford. We are glad to see sustainable aviation come to this university, where we hope it will inspire our students across its many related disciplines.”

Dr. Jangwoo Kim from the IBM Research-Almaden Lab discussed the *IBM’s Next-gen Battery Breakthrough*. He pointed out that this new battery technology outperforms the existing lithium-ion battery in multiple measures. Depending on the application, this family of batteries can be modified to deliver on critical performance factors. The years-long research and development process behind the discovery of this new kind of battery in the lab revealed the complex chemistry involved in the electrochemical reaction during charge and discharge. Then, the presentation discussed the remaining challenges for bringing these batteries out of the lab and into commercial and industrial applications. Dr. Kim’s cobalt-free battery is 350 wh/kg with less flammable electrolyte, and at 10C can charge the battery to 80% of capacity in just 6 minutes. To date, this battery has the higher specific power in comparison with other batteries on the market.

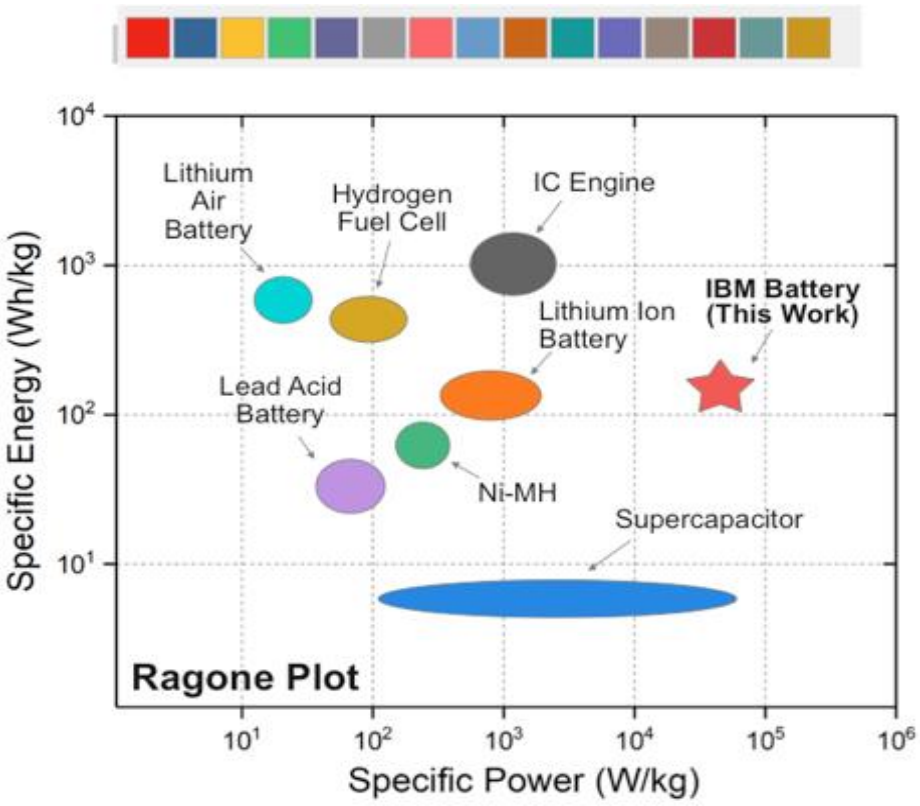

Figure 17. Specific Power vs Specific Energy

Robert McSwain from NASA Langley Research Center and Jason Lechniak from NASA Armstrong Flight Research Center presented their work on NASA AQUIFER: Nano Electrofuel Aqueous Flow Battery and Rim-driven Motor (RDM). This system uses a "nanoelectric fuel" (NEF) to speed charging time, tailor range to fuel carried, and reduce fire hazards. Mr. McSwain then continued with a presentation about NASA's many development programs in the area of UAM, including those for small UAS, air traffic system research, rim driven motors, noise reduction, safety, security, certification and vertiports.

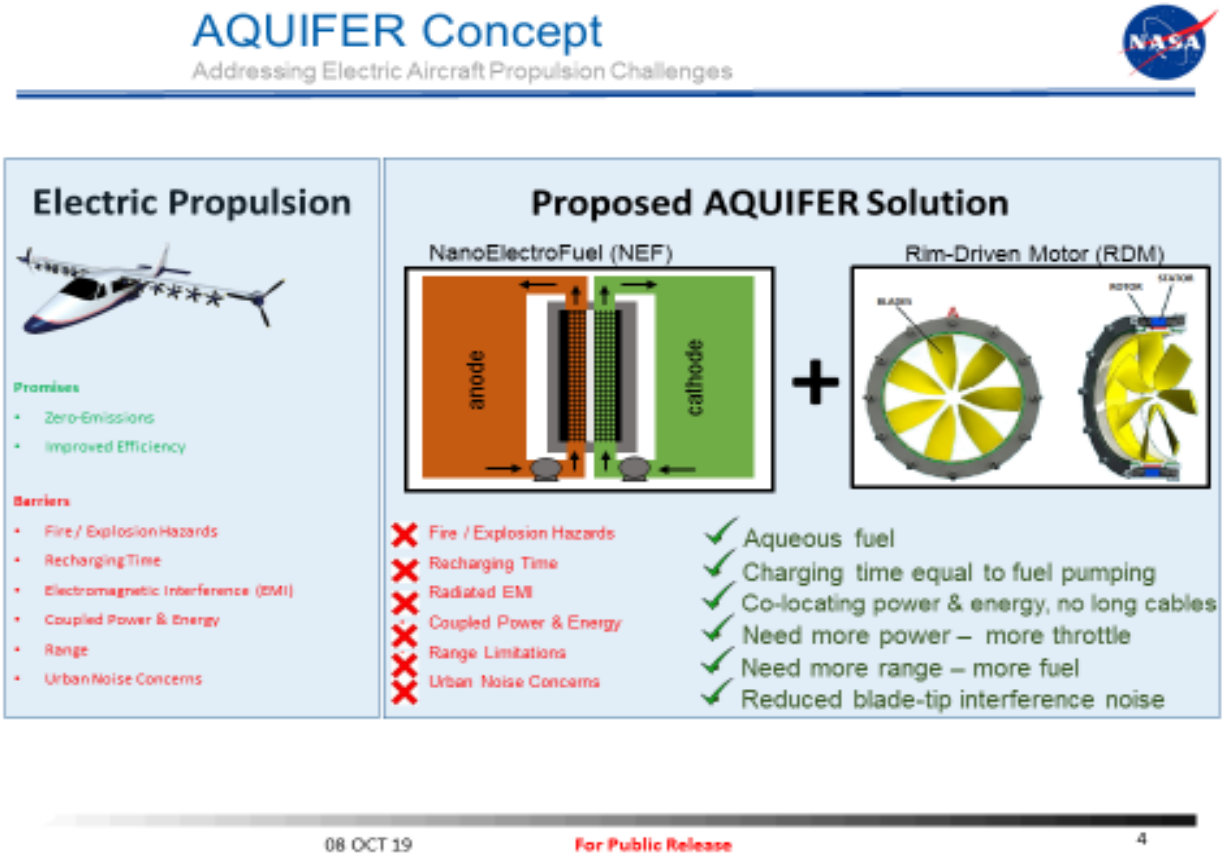

Figure 18. AQUIFER Concept

Dr. Ajay Misra from NASA Glenn Research Center presented a detailed look at the latest breakthroughs in battery technology including the potential for alternate energy conversion and storage technologies such as fuel cells, supercapacitors, hybrid battery-supercapacitors, and flow batteries. Energy densities as high as 1350 wh/kg were forecasted as being achievable.
He pointed out that energy storage and conversion technologies are enabling for commercial deployment of all-electric UAM aircraft with desired range and performance. Although the battery will remain as the preferred energy storage device for UAM vehicles, alternate energy storage and conversion technologies are currently being explored for the UAM market segment. His presentation reviewed the battery requirements for various UAM missions and compared the requirements against the current state-of-the-art and developmental batteries. The battery technology gap for UAM vehicles was highlighted along with proposed technology development pathway for meeting UAM needs. Battery technology challenges related to safety and sustainability were addressed.

