Current Technological Trends in Sustainable Aviation

Brett Oakleaf
Scott Cary P.E. LEED AP
November 2021
NREL at-a-Glance

**Workforce, including**
- 219 postdoctoral researchers
- 60 graduate students
- 81 undergraduate students

**World-class**
facilities, renowned technology experts

**Partnerships**
with industry, academia, and government

**Campus**
operates as a living laboratory

2,926
More than 900
NREL Science Drives Innovation

Renewable Power
- Solar
- Wind
- Water
- Geothermal

Sustainable Transportation
- Bioenergy
- Vehicle Technologies
- Hydrogen

Energy Efficiency
- Buildings
- Advanced Manufacturing
- Government Energy Management

Energy Systems Integration
- Grid Integration
- Hybrid Systems
- Security and Resilience
We Reduce Risk in Bringing Innovations to Market

• NREL helps bridge the gap from basic science to commercial application

• Forward-thinking innovation yields disruptive and impactful results to benefit the entire U.S. economy

• Accelerated time to market delivers advantages to American businesses and consumers
Answering crucial questions about:

**Technologies**
What electric technologies are available now, and how might they advance?

**Consumption**
How might electrification impact electricity demand and use patterns?

**System Change**
How would the electricity system need to transform to meet changes in demand?

**Flexibility**
What role might demand-side flexibility play to support reliable operations?

**Impacts**
What are the potential costs, benefits, and impacts of widespread electrification?
Four Elements of Sustainable Mobility

- Movement of people
- Powering mobility
- Movement of goods
- Transformative technologies
Moving people

Advanced Materials
Energy Storage & Power Management
Power electronics
Charging/Load Management
Connectivity
Moving goods

Advanced Combustion

Hydrogen

Hybridization & Electrification

Biofuels

Energy storage

NREL/Benjamin Ihas
Powering mobility

Renewables
Grid Integration / Energy Supply
Buildings integration
Cybersecurity
Extreme fast charging
Transformative technologies

- Automation
- PHIL - Testing
- Wireless charging
- Big data/analytics
- Deep learning
Transportation Megatrends

Seven key megatrends are poised to transform our transportation system.

These trends have begun to affect our mobility behaviors, and impact how we, and the goods we need, will travel sustainably in the coming decades.

1. Rapid technology change
2. Customer demand
3. Live, work, and study anywhere
4. Environmental sustainability and energy security
5. International trade
6. Our growing and aging population
7. The need for healthier lifestyles
Implications for Research Needs

- **Rapid changes in vehicle technologies** – electrification (batteries and fuel cells), connectivity, automation

- **Global drive for increased transportation efficiency** – reducing emissions and decarbonizing transport across the light-, medium-, and heavy-duty vehicle, rail, aviation, and marine sectors

- **Maximizing future use of renewable electrons through time and sector shifting** – storing as $\text{H}_2$, liquid fuels, chemicals (long-term storage)

- **Realizing the system-wide benefits** of optimally integrating transportation with buildings, grid, renewables.
Scott Cary
GHG - Scope 1-2 Airport Pathways

- Efficiency
  - Landside
  - Building
  - Airside
- Ground Fleet Improvements
  - Green energy sources
- Clean energy/resiliency
- Grid Interactive Efficient Buildings (GEB)
- Energy Source/Storage Diversity
But what about Scope 3 emissions?

• 9% of global emissions from aviation

• Airport Controlled Emissions
  – 9-20% of total emissions

• To meet industry goals, Scope 3 (aircraft, passenger, and tenant emissions) are the next step.
## Aviation Low- and Zero-carbon energy sources