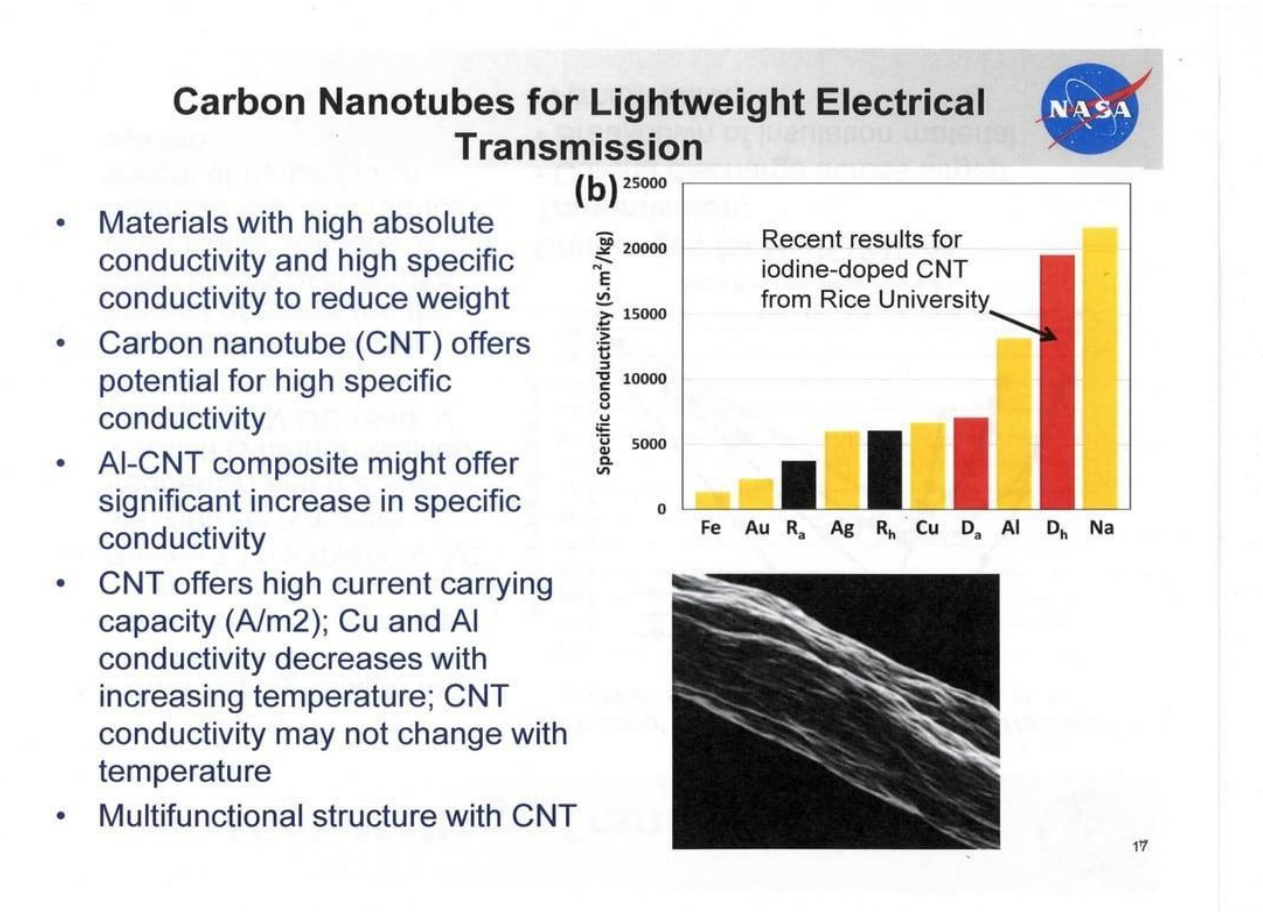

Figure 19. Carbon Nanotubes for Lightweights Electrical Transmission

Larry Cooke of NovaSolix presented the design and process they are developing to produce rectenna arrays and the advantages they will provide to mobile applications. He described a breakthrough in solar energy capture using rectennas made of carbon nanotubes. By capturing a broader wavelength spectrum, these new devices offer theoretical energy capture efficiencies that are nearly 4 times greater than conventional photovoltaic panels. The developed rectifying antenna based solar devices used to capture solar energy with an initial target of twice the efficiency at 20% of the cost and 20% of the weight per watt of current single junction solar cells. NovaSolix is using multi-wall carbon nanotubes (CNTs) grown in arrays of tiny antennas that are suspended between Aluminum ground/contact lines.

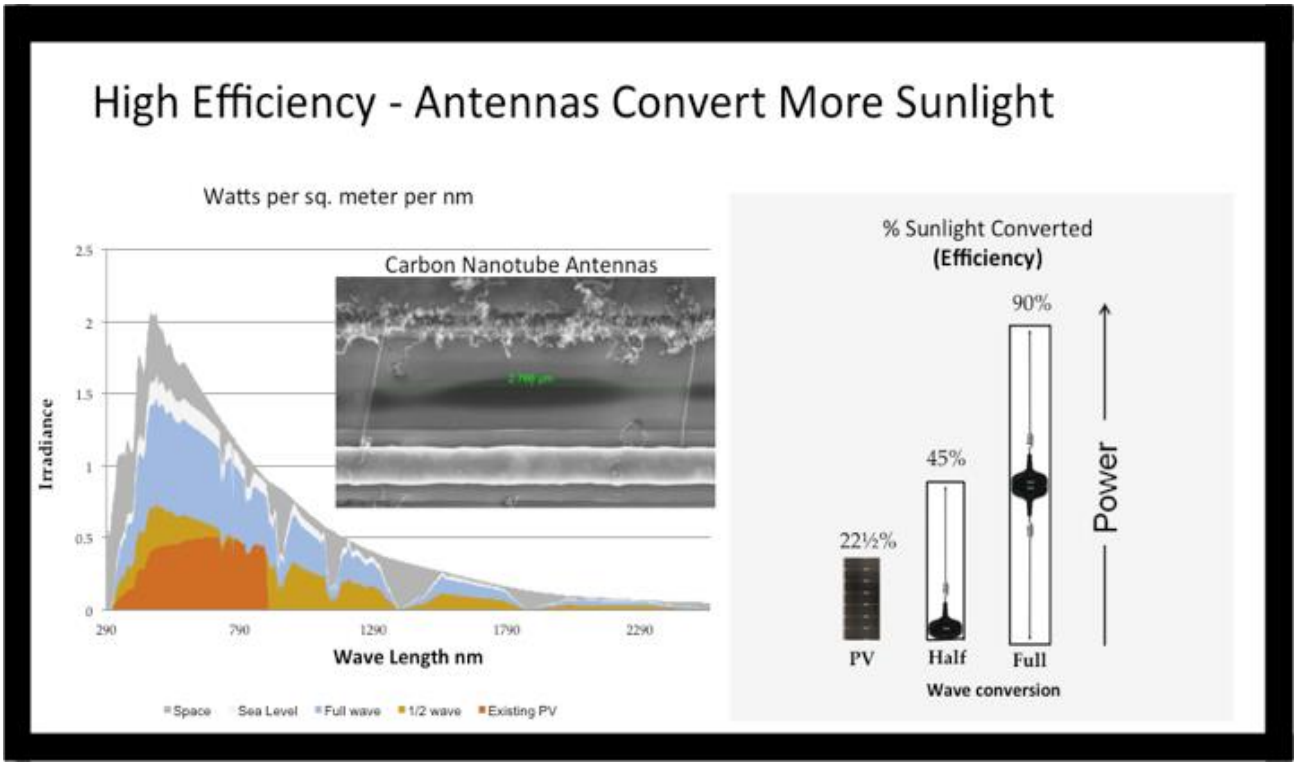

Figure 20. Carbon Nanotube Antennas

David Calley, founder of Planet Rider Motors LLC in Arizona, presented on *High Torque Motors for UAM*. He began by emphasizing that thrust efficiency in thrust per horsepower for rotors and propellers depended strongly on disc loading in pounds per square foot of propeller disc. He went on to detail the several sources of losses inside motors and how to minimize them. This allowed prediction of the extremes of how future ideal motors could perform and enable improved range and speed in electric aircraft.