<table>
<thead>
<tr>
<th>Category</th>
<th>Size Range</th>
<th>Flight Duration</th>
<th>CO2 Reduction</th>
<th>Energy Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Commuter</strong></td>
<td>9-50 seats</td>
<td>&lt;60 min</td>
<td>&lt;1%</td>
<td>SAF, Electric and/or SAF</td>
</tr>
<tr>
<td></td>
<td>&lt;60-90 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Regional</strong></td>
<td>50-100 seats</td>
<td>30-90 min</td>
<td>~3%</td>
<td>SAF, Electric or Hydrogen fuel cell and/or SAF</td>
</tr>
<tr>
<td></td>
<td>60-120 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Short haul</strong></td>
<td>100-150 seats</td>
<td>45-120 min</td>
<td>~24%</td>
<td>SAF, Electric or Hydrogen fuel cell and/or SAF</td>
</tr>
<tr>
<td></td>
<td>60-150 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Medium haul</strong></td>
<td>100-150 seats</td>
<td>60-150 min</td>
<td>~43%</td>
<td>SAF, Electric or Hydrogen fuel cell and/or SAF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SAF, Potentially some Hydrogen</td>
</tr>
<tr>
<td><strong>Long haul</strong></td>
<td>250+ seats</td>
<td>150+ min</td>
<td>~30%</td>
<td>SAF, SAF, SAF, SAF</td>
</tr>
</tbody>
</table>

Source: ATAG Waypoint 2050 Report
Sustainable Aviation Fuel (SAF) Development

- Strong US focus
  - Drop-in replacement
  - Multiple pathways
    - Waste product
    - Biomass
    - E-fuels

More information from:
What about Electrified Aviation?

- Case Study – Essential Air Service – Denver
  - Four routes served by Pilatus PC-12

Figure 2. Case study area
Illustration by Emma Robertson, NREL
# Essential Air Service Subsidies

Table 2. Essential Air Service Subsidies (2019–2022)\(^a\) and 2020 Enplanements for Markets Served within 280 Miles of Denver International Airport

<table>
<thead>
<tr>
<th>Airport</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2020 Enplanements(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCK</td>
<td>$2,462,456</td>
<td>$2,511,705</td>
<td>$2,561,939</td>
<td>$2,613,178</td>
<td>1,269</td>
</tr>
<tr>
<td>CDR</td>
<td>$2,456.787</td>
<td>$2,518,208</td>
<td>$2,737,716</td>
<td>$2,808,159</td>
<td>2,462</td>
</tr>
<tr>
<td>ALS</td>
<td>$2,891,307</td>
<td>$2,949,133</td>
<td>$3,505,574</td>
<td>$3,505,574</td>
<td>4.742</td>
</tr>
<tr>
<td>CEZ</td>
<td>$3,579,703</td>
<td>$3,669,195</td>
<td>$3,760,925</td>
<td>$3,854,948</td>
<td>5,603</td>
</tr>
</tbody>
</table>


\(^b\) MCK = McCook Ben Nelson Regional Airport; CDR = Chadron Municipal Airport, ALS = San Luis Valley Regional Airport; CEZ = Cortez Municipal Airport

\(^c\) “Passenger Boarding (Enplanement) and All-Cargo Data for U.S. Airports,” FAA, last modified August 12, 2021, https://www.faa.gov/airports/planning_capacity/passenger_allcargo_stats/passenger/
Essential Air Service Subsidies

Initial finding – high subsidies in place where a new technology can reduce operating cost, emissions, and potentially noise. Infrastructure cost, energy demand models needs more analysis.

Table 3. Information for Select Flights from Denver (DEN) for Liquid-Fueled and Electric Aircraft

<table>
<thead>
<tr>
<th>Destination</th>
<th>Flights /day</th>
<th>Miles</th>
<th>Flight Time (mins)</th>
<th>Fuel Use (gals)</th>
<th>Fuel Costs$</th>
<th>kgCO₂ /PAX$</th>
<th>kWh (approx.)</th>
<th>Electricity Cost$</th>
<th>kgCO₂ /PAX</th>
<th>kgCO₂ /PAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALS</td>
<td>4</td>
<td>179</td>
<td>80</td>
<td>88</td>
<td>$440</td>
<td>36</td>
<td>334</td>
<td>$43</td>
<td>34</td>
<td>2</td>
</tr>
<tr>
<td>CEZ</td>
<td>3</td>
<td>277</td>
<td>80</td>
<td>88</td>
<td>$440</td>
<td>56</td>
<td>516</td>
<td>$66</td>
<td>53</td>
<td>3</td>
</tr>
<tr>
<td>MCK</td>
<td>2</td>
<td>217</td>
<td>65</td>
<td>72</td>
<td>$358</td>
<td>44</td>
<td>404</td>
<td>$52</td>
<td>41</td>
<td>2</td>
</tr>
<tr>
<td>CDR</td>
<td>2</td>
<td>222</td>
<td>70</td>
<td>77</td>
<td>$385</td>
<td>44</td>
<td>414</td>
<td>$53</td>
<td>42</td>
<td>2</td>
</tr>
</tbody>
</table>

$ Assuming a $5/gallon fuel cost

$ PAX = number of passengers carried by an airline, assuming eight passengers.

$ Based on commercial electricity costs for Cortez, Colorado; these values provide a conservative estimate of the electricity costs. Industrial electricity cost pricing could provide a 50% reduction in these costs.

$ d kg CO₂ calculated from the use of coal and utility scale solar to produce the needed amount of energy ("IPCC Working Group III – Mitigation of Climate Change, Annex II Metrics and Methodology" IPCC https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-ii.pdf#page=26).
Initial finding – high subsidies in place where a new technology can reduce operating cost, emissions, and potentially noise. Infrastructure cost, energy demand models needs more analysis.
Delivering Power to Electric Vehicles

**Distribution Substation**
Lowers voltage from transmission lines and protects downstream distribution system

**Distribution Feeders**
Distributes electricity to end users

**On-Site**
Lowers voltage to customer level (if secondary service) and distributes electricity throughout property

**High Voltage Bus**
Connects to transmission system

**Substation Transformer Bank**
Steps down high transmission voltage (≥ 110 kV AC) to medium voltage (4-35 kV AC)

**Feeder Breaker**
Provides overcurrent protection for distribution feeder circuit

**Feeder Conductors**
Transmits electricity either overhead or underground

**Meter**
Measures electricity usage

**Load Center**
Provides overcurrent protection and distributes power to EVSE

**Commercial Loads**

**Distribution Transformer**
Steps down medium voltage (4-35 kV AC) to customer level (480 V AC)

**Service Conductors**
Transmits power to EVSE via underground cabling

**On-Site Generation and Storage** (optional)

**EVs**
Electric vehicles

**EVSE**
Electric Vehicle Supply Equipment

Potential load impacts of 2019 flight schedule between DEN and ALS, CDR, CEZ, and MCK
Hydrogen

Primary Aviation Focus

U.S. DOE Hydrogen and Fuel Cell Technology Office
H2@Scale Vision
The Opportunity: Clustering Fuel Cell Applications To Drive H2 Demand At Airports

Long-Term Application Goals

Stationary Power

Large Aircraft

Transit Bus

FCEV LDV

Perimeter H2 Fueling Station (Public Access)

Delivery Van

Shuttle Bus

Federal Express (FedEx)

Cargo Tractor

Regional HD Truck

FC MHE

Baggage Tow Tractor

H2 Production and Distribution

H2@Airports Workshop November 4, 2020

Dr. Sunita Satyapal
Director, Hydrogen and Fuel Cell Technologies Office

U.S. DEPARTMENT OF ENERGY
Hydrogen

- Department of Energy announced Earth Shot – 2021

- Multiple OEM’s
  - Airbus/Universal Hydrogen/ZeroAvia/Cranfield Aerospace

- FAA – currently focusing upon SAF

- Growing interest and energy delivery models growing

- https://www.energy.gov/eere/fuelcells/hydrogen-shot
Potential Benefits of Electrolyzer Grid Integration

Reduce energy usage and emissions in end-use applications
- Petroleum displacement
- Chemical processes (metals refining, fertilizer production)
- Natural gas supplementation
- Combined heat and power with fuel cell systems

Improve grid performance, reliability, and resiliency
- Avoid curtailment of renewables
- Mitigate voltage/frequency disturbances

Managing Energy Demands with Electrolyzers
Who is working on solutions to assist industry?