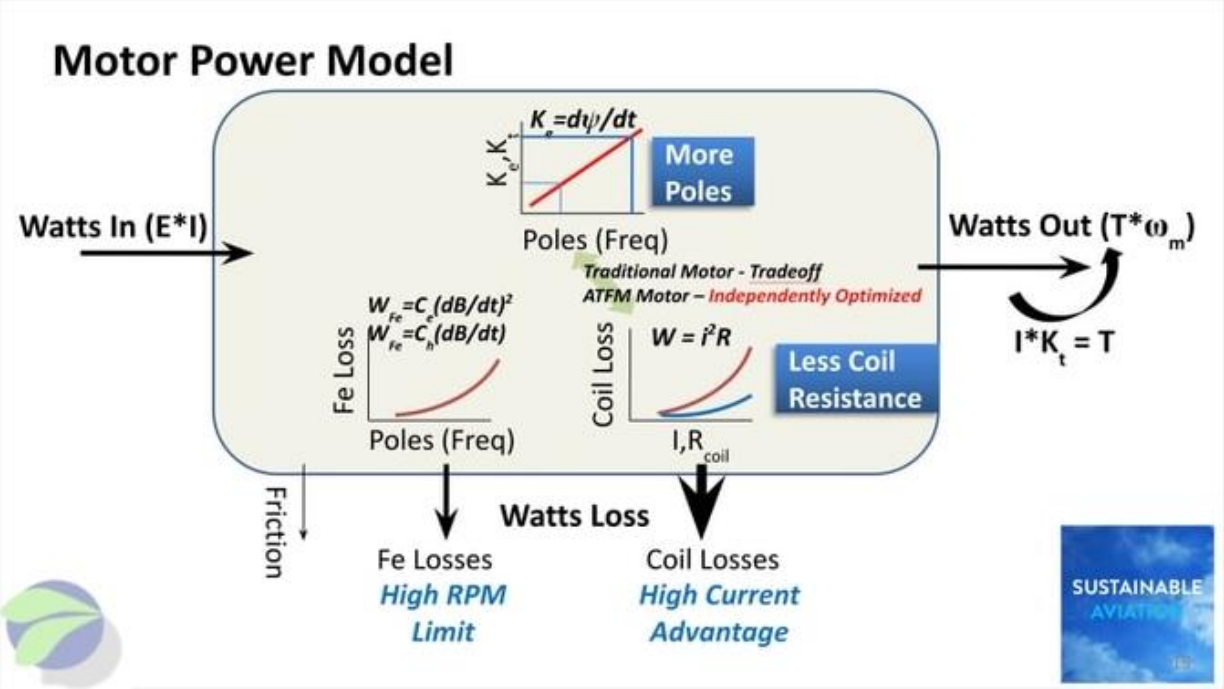

Figure 21. Motor Power Model

Terence Smith of SLM Solutions presented his company's breakthrough in 3D printing using metal powder to make high strength parts with ideally loaded internal skeletons. He pointed out its importance in rapid prototyping and testing, minimizing part counts and part weights in cases of low production volume, protection in-house of intellectual property, reducing lead times and material waste as well as shortening supply lines. Several impressive examples of these metal parts were on exhibit in Pauley Ballroom during the symposium.

Figure 22. Metal-based 3D Printing of Direct Part Manufacturing by SLM Solutions

Dr. Brien Seeley, President of the Sustainable Aviation Foundation, presented on the topic of *Selection Pressures for Urban Air Mobility*. He began with an explanation of why "Cars are bad", citing the facts that:

- They're poisoning the ocean
- They're wrecking the climate
- They're the leading cause of death for young humans
- They take up most public space in our cities
- They drive up the cost of housing
- They're the leading cause of hazardous air quality in most cities
- We subsidize them at levels approaching trillions
- Their fuel is a primary cause of global conflict
- It is legal for drivers to kill pedestrians and cyclists if they stay with the corpse and tell police they couldn't see them.

His message was that there are some identifiable metrics that are the most influential drivers of success in the adoption of UAM. These are mainly human factors relating to human physiology and tolerances for ride quality, jerk rate, comfort, personal space, field of view, range (as in bladder capacity) and cabin noise. There are also drivers of economic success and these include the vehicle cost, ground travel time (GTT), turnaround time (TAT) and noise emissions.

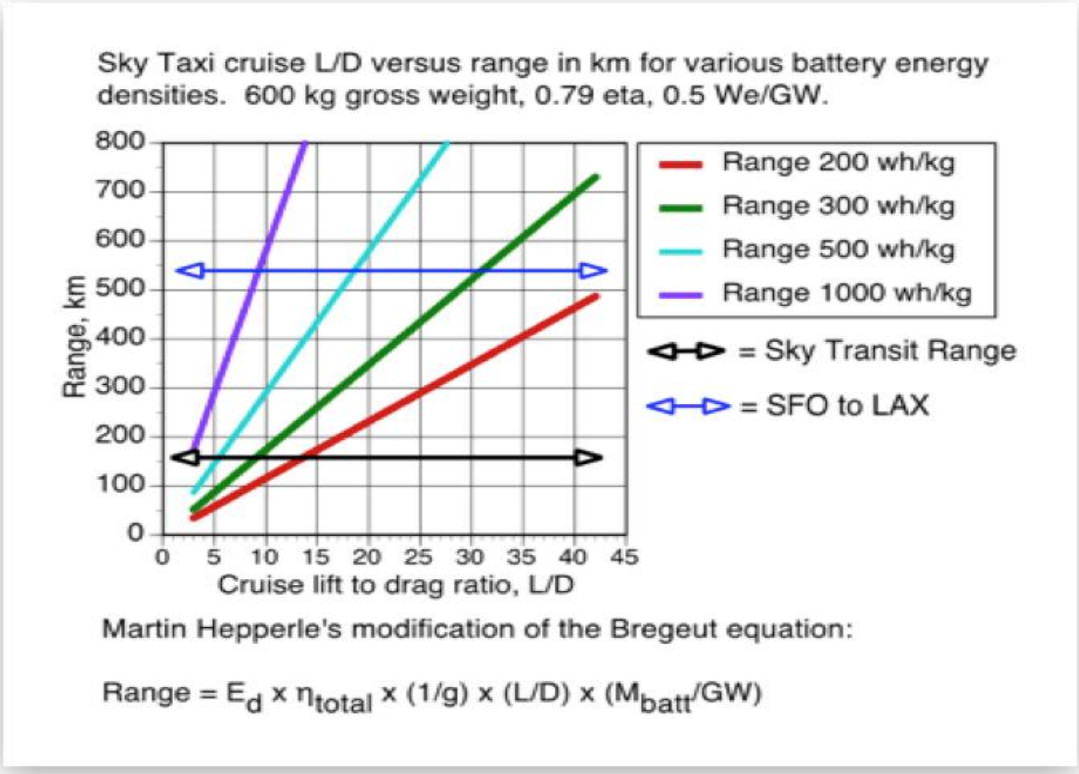

Figure 23. Range vs Cruise L/D

Dr. Raja Sengupta, Professor in the Systems Engineering Program, Civil & Environmental Engineering at UC Berkeley, presented on the topic of *Can Urban Air Mobility Serve Urban Mobility?* His presentation examined the mobility statistics of the San Francisco Bay Area and how they could be improved by UAM. He discussed the challenges of capacity, air traffic crowding, the demand for public funding for UAM infrastructure, the crucial importance of achieving mass transit levels of ridership and system safety. Then, he detailed the advantages of using UAM as the means to travel between UC Berkeley and NASA Ames campuses. His statistics show the kind of population and transportation statistics that are needed for a complete study of UAM's potential benefits.

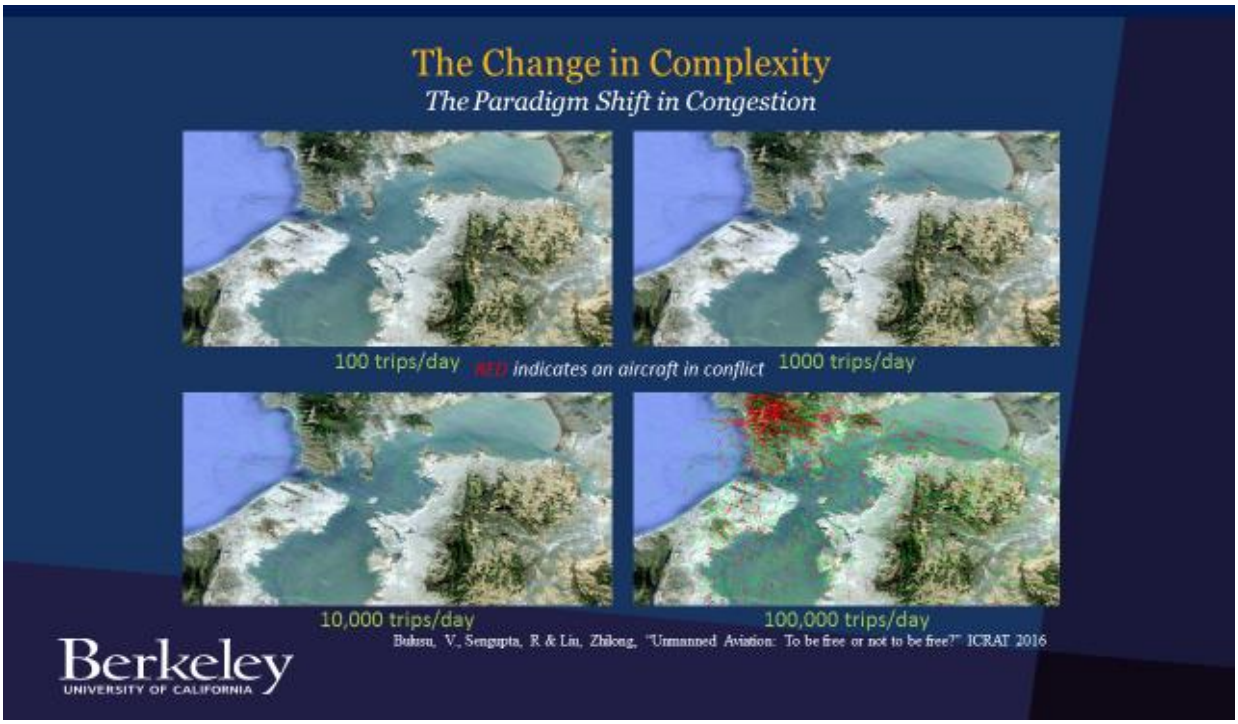

Figure 24. Simulation of Four Bay Area Scenarios

Dr. Parimal Kopardekar, Director of the NASA Aeronautics Research Institute (NARI), presented on the topic of *Urban Air Mobility Regional Readiness*. He emphasized the needs for future airspace to integrate UAM into the unmanned traffic management system (UTM) by:

- Finding new ways to accommodate new entrants – drones and urban air mobility,
- Enabling scalability – however that needs to be interoperable as well; we can't segregate airspace for every new entrant,
- Integration where possible and segregation where necessary (e.g., commercial space launches),
- Flexibility where possible and structure where necessary to ensure safety and high capacity (e.g., bike lanes vs cars)

He reported that NASA is working on developing tools to help regional, state and federal agencies implement UAM and he urged that UAM manufacturing adopt and employ current automobile manufacturing technologies that enable mass production.

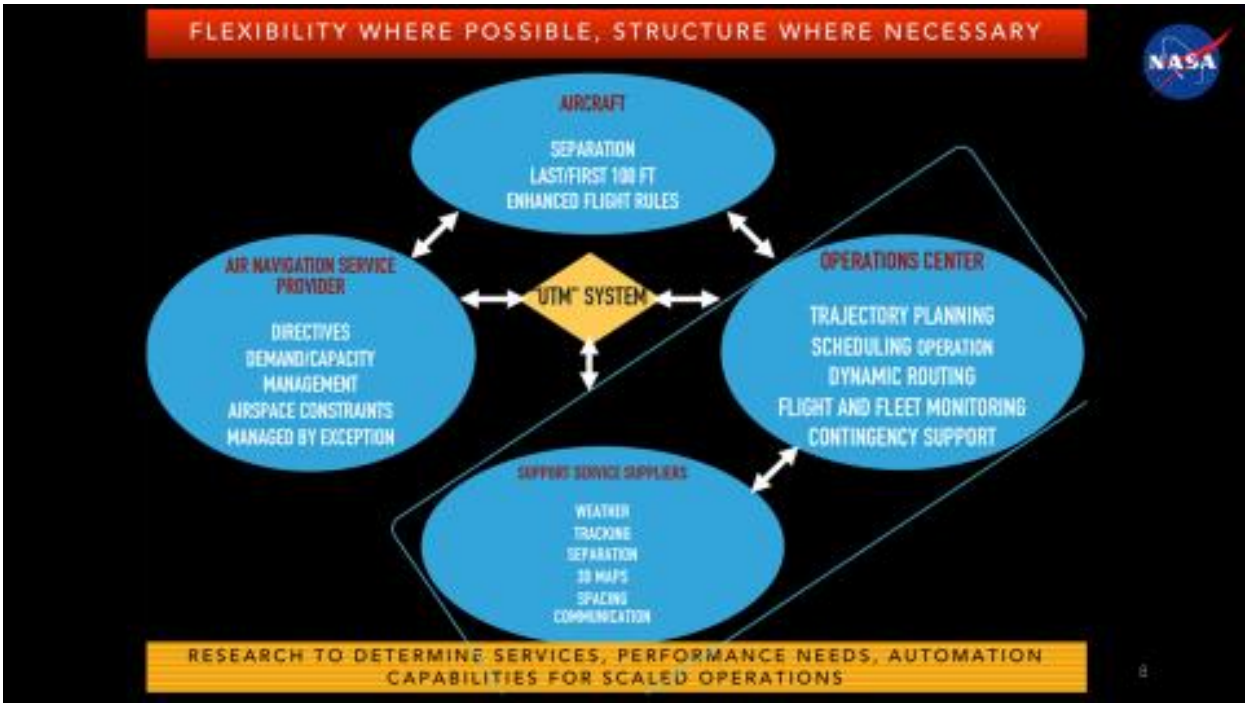

Figure 25. Determining Services, Performance Needs and Automation Capabilities

Dr. Mark Mueller, Assistant Professor of Mechanical Engineering, UC Berkeley, presented on the topic *Long Range Flight from Small Electric VTOL Aircraft*. He discussed the promise of urban air mobility that exploits electric powertrains for clean, low noise, operation in dense environments. However, he pointed out that electric power suffers from comparatively poor specific energy (that is, the amount of energy stored per unit mass). In this talk he explained some of the fundamental tradeoffs that face UAM solutions that build on electric powertrains, coupled with the requirement of being hover-capable so that they may maneuver in tight urban environments. He emphasized the importance of low disc loading to improving range. He described an innovation by which range could be enhanced by autonomous battery swapping performed during flight. Another innovation used a flywheel effect to enhance ride quality in turbulence. Two recent research results were presented in this context, one allowing for online optimization of flight characteristics, and the second exploiting modular vehicles which promise almost unlimited flight range.

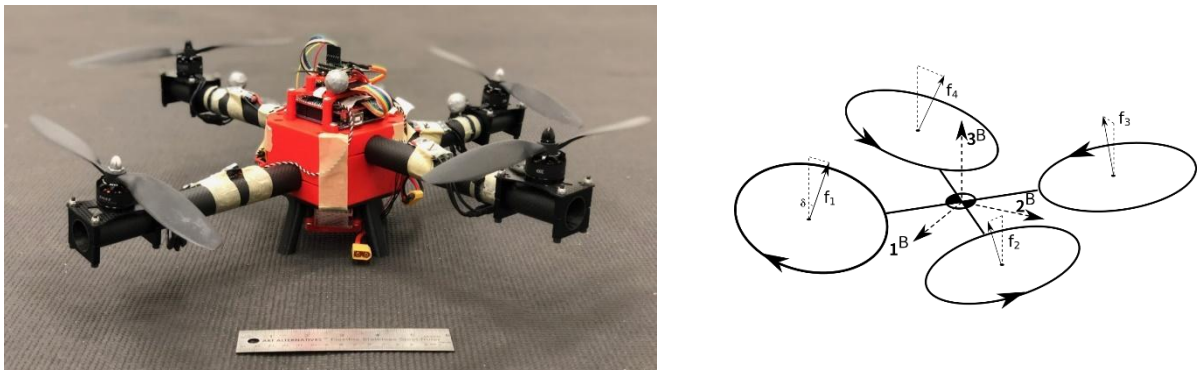

Figure 26. Tilting Multicopter rotors for Increased Power Efficiency and Yaw Authority

An expert panel *UAM in the Sky*, moderated by Prof. Ella Atkins, included the following panel members: Dr. Parimal Kopardekar, Prof. Raja Sengupta and Prof. Mark Mueller. The panel discussed how to best integrate mass-scale autonomous UAM into the national airspace, including the issues of safety, sentient vehicle sovereignty, mixing traffic, and the user experience.