- ICAO
- IATA
- FAA
  - Sustainable Aviation Fuel/Electrification /Hydrogen
- Department of Defense
  - AFWERX – Agility Prime
  - AFRL
- Department of Energy/NREL
  - Sustainable Aviation Fuel
  - Grid Modernization
  - Onsite energy solutions
  - Charging system fundamentals
  - Cybersecurity/Energy Resilience
  - Battery technologies
- NASA
  - Prototype aircraft
  - Regional Air Mobility –
    - Regional Energy Analysis – Pending
  - Grand Challenge
- State DOT/Cities

- System Integration
- Grid Planning and Services
- Analysis and Modeling
- Advanced Computing
Resources

A sampling of resources/activities:

- NASA RAM study [https://sacd.larc.nasa.gov/ram/](https://sacd.larc.nasa.gov/ram/)
- NREL
  - Extreme Fast Charging – Lessons underway in Class 8 trucking [https://www.nrel.gov/docs/fy20osti/75705.pdf](https://www.nrel.gov/docs/fy20osti/75705.pdf) – Partner with multiple OEM’s
  - FAA/NASA/DoD – recurring Aviation efforts – Batteries, SAF, H2, Electric, Power Electronics
  - State/Local – assisting early adopters accelerate adoption
  - OEM’s – Component, Infrastructure and Life Cycle Support
- DOE
  - Grid Modernization Initiative - [https://www.energy.gov/gmi/grid-modernization-initiative](https://www.energy.gov/gmi/grid-modernization-initiative)
  - H2 @ Airports - [https://www.energy.gov/eere/fuelcells/h2airports-workshop](https://www.energy.gov/eere/fuelcells/h2airports-workshop)
- CAMI - [https://www.communityairmobility.org/resources](https://www.communityairmobility.org/resources)
- Future efforts – ACRP, FAA, NREL, NASA, SAE, DOE, etc.
GHG Emissions Intensity

Grams CO$_2$-e per tonne-km for transport of goods by sea, land, and air

- **3.0** Very Large Container Vessel (18,000 teu)*
- **5.9** Oil Tanker (80,000 - 119,999 dwt)
- **7.9** Bulk Carrier (10,000 - 34,999 dwt)
- **80.0** Truck (> 40 Tonnes)
- **435.0** Air Freight (747, Capacity 113 Tonnes)

Source: IMO GHG Study, 2009 (*AP Moller-Maersk, 2014. Graph provided courtesy of the International Chamber of Shipping (ICS)
Initial charging implications

- Charging capabilities
  - Current High power charging – maxes at 350kW
  - Class 8 Truck – 1MW Charging Analysis underway
  - CHARin- Testing 3.75MW testing standard
  - Initial deployments possible
  - Scale and battery improvements are focus area
- No Standard currently exists in Aviation
  - eVTOL – focusing upon existing technologies with potentially cooling of cables, batteries, etc.
  - RAM – appears targeting 1MW level and higher to meet ops pace
Fuel cells may be promising for UAVs, UAM-air taxis, UAM-helicopters, and regional planes

H₂ fuel cells can provide competitive TCO in UAV, UAM-air taxis, UAM-helicopters, and regional planes

**UAVs**
- Longer lifetime and lower maintenance cost than ICE and battery-powered UAV
- Longer mission times than batteries, allowing for a smaller fleet and lower TCO

**UAMs**
- Air taxis: Fuel cells provide longer durability than batteries as the duty cycle has rapid charge and discharge rates
- Helicopters: Can replace aviation gasoline and piston engines on the basis of gravimetric energy density

**Small regional planes**
- Can replace aviation gasoline and piston engines on the basis of gravimetric energy density
- Fuel cells have lower specific power (W/kg) than turbine engines, but hydrogen can replace aviation gasoline
- Hydrogen has lower volumetric energy density than aviation gasoline

![TCO ($/PAX.mile) for battery powered UAM more expensive than FC versions](image)

![TCO ($/h) for FC regional plane less than that for piston engine plane](image)

Dr. Sunita Satyapal
Director, Hydrogen and Fuel Cell Technologies Office
H₂@Airports Workshop
November 4, 2020
Hydrogen and Fuel Cell Technology Growth Worldwide

Global fuel cell shipments surpass 1 GW

- **Transport** shows the largest growth, including buses, trucks, cars, rail, forklifts, etc.
- **Stationary** electrolyzers deployed in the last decade: <1 MW in 2010 to >25 MW by the end of 2019
- **Global FCEVs** doubled to >25,200, >12.3K sold in 2019 vs. 5.8K in 2018
- **470 H₂ fueling stations** worldwide, >20% increase from 2018

Source: E4tech for DOE analysis project

**Dr. Sunita Satyapal**
Director, Hydrogen and Fuel Cell Technologies Office
H2@Airports Workshop November 4, 2020

Significant challenges exist today for fully electrified aviation (especially long haul)

- **Sufficient battery size (energy capacity) for flights over >500 miles**
- **Energy storage need to “refuel” plane would be astronomical (TWhs of energy)**
- **Charging Infrastructure poses very high hurdles to deliver energy in 30-45 minutes for each plane**

➢ **Research ongoing in various segments of aviation market with SAF, electrified, and hydrogen solutions**
SAF - An “All of the Above” Approach Will Have To Be Used To Achieve 35 BGPY of SAF

ASTM Approved Pathways Address a Broad Range of Feedstock To Achieve Scale

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Pathway</th>
<th>Approved Name</th>
<th>Blending Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal solid waste, agricultural and forest wastes, energy crops</td>
<td>Fischer-Tropsch Synthetic Paraffinic Kerosene</td>
<td>FT-SPK, ASTM D7566 Annex A1, 2009</td>
<td>50%</td>
</tr>
<tr>
<td>Municipal solid waste, agricultural and forest wastes, energy crops</td>
<td>FT-SPK with Aromatics</td>
<td>FT-SPK/A, ASTM D7566 Annex A4, 2015</td>
<td>50%</td>
</tr>
<tr>
<td>Oil-based feedstocks (e.g., jatropha, algae, camellina, and yellow grease)</td>
<td>Hydroprocessed Esters and Fatty Acids</td>
<td>HEFA-SPK, ASTM D7566 Annex A2, 2011</td>
<td>50%</td>
</tr>
<tr>
<td>Algal oil</td>
<td>Hydrocarbon-Hydroprocessed Esters and Fatty Acids</td>
<td>HC-HEFA-SPK, ASTM D7566 Annex A7, 2020</td>
<td>10%</td>
</tr>
<tr>
<td>Fatty acids or fatty acid esters or lipids from fat oil greases</td>
<td>Catalytic Hydrothermolysis Synthesized Kerosene</td>
<td>CH-SK or CHJ, ASTM D7566 Annex A6, 2020</td>
<td>50%</td>
</tr>
<tr>
<td>Sugars</td>
<td>Hydroprocessed Fermented Sugars to Synthetic Isoparaffins</td>
<td>HFS-SIP, ASTM D7566 Annex A3, 2014</td>
<td>10%</td>
</tr>
<tr>
<td>Cellulosic biomass, waste gas, syngas</td>
<td>Alcohol-to-Jet Synthetic Paraffinic Kerosene</td>
<td>ATJ-SPK, ASTM D7566 Annex A5, 2016</td>
<td>30%</td>
</tr>
</tbody>
</table>
Ground Infrastructure for Complex UAS Operations: The Role of Network Alliances

November 30th, 2021
Trends driving advanced UAS operations

**Regulatory enablement**
- Enabling BVLOS regulation settling in place (Part 92 / Part 135)
- Part 107 rule mature. Focus shifting to Part 91, BVLOS NPRUM
- FCC/FAA spectrum policy maturing; shift from Part 15 to C-band, LTE, Satcom
- Industry standards slowly emerging (RTCA, ASTM)

**Technology**
- BVLOS-ready UAV’s proliferating – 10+ aircraft pursuing certification
- First generation of UTM network (Vantis) turned BVLOS operational in 2021
- Testing of LTE for use in commercial drone application is growing

**Customer demand**
- Line-of-sight growth continues unabated – building momentum for BVLOS
- Package delivery, industrial, public safety, and security accelerating
- Public UTM networks poised to open up new applications (ND, NY, OH)

Momentum building up for accelerating advanced operations in 2022 and beyond

End customers are increasingly embracing UAS

Timing is opportune to implement and validate UAS networks to enable BVLOS operations
Capabilities needed to commercialize advanced UAS operations