The first question posed to the panel by Dr. Atkins was a hypothetical one framed as follows: if 5 years into the future, an autonomous air vehicle were available to use for a flight from Berkeley to Mountain View, would any of the panelists consent to fly in such a driverless aircraft. Dr. Sengupta replied that yes, he would make such a trip. Dr. Atkins replied that in her informal surveys on this question over the last few years, that no more than 20% of those asked would consent to make such a flight. Dr. Mueller stated that his consent would hinge upon whether the company producing the aircraft was a small start-up or a large corporation such as Airbus. Dr. Kopardekar replied that he would consent to fly if the vehicle had passed reputable certification with safety supported by data. He went on to state that such certification standards are being developed but are not yet in place. Dr. Atkins pointed out that the present certifications consisted of waivers and self-certification, which she expects to continue for the next 5 years. Dr. Sengupta pointed out that the only way to know if an AI system of machine learning actually works is to test it for something like a million miles to obtain actual data, instead of relying on theorem proofs. A developer will ultimately have to have such data before it can reasonably take the responsibility of placing humans in such vehicles. Dr. Kopardekar pointed out that such data can be obtained in a non-urban setting with flights over unpopulated areas and with cargo before people as payloads. The option of using Optionally Piloted Aircraft (OPA) to obtain such data was questioned due to studies that have shown that such human-in-the-loop systems were problematic and created unpredictable scenarios.

Dr. Seeley asked the panel for their views regarding where on a spectrum from full on-board vehicle autonomy (“free-flight”) to centralized ground-based authority that assigns air traffic trajectories would urban air mobility systems be most likely to operate. “Flexibility where possible and structure where necessary” was the working strategy at NASA in order to balance safety with efficiency, according to Dr. Kopardekar, who stated that sometimes the user space has to be segregated for safety, as with bicycle lanes and car lanes. “Research is on-going regarding separations minima” and how to share the airspace, he said. This has led to NASA adopting the concept of staged maturity levels for autonomous UAM operations whereby the operations can be authorized to function at the maturity level that has demonstrated a satisfactory level of safety. Dr. Mueller commented that having to file for permission to make each trip would strain user anonymity and require consideration of privacy issues before being an acceptable system. Dr. Sengupta stated that, based on his experience with travel behavior studies, requiring FAA approval of a flight plan prior to each UAM flight was an unworkable and untenable use model. Dr. Ullmer asked that the audience show of hands regarding who would fly in an autonomous driverless small aircraft be recast for only those who are licensed pilots and the result was that 30-50% of pilots in the audience affirmed that they would fly in such an

aircraft in the next 5 years. Among non-pilots attending the symposium, the response was nearly 60% affirming that they would fly in a driverless aircraft in the next 5 years. However, Dr. Atkins pointed out that this audience represented a self-selected cohort. Dr. Ullmer then asked if the electric aircraft movement needs to expand to other areas that are beyond urban air mobility in order to reach a sustainable outcome. Dr. Sengupta answered that success would mainly depend upon funding support. Dr. Kopardekar replied that NASA is focusing on other areas besides UAM including lowering emissions from all aircraft, reducing contrails, developing longer range electric aircraft, efficient air traffic routings, etc. Dr. Mueller responded that faculty researchers inherently tend to focus on solving the difficult problems at the cutting edge of a new technology while entrepreneurs aim at the opposite, i.e., immediate and practical solutions. Dr. Atkins pointed out the market for UAM must face the disparities in location whereby her home state of Michigan had weather conditions that, unlike California and Arizona, were not amenable to solar energy capture and year-round flying. Dr. Winfried Wilcke of IBM Labs stated that to be sustainable, UAM should not have a central control structure but should instead rely upon on-board sentient see and avoid technologies and local rules. Dr. Kopardekar replied that NASA was similarly aligned and was modeling air traffic as management of exceptions with vehicle to vehicle cooperation. Dr. Sengupta stated that car traffic relies upon separate assigned lanes, signal lights and rules while preserving a see and avoid responsibility for every vehicle. Dr. Atkins then rephrased this discussion as a question of “How do you go from voice to data-link? which will be absolutely essential to achieving the necessary bandwidth.”

Next, an attendee asked to what extent aerial agility will be a requirement for the vehicles in the UAM space. Dr. Kopardekar replied that passenger comfort would have to mitigate the degree to which such agility could be utilized. Dr. Mueller pointed out that aerial agility, even though not routinely used, would be valuable because it could add to safety by providing a capability to avoid a collision that was not otherwise avoidable.

Byron Thurber, an ARUP architect, presented in collaboration with Pickard Chilton, detailed studies based on a high capacity vertiport designed for the Uber Elevate vision of sky transit, titled *A Practical and Sustainable Transit Hub for Urban Air Mobility – the Uber Elevate Skyport*. The 2019 Uber Elevate theme was to design a vertiport system that would serve a smaller facility, intended for actual implementation within 3-4 years. The design concept presented at the symposium would be a retrofit of an existing parking garage located at the edge of the downtown core. Using sustainable building materials, the design provides spaces for landing and take-off of eVTOLs, and the associated passenger facilities, and also functions as a true transit hub, providing accommodation for a network of other modes, including e-bikes, e-scooters, electric cars, and Uber rideshares.