Conduct various UAS flight operations utilizing the UAS network and related services
Define the operational requirements (CONOPS)
Determine pricing for flight and technology services

Design and manufacture aircraft meeting customers’ operational needs
Integrate UAS network elements on the aircraft (C2 radios, surveillance sensors)
Secure aircraft type certification
Support UAS network operational authorization / certification

Federal regulators: FAA, FCC
Consultants/Experts: UAS test sites and industry players with capabilities to facilitate the projects
UAS value-added services: USS and related UTM services supporting UAS aviation

Supply the foundational telecommunications infrastructure and services to host the UAS network
Network operations, maintenance, and expansion
Supply data feeds to UAS operators and USS’s

Design, develop, and deploy the UAS network
Lead system certification with FAA and FCC
On-going technical support and maintenance
NextGen system development
Network operations partner

State and local governments: facilitate UAS network deployment and acceptance through policy, administrative, and regulatory actions; potential co-investors
Agencies: provision of drone-enabled public services
Goals for a UAS Network Alliance (UNA)

**Technology**: Identify, mature, and validate the stack of UAS technologies that can enable efficient and advanced commercial drone services

**Regulatory approvals**: Secure regulatory authorizations for launching commercial network operations

**Business model**: Demonstrate customer value creation and profitability of the core business models supporting advanced UAS operations

**Business Plan**: Develop a robust business plan for rolling out the UAS network and related supporting UTM services across the country

**Operating entity**: Define the long-term operational business model and structure partnerships to execute the business plan

**Market development**: Coordinate alliance activities in maturing public and private implementation opportunities

Enable drone commerce and public services across the country
### Crown Castle Wireless and Fiber Solutions

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Towers</strong></td>
<td>40,000 towers in 100 markets (49 states / 1 US territory) Additional access to 10,000 rooftop sites Wireless voice/data/broadband, TV, radio signals, hub for remote transmitters and monitors (IoT)</td>
</tr>
<tr>
<td><strong>Small cells</strong></td>
<td>80,000 small cells in indoor, outdoor, and mixed-used areas Coverage in 700 municipalities Extending core tower network coverage and adding density 24/7 monitoring by Network Operations Center</td>
</tr>
<tr>
<td><strong>Dark fiber</strong></td>
<td>80,000 route miles – one of the largest/densest networks 25 years of experience in building DF network solutions Customized networks – single and multi-site, from individual strands to complex multi-site designs</td>
</tr>
<tr>
<td><strong>Ethernet</strong></td>
<td>High-performance, efficient, and fully restorable networks Carrier Ethernet + metro-area transport solutions – MAPL (Metro-E Advanced Private Line), E-Line, EVPL (Ethernet Virtual Private Line), and E-LAN (Ethernet Private LAN)</td>
</tr>
<tr>
<td><strong>Wavelength</strong></td>
<td>Private, point-to-point wavelength service over DWDM network and Managed Private Optical Networks Data-intensive applications, data center backup and recovery, cloud services</td>
</tr>
<tr>
<td><strong>SD-WAN</strong></td>
<td>Turnkey managed SD-WAN providing highly secure, scalable, and reliable virtual network Leveraging 80,000 route miles of fiber, 900 connected data centers, PoP’s, and CO’s</td>
</tr>
<tr>
<td><strong>Internet access</strong></td>
<td>Enterprise-class fiber optic Internet access service – at CCI facilities, dedicated IA, and Burstable Internet Access Supports full range of applications: cloud connectivity, VPN, email, IM, social media traffic, VoIP and video, etc.</td>
</tr>
<tr>
<td><strong>Private network</strong></td>
<td>Turnkey, dedicated, private network with custom-designed dark fiber routes, DWDM equipment, and 24/7 NOC Managed Private Optical Network (MPON) supporting multiple technologies, protocols, and applications</td>
</tr>
</tbody>
</table>

PRORPRIETARY AND CONFIDENTIAL
### Crown Castle value-added solutions

<table>
<thead>
<tr>
<th>Cloud Connect</th>
<th>Fast, secure and direct connection between main offices, data centers, and colocation environments and the cloud. A range of bandwidth and interface options to access public, private, and hybrid clouds (AWS, MS Azure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical encryption</td>
<td>Federal Information Processing Standards (FIPS)-certified encryption of in-flight data from end-point to end-point. Maximum protection and throughput while optimizing latency by encrypting data at optical level.</td>
</tr>
<tr>
<td>DDoS defense</td>
<td>Best-in-class security technology to monitor traffic, detect threats, and alert key personnel to mitigate the attacks. Combines network monitoring centers, threat analysis and defense systems, 24-7 available security experts.</td>
</tr>
<tr>
<td>Managed security</td>
<td>Portal access to real-time analysis, monitoring, threat-detection and alert notification for suspicious activities. Best-in-class Security Operations Center SOC with AI machine learning platform.</td>
</tr>
<tr>
<td>Bandwidth on demand</td>
<td>Agility and control to upgrade bandwidth as needed across the Internet and Ethernet platforms. Ability to increase near real-time circuit capacity to port speeds in standard increments.</td>
</tr>
<tr>
<td>Fixed wireless</td>
<td>Complementary to fiber, enterprise-grade solutions for high-speed broadband Internet and ethernet access. Technology connects two fixed locations with line-of-sight radio link (network diversity, service in challenging areas, temporary services).</td>
</tr>
<tr>
<td>Ultra-low latency</td>
<td>Enables transport of critical data between key data centers and interconnected facilities. Leveraging Crown Castle’s state-of-the-art wavelength (DWDM) technology and nationwide fiber network.</td>
</tr>
<tr>
<td>Video transport</td>
<td>High-capacity transport for HD and 4K video (ASI, SD-DI, HD-SDI, and 3G-SDI video formats). Leveraging Crown Castle’s industry leading fiber network.</td>
</tr>
</tbody>
</table>
Crown Castle’s potential contributions to UNA

Deep expertise and experience in **mission-critical networks**

The country’s leading portfolio of **communications infrastructure and related value-add services**

**Low-cost and commercial business** model for network financing and operations

**Thought leadership** in UAS strategy and business development

Strategic and growth **capital**

**Brand and credibility**
Next steps: assemble a team to drive implementation in a particular area

Engage UAS thought leaders in a forward-leaning region to align on vision and goals

Develop a pragmatic network solution to meet the UAS industry’s operational needs

Conduct a focused pilot to validate the concept

Outline a long-term implementation roadmap

Identify potential long-term partners to execute the roadmap

Industry growth, innovation, and economic development
EHang’s COVID Relief Efforts Continue Amidst Second Wave in Guangzhou

- 06/04/2021 – Successively deployed multiple autonomous aircraft for COVID-19 prevention and control efforts

- Completing multiple support tasks in the quarantine and containment zones of Guangzhou

- Aerial logistics, emergency transportation, aerial inspections, transporting necessary daily household supplies to residents and implementing AAM systems in emergency transportation scenarios
Joby Aviation Announces Infrastructure Partnership With Largest Mobility Hub Operator in North America

- Partnership with REEF Technology and Neighborhood Property Group to develop takeoff and landing sites
- Largest parking garage operator focused on transforming these underutilized assets into multi-use mobility hubs
- Joby gains access to rooftop locations across key metropolitan areas in the US
- Los Angeles, Miami, New York, Bay Area
DHL Orders 12 Eviation Planes, Plans First Electric Network

- Ordered 12 electric cargo aircraft for delivery in 2024 and plans to build the world's first electric air cargo “eCargo” network

- First company in the world to order Alice aircraft from Eviation

- Alice can be flown by a single pilot and can carry over 2,600 pounds of cargo

- Charging time per flight hour is approximately 30 minutes, and the maximum range is 440 nautical miles

- Charged while loading and unloading operations occur
EHang and Spanish Police to Collaborate on AAV EMS and Security Applications

- Coordination with Spanish National Police to explore potential use cases
- Emergency situations such as rescue, surveillance, and other missions
- EMS & Security application may be ready sooner than commercial transport (overcoming regulatory approvals, public/societal benefit)
Kaman Corporation to Develop Commercial and Military Use eVTOLs