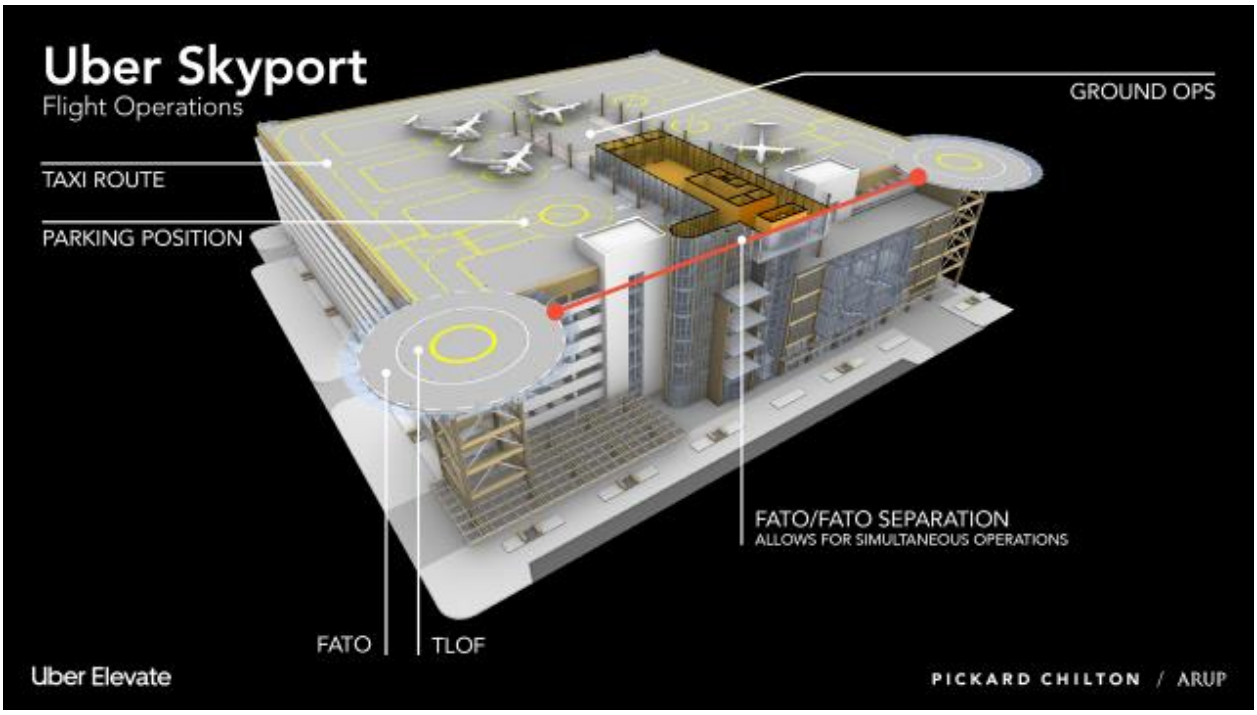

Figure 27. Skyport Design by ARUP and Pickard Chilton

Dan Chatman, Associate Professor in the Department of City and Regional Planning at UC Berkeley, led the connection of UAM to city planning. His topic was *Air Mobility in the Context of Travel Patterns and Urban Planning*. In his presentation he discussed if UAM has the potential to make additional housing opportunities available and to cause us to fail to address the housing supply issues that we have by providing an outlet so that we don't have to solve housing affordability issues and, in that sense, UAM might be a problem. UAM has the potential to enable densification in central city areas, while not increasing road traffic very much because it offers an additional outlet for travel to and from core areas that have demand. In addition, UAM has the potential to improve accessibility opportunities to disadvantaged residents. He stated the most important pros and cons of UAM from the social welfare perspective (Figure 28), and indicated the following main points: (1) the up-front and less-obvious user costs of passenger UAM are relatively high, (2) household travel patterns and spatial distribution suggest UAM may have a smaller initial market niche than expected, (3) UAM has natural monopoly characteristics requiring a regulatory apparatus that does not yet exist, and (4) the social value of UAM depends on solving this problem as well as managing road space differently for road vehicles.

Figure 28. UAM Pros and Cons from a Social Welfare Perspective

Darrel Swanson, Director of the Swanson Aviation Consultancy, presented on the topic of *Vertiports: Multimodal Transport Hubs Where the 3rd Dimension is Accessed* on the second day of the symposium. He explored the impacts that UAM might have to ground operations and future community transport. He reiterated that the UAM will succeed in areas where the noise control is achieved, high capacity vertiports can operate, and certification obstacles are solved. Mr. Swanson pointed out to the following challenges:

- Safeguarding of vertiports – challenging built environments,
- Wind & wake turbulence – some cities may not be suitable for UAM,
- Wildlife hazard management, aka birds, deer,
- Buildings withstanding the weight of a vertiport,
- Grid power capacity,
- Managing expectations and relationships with utility providers,
- Fire protection,
- Swappable batteries vs recharging & hybrid (carbons vs hydrogen or flow battery),
- Passengers with reduced mobility – steps, boarding; parking lot location.

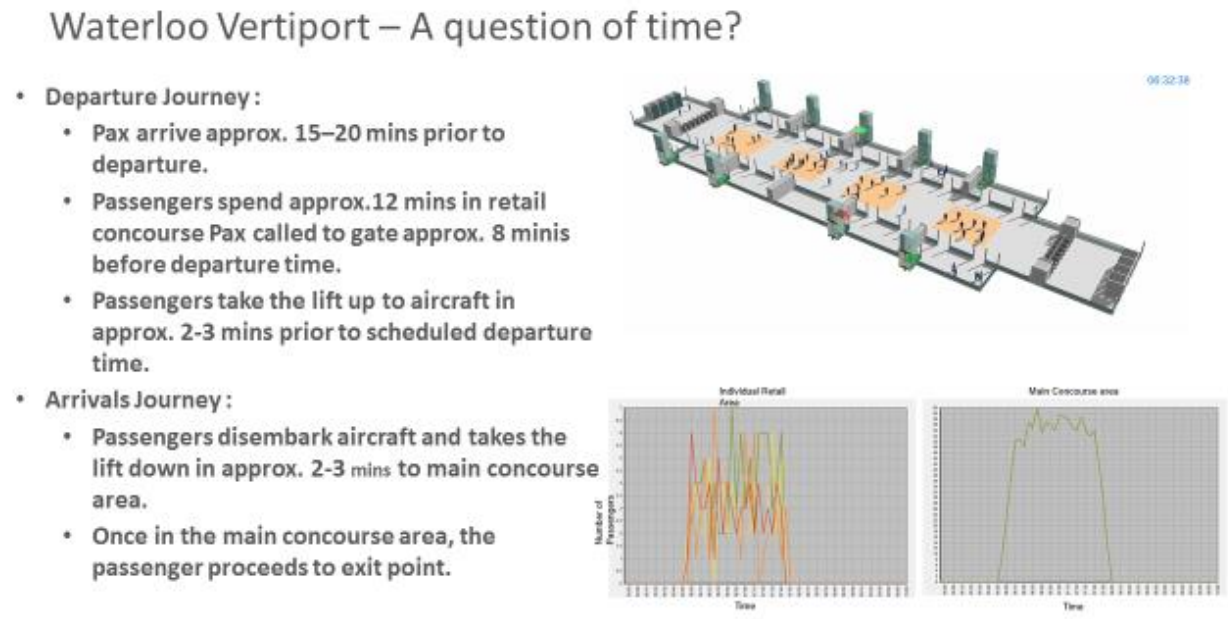

Figure 29. Simulation of Passenger Arrivals and Departures at Waterloo Vertiport

An expert panel *UAM on the Ground*, moderated by Dr. Brien Seeley, included the following panel members: Darrel Swanson, Dr. Anita Sengupta, Emilien Marchand, Strategic Engagement Manager at Airbus, Prof. Dan Chatman and Byron Thurber. First they discussed UAM landing sites and agreed that UAM landing sites could be sited on piers or aircraft carriers placed along coastlines bordering major metropolitan areas. Mr. Thurber stated that flying over water was a good idea, and Mr. Marchand indicated that regulations would be the biggest obstacle. He added that until we have policies that are put in place over the next 5 years, UAM is still going to be at the same place that it is today. Then Dr. Anita Sengupta initiated a topic on seaplane bases but discounted chances of amphibious aircraft. Prof. Chatman added that ferry services have had problems because they drop people off in inconvenient places distant from destinations. Mr. Thurber then commented that Uber looked at sports stadiums and amusement parks as UAM destinations, but Prof. Chatman saw these as peak flow problems that do not deserve large infrastructure expenditures.

The next discussion was about whether we'll see sky taxis going suburb to suburb or suburb to wildlands. Mr. Swanson asserted that "the cost advantages of electric propulsion systems are going to completely disrupt the current aviation market and allow more point to point journeys where the actual airport or vertiport or airport or infrastructure point that you're entering or leaving the system is closer to your origin and closer to your destination so we'll see traffic distributing away from the hub-and-spoke system and possibly from other modes of transport and actually using flights." So he thinks electric aviation is going to change the 'why' we use aviation as a mode of transport—not just 'where' but 'why' we're actually choosing to fly. He further added that the opportunities are fundamental so that we really could hopefully decarbonize sub-regional aviation. Mr. Thurber cautioned about sprawl and about inducing demand to travel to places that right now are hard to get to. He further indicated that it may be good that certain places are hard to get to so that they won't be overcrowding, taking extra time or effort to get there. On the flip side, it could make those destinations reachable for those who currently have no way to get there. Mr. Dean Sigler questioned Uber's business model regarding ownership of sky taxi vehicles and vertiports, citing that currently they do not own their rolling stock. He directly asked "how will Uber manage these future air vehicles?", and Mr. Thurber answered: "That remains to be seen. This question was asked at the Uber Elevate conference. Uber has been working with the vehicle manufacturing partners to set specifications. There may be 3 different manufacturers who meet those specs." Dr. Anita Sengupta mentioned that existing General Aviation (GA) airports can serve as part of the vertiport network, and Mr. Marchand added that the siting of MTBA at a GA airport could rejuvenate it and the surrounding community. When the panel was asked whether driverless sky taxis need any TSA security checks, Mr. Swanson answered that "they will if they have human pilots at first, but this is a question on which we are organizing workshops."

5. The Paul B. MacCready Honorary Lecture

The Paul B. MacCready Honorary Lecture was presented by Gabriel DeVault, Aerospace Engineer and EV Systems Architect, Head of Drivetrain Development, ZeroAvia.

His presentation, titled *Doing More with Less, Right Now!*, focused on what we can do 'right now' with existing technologies. As he pointed out, we don't need fully autonomous flying cars to realize the benefits that Electric Aviation will bring; and we don't need to wait further decades. He believes that we can have fun, safe, hi-performance Electric Aircraft right now, as evidenced by Gabriel's E-Gull and similar aircraft. He thinks that all that is really missing is the charging infrastructure, and the most "democratic" open network that can be provided is a simple NEMA 14-50 outlet. This can provide nearly 10kW of charging power to any form of charger that the user wishes to connect. This amount, 10 kW, should be enough to charge ultralights and Light Sport Aircraft (LSA) type aircraft in just a couple hours and should really spark and enable this new frontier.

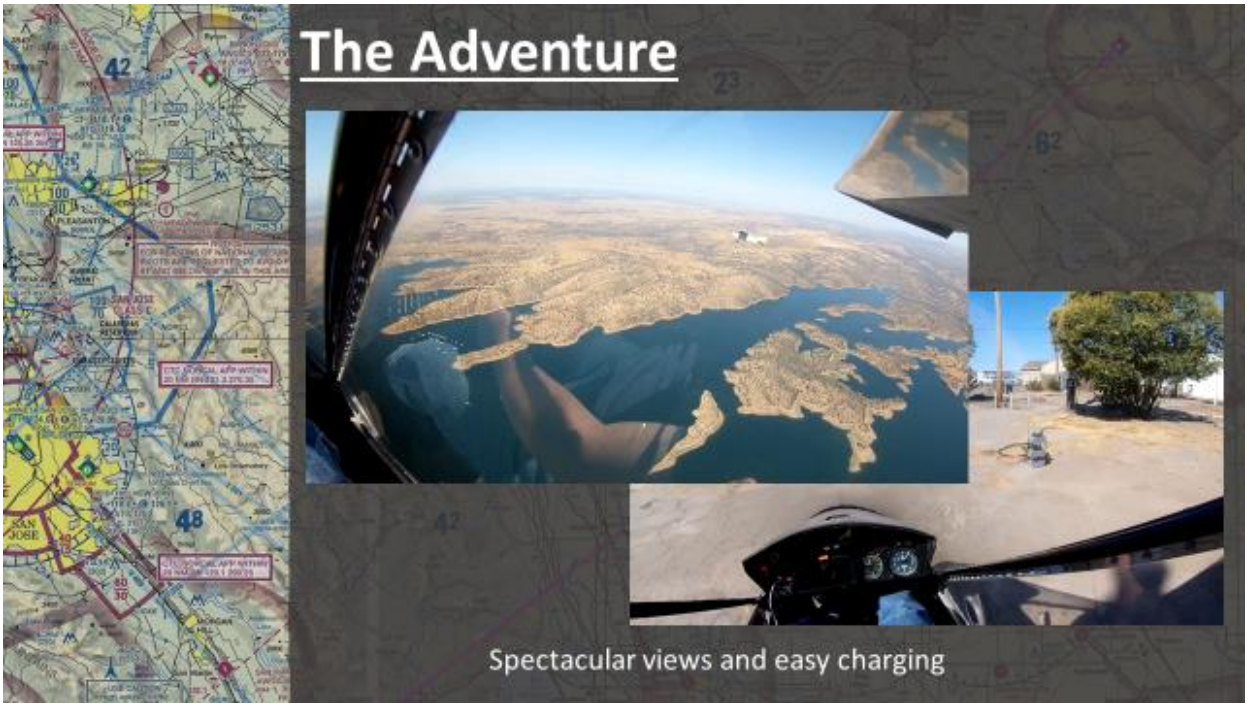

Figure 30. Flying from Watsonville to Pine Mountain Lake

6. The 2019 Personal Aircraft Design Academy (PADA) Trophy

The 2019 Personal Aircraft Design Academy (PADA) Trophy honored Dr. John Langford, the CEO of Aurora Flight Sciences. Tom Clancy, CTO, Aurora Flight Sciences, accepted the 2019 PADA Trophy on behalf of its honoree, John Langford. As a long-standing close associate of John's, Mr. Clancy presented an in-depth account of John Langford's long and great career in developing important and unique high tech aircraft that are crucial to today's urban air mobility movement.

Figure 31. On behalf of Dr. John Langford, Boeing/Aurora Flight Sciences CTO Tom Clancy accepts the Honorary Personal Aircraft Design Academy (PADA) Medal and the PADA Trophy with SAS Co-Chair Dr. Brien Seeley

7. Closing Remarks

The organizing team from the Sustainable Aviation Foundation, consisting of Dr. Seeley, Dr. Rakas, SAS Producer Damon Seeley and Wayne Cook closed SAS 2019 by thanking the audience and faculty and announcing that its success would help ensure further collaborations by the Sustainable Aviation Foundation and UC Berkeley's ITS. Damon Seeley pointed out that this 4th Annual Sustainable Aviation Symposium had evolved its curated content to a program with a far greater relevance to transportation from those in earlier Symposia that had been mainly about innovative electric-powered aircraft. Wayne Cook cited the very rapid growth of the urban air mobility movement from what this team initiated as a small gathering of aircraft enthusiasts in San Francisco, and the satisfaction and excitement of stewarding this movement from its early days to its bright future and broader horizons. Dr. Rakas pointed out that UC Berkeley, as a thriving multi-disciplinary community, is an ideal home for this symposium on urban air mobility and that its high level knowledge centers are working on all of the many different topics that are

important to UAM and our common good. She reminded the audience that Sustainable Aviation Foundation is working towards reducing any type of pollution in order to make our lives and communities better, a mission it shares with UC Berkeley. The Symposium is also serving to inspire students and create definable projects for their theses. Special thanks were given to volunteer videographer Tim Seeley, event publisher Amanda Cairo, registrar Anne Seeley, and numerous graduate students-volunteers. The team from Kevin Wright Productions produced a high-quality audio-visual production throughout the symposium.

8. Summary and Events Emerging after the 2019 Sustainable Aviation Symposium

After SAS 2019 concluded, the world of UAM developments continued with more new aircraft designs, progress in autonomous flight controls and in regulatory guidelines and approvals, with a growing awareness of the inevitability of UAM as a service.

The conference engaged for the first time the disciplines of urban and environmental planning, civil engineering and sustainable development by bringing together leading faculty members in each area. It explored the socio-enviro-economic prospects and UAM's potential for regional mass transit by air that could ease surface gridlock, untenable infrastructure costs and climate change. The growing awareness of the pan-topic relevance of UAM not only justified the continuation of SAS at UC Berkeley, it sparked a continued spread of initiatives in that domain.

SAS 2019 inspired a large number of UCB graduate and undergraduate students to pursue research and careers in the UAM domain as the symposium enabled students to network with participating companies and speakers. Students were very grateful to UCB COE Dean Liu to co-sponsor the symposium and wrote her thank-you notes. The following thank-you note by a student-attendee provides a great reflection of the symposium: "Coming in on the first day, I had no idea what to expect from a relatively specific field. Throughout this symposium I have learned so much about cross-engineering efforts, met many pioneers in green aviation, and gained optimism for the state of green/electric flight. I feel inspired to pursue some of the fields brought up here!" In addition, significant expansion of UAM research started to occur in The Aviation Futures Lab at UCB, which is affiliated with The Sustainable Aviation Foundation and with Dr. Rakas' research and her aviation courses CE153 (Airport Design) and CE257 (Sustainable Aviation and Infrastructure).

Shortly after SAS 2019, the United States Air Force launched its initiative known as Agility Prime, an effort to use their resources and the USAF Research Lab to accelerate the development of UAM vehicles. The number of emergent aircraft designs in the electric VTOL category

continued to blossom to over 300 types. The emergence of the COVID 19 pandemic and its devastating impact on air travel, sparked those in the UAM movement to begin planning for social distancing, disinfection and solo seating. First-flight announcements of new electric powered aircraft and sea-planes continued in the news, and a major Northern California radio station aired a 30 minute special feature program in which Dr. Seeley presented the concept and future benefits of urban air mobility to a large audience across Northern California.