- KARGO UAV is the only system of its class that is purpose-built to provide deployed Marines, Sailors, Airmen, Soldiers and Coast Guard autonomous resupply

- Rugged design for easy transport and deployment

- System’s compact form-factor fits in a standard shipping container and is designed to be unloaded/operated by as few as two people

- Demonstration
Archer Receives Certification Standards Approval in G1 Issue Paper from FAA

• G-1 Issue Paper establishes the airworthiness and environmental requirements necessary to achieve FAA Type Certification

• Focus turns towards G-2 Issue Paper, which sets forth the means of compliance to meet the requirements set forth in G-1

• Become the third air taxi company to be listed publicly since August 2021 after successfully completing a merger with SPAC Atlas Crest Investment Corp.
ABB to Provide Charging Infrastructure for Lilium

- Provide development, testing, and supply services for the MegaWatt fast charging systems that will be used in Lilium’s network
- Charging points designed to be capable of bringing batteries to full charge within 30 minutes
- Services in Brazil, Germany, and the US with plans to expand further
- Another vital step in the fight against climate change and building a more sustainable future
Several EU Airports Partner on Vertiport Development

- Urban Blue - a joint venture between airport operators and administrators that will oversee the construction and management of eVTOL vertiports

- Transport airline customers on the final leg of their journey from their passenger jet to the city center

- eVTOL routes operated by Volocopter beginning in Summer 2024 in conjunction with the Summer Olympics hosted in Paris

- 2022 - Conduct technical and economic studies and begin master plans for vertiports
Vertical Aerospace & Heathrow Airport to Collaborate on Future of Urban Air Mobility

- Gearing up to operate its electric vertical takeoff and landing aircraft at Heathrow by mid-2020s
- Has the potential to reduce congestion and pollution on local roads
- Transport 4 passengers from Heathrow to London in 12 minutes, with zero operating emissions and at a cost similar to a taxi
- Partnering with Ferrovial to build 25 vertiports across the UK. This will allow Vertical’s eVTOL to operate from these sites for the proposed launch of its UK services with Virgin Atlantic
- Significant milestone for Britain’s zero-emissions aviation industry

Image // Vertical Aerospace

Service | Innovation | Results
Updates

➢ Texas Urban Air Mobility Advisory Council
  ➢ Voted on today
  ➢ Task Force Members Listed
    ➢ Chad Sparks – Bell
    ➢ Chris Ash – Hillwood/Alliance
    ➢ Michael Hill – Cumulus Technologies
    ➢ Gus Khankarli – City of Dallas
Infrastructure Investment and Jobs Act

➢ Airport Funding
   ➢ 25 Billion over the next 5 years

➢ The Promoting Services in Transportation Act
   ➢ 5 Million a year to promote Transportation Careers

➢ The Strengthening Mobility and Revolutionizing Transportation program
   ➢ $100 Million a year over the next 5 years
   ➢ To help cities conduct “smart city technologies” demonstrations that include supporting advanced air mobility initiatives.
Updates

➢ NASA Community Planning and Integration Annex
  ➢ Workshop #4 tomorrow
    ➢ Planning and Multimodal Integration
    ➢ Interoperable Infrastructure and Operations
    ➢ Workforce Development

➢ Regional Conference with Choctaw Nation
  ➢ February 8th
  ➢ Still determining the duration

➢ Building Back Better Communities Grant

➢ Working Groups meetings next week
  ➢ December 7th

➢ Know Before You Fly Your Drone Workshop -
  https://www.youtube.com/watch?v=SFdemmexMXE
  ➢ Saturday December 4th
  ➢ UAS Rules and Regulations
  ➢ Tyler Dicks – Airspace Link’s Pilot App
  ➢ Mark Colburn – Notify and Fly
  ➢ Evan Merelli – UAS Mapping
➢ Community Integration Working Group Update
   ➢ Cities interested in UAS Pilots and Operations
     ➢ City of Arlington
     ➢ City of Carrollton
     ➢ City of Dallas
     ➢ City of Fort Worth
     ➢ City of Frisco
     ➢ City of Lakeside
     ➢ City of Plano
     ➢ City of Richardson
     ➢ Duncanville

➢ Next Meeting
  ➢ January 25th, 2022