9. Acknowledgements

The SAS 2019 is very grateful to the following individuals who contributed to its success:

- Tsu-Jae King Liu, Dean and Roy W. Carlson Professor of Engineering
- Alex Bayen, UCB ITS Director
- Daniel A. Rodríguez, ITS Associate Director and Chancellor's Professor of City and Regional Planning
- Laura Melendy, ITS Assistant Director, TechTransfer Director
- Amanda Cairo, UCB ITS Communications Director
- Theresa Ajari, CMP Coordinator, Business Development & External Relations
- ASUC Student Union | University of California, Berkeley
- Kevin Wright Productions
- Tim Seeley, Videographer
- Aleksandar Bauranov, Harvard University

Volunteers:

- Registrar: Anne E. Seeley
- UC Berkeley COE graduate students:
- Qilei Zhang, Patrick Savage, Dingy Dong, Raj Punyaamurthula, Suhas Bommenahally Umesh

10. Sustainable Aviation Foundation (SAF) and ITS Berkeley/UC Berkeley Host Organizing Committee

- Sustainable Aviation Foundation: Dr. Brien Seeley, Damon Seeley, Wayne Cook
- UCB CEE/ITS and SAF: Dr. Jasenka Rakas
- ITS Berkeley
    - Amanda Cairo, Communications Director
    - Laura Melendy, Assistant Director, ITS
    - Helen Bassham, Assistant to the ITS Director.

11. SAS 2019 Program

Day One, October 7, 2019

08:00 SAS 2019 WELCOME AND OPENING REMARKS
Dr. Tsu-Jae King Liu, Dean and Roy W. Carlson Professor of Engineering, UC Berkeley College of Engineering

08:05 OVERVIEW OF UC BERKELEY ITS
Dr. Daniel Rodríguez, Associate Director, Institute of Transportation Studies, UC Berkeley

08:10 ENABLING A SUSTAINABLE UAS/ODM/UAM/PAV INDUSTRY
Dennis Bushnell, NASA Langley Chief Scientist

08:40 IDEAL, THE ULTRA-STOL ELECTRIC AIRCRAFT
Dr. David Ullman, Aircraft Designer, Emeritus Professor of Design, Oregon State University

09:10 A HIGH EFFICIENCY LOW NOISE VTOL/ESTOL CONCEPT USING COFLOW JET
Dr. Gecheng Zha, Director of the Aerodynamic and CFD Lab, University of Miami (UM)

09:40 HOW THE DRIVE & FLY WILL IMPACT THE FUTURE OF GENZ
Guy Kaplinsky, Chairman and Cofounder of NFT

10:40 JAUNT'S ROSA: A SAFE, ULTRA-QUIET EVTOL UAM SOLUTION
Martin Peryea, Chief Technology Officer Jaunt Air Mobility, LLC

11:10 CARGO UAV: ADVANCING FLIGHT AND OPERATIONS EFFICIENCIES
Oliver Garrow, CTO and co-founder of Sabrewing Aircraft Co

11:40 URBAN AIR MOBILITY REVOLUTION WITH ASX
Dr. Anita Sengupta, Co-Founder and Chief Product Officer, Airspace Experience Technologies

13:00 THE FIRST PRACTICAL ZERO-EMISSION AVIATION POWERTRAIN
Valery Miftakhov, Founder & CEO of ZeroAvia

13:30 2019 HIGHLIGHTS OF ELECTRIC AIRCRAFT BREAKTHROUGHS
Dean Sigler, Editor-in-Chief, SustainableSkies.org

14:00 PLANNING SUSTAINABLE COMMUNITIES FOR CALIFORNIA'S FUTURE
Susan Dell'Osso, President, River Islands Development, LLC

14:30 DISTRIBUTED AVIATION - A FUTURE HISTORY OF HOW ELECTRIC AIRCRAFT AND VERTIPORTS GOT US THERE
Darrell Swanson, Director, Swanson Aviation Consultancy Ltd.

15:25 DATA TO DECISIONS FOR SAFE FLIGHT
Dr. Ella Atkins, Professor, University of Michigan

15:55 AIR PIERS FOR UAM
Dr. Jasenka Rakas, Deputy Director, UC Berkeley NEXTOR II

16:25 THE ECOLOGY OF SUSTAINABLE CIVIL INFRASTRUCTURE
Dr. Arpad Horvath, Peirano Professor of Civil and Environmental Engineering, UC Berkeley

16:55 LEGAL CONSIDERATIONS FOR MASS-TRANSIT UAM
Jordan Jaffe, Partner, Quinn Emanuel San Francisco

17:25 END OF DAY ONE

Day Two, October 8, 2019

08:00 OPENING REMARKS - RESEARCH NEEDS SESSION
Dr. Karl van Bibber, Professor and Department Co-Chair, UC Berkeley Department of Nuclear Engineering

08:05 IBM'S NEXT-GEN BATTERY BREAKTHROUGH
Dr. Jangwoo Kim, Researcher, IBM Almaden Lab

08:35 NASA AQUIFER: IMPLICATIONS FOR OVERALL ENERGY ECONOMY, AND NASA EVTOL DISCOVERIES
Jason Lechniak, NASA Armstrong AQUIFER project CO-PI

09:05 NASA AQUIFER: NANO ELECTROFUEL (NEF) AQUEOUS FLOW BATTERY AND RIM-DRIVEN MOTOR (RDM)
Robert McSwain, NASA Langley AQUIFER project CO-PI

09:35 ENERGY STORAGE AND CONVERSION FOR URBAN AIR MOBILITY – CHALLENGES AND OPPORTUNITIES

Ajay Misra, Deputy Director of Research and Engineering at NASA's John H. Glenn Research Center

10:30 RECTENNA ARRAYS, A REVOLUTIONARY NEW SOLAR CELL TECHNOLOGY FOR MOBILE APPLICATIONS
Larry Cooke, CTO, Chairman, Novasolix

11:00 HIGH TORQUE MOTORS FOR UAM
David Calley, Founder, CEO, CTO, Planet Rider

11:30 HIGH-STRENGTH METAL AIRFRAME PARTS FROM SELECTIVE LASER MELTING POWDER BED ADDITIVE
Terence Smith, Western Regional Manager at SLM Solutions NA

13:00 SELECTION PRESSURES FOR THE IDEAL SKY TAXI
Dr. Brien A. Seeley M.D., President, Sustainable Aviation Foundation

13:30 CAN URBAN AIR MOBILITY SERVE URBAN MOBILITY?
Dr. Raja Sengupta, Professor, UC Berkeley, Systems Engineering

13:50 URBAN AIR MOBILITY REGIONAL READINESS
Parimal Kopardekar, Director, NASA Aeronautics Research Institute

14:10 LONG RANGE FLIGHT FROM SMALL ELECTRIC VTOL AIRCRAFT
Dr. Mark Mueller, Assistant professor of Mechanical Engineering, UC Berkeley

14:30 PANEL - UAM IN THE SKY
Moderated by Dr. Atkins, inc. Dr. R. Sengupta, Dr. Kopardekar, Dr. Mueller

15:10 A PRACTICAL AND SUSTAINABLE TRANSIT HUB FOR URBAN AIR MOBILITY – THE UBER ELEVATE SKYPORT
Byron Thurber, Associate, Arup Aviation Planning Group

15:30 URBAN AIR MOBILITY IN THE CONTEXT OF TRAVEL PATTERNS AND CITY PLANNING
Dr. Dan Chatman, Professor, UC Berkeley, Dept of City and Regional Planning

15:50 VERTIPORTS: MULTIMODAL TRANSPORT HUBS WHERE THE 3RD DIMENSION IS ACCESSED
Darrell Swanson, Director, Swanson Aviation Consultancy Ltd.

16:10 PANEL - UAM ON THE GROUND

Moderated by Dr. Seeley, inc Dr. A. Sengupta, Dr. Chatman, Mr. Thurber, Mr. Marchand & Mr. Swanson

16:30 DOING MORE WITH LESS, RIGHT NOW!
Gabriel DeVault, Aerospace Engineer and EV Systems Architect

17:10 THE 2019 PERSONAL AIRCRAFT DESIGN ACADEMY (PADA) TROPHY HONORING JOHN LANGFORD
Tom Clancy, CTO, Aurora Flight Sciences

17:50 CLOSING REMARKS
Sustainable Aviation Foundation Organizers