The Flying Car - Emergent Modeling & Simulation (M&S) Policies and Standards concerns

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ABSTRACT

Emergent modes of Transportation are becoming increasingly paramount to our everyday lives. Simultaneously however, our surface transportation infrastructure is suffering from overuse, extreme traffic congestion, and roadway disrepair, which necessitates novel mechanisms for "motorized mobility". Current pathways to overcoming these limitations include the gradual transition towards autonomous motor vehicles for human transport, as well as unmanned aerial vehicles (UAV's) and "drone" technologies that are steadily revolutionizing airborne egress and transport logistics for surveillance, package deliveries, and agriculture. Longer-term, Transportation scientists are already investigating the technology – and forecasted regulations - associated with "passenger drones" - a convergent form of ground/air vehicle transportation - the once-seemingly futuristic notion of The Flying Car.

In this paper, we conduct an extensive review of current literature to explore emergent and timely Flying Car technological capabilities – each requiring appropriate regulations and governance - to become fully sustainable. For specific benefit to I/ITSEC and the Policies, Standards, Management, and Acquisition (PSMA) subcommittee, a targeted focus is placed on the rapidly emerging Policies and Standards concerns – each with relevance to wide-ranging Modeling & Simulation (M&S) disciplines - that will advise and dictate future Test, Evaluation, Validation, and deployment of Flying Cars. Namely, this paper will explore specific issues pertinent to: Training, Safety, Environment, Navigation, Infrastructure, Logistics/Sustainability, and Cybersecurity. By addressing these M&S-critical Policies in advance, we can forecast and enable Readiness for the downstream impacts upon the key foundational aspects of I/ITSEC: Training, Simulation, and Education.

The comprehensive overview presented in this paper is driven by qualitative and anecdotal reporting that is representative of the present state-of-the-art, and highlights critical areas of focus relevant to M&S. This paper concludes with a preliminary quantitative analysis exploring the Human Factors associated with Flying Cars – including anticipated Benefits, Concerns, and willingness to both hire and acquire the technology once available to consumers. This data will help to inform next-generation Policies and Standards associated with the gradual advancement of Flying Cars, and highlights their disciplinary impacts upon key M&S domains of interest.

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INTRODUCTION AND BROADER IMPACTS

The "Transportation network of Tomorrow" has long been a topic of discussion and debate, with forward-thinking possibilities (e.g., Hyperloop and Personal Rapid Transit; Cunningham, 2017) at times seeming limitless. Since the introduction of futuristic vision cartoons such as The Jetsons (see Figure 1) more than a half century ago, as well as more recent future vision films such as Blade Runner (see Figure 2), the notion of a "Flying Car" has long-seemed nearer to science fiction than science fact. However, recent technological advances are slowly bringing these capabilities closer to reality (Covington, 2018). The surmised advantages of a Flying Car network are many, as it effectively combines ideal characteristics of both planes and cars. Namely, a Flying Car is much more maneuverable and would be less susceptible to traffic jams while traversing 3D airspace as compared to 2D roadways (Soffar, 2018).

Figure 1 – Future vision #1 (*The Jetsons*)

Figure 2 –Future vision #2 (*Blade Runner*)

However, despite recent technological progress, the ongoing evolution of Flying Cars will have profound impacts upon various Policies and Standards that govern future development, Test, Evaluation, Validation, and deployment of the technology (Lineberger, 2018). Forecasting existing regulations and establishing appropriate incentives that will serve to standardize and sustain a full-scale Flying Car Transportation network will be required. In the next section, we present a brief overview highlighting the relevance of this work to the prevailing I/ITSEC themes for 2019.

TOPIC RELEVANCE TO 2019 CONFERENCE THEMES

The current topic scope is technologically relevant to the prevailing themes at the 2019 I/ITSEC: "winning the war of *cognition* by pushing *readiness* and lethality boundaries". The notion of "cognition" (i.e., *the process of acquiring knowledge and understanding*) will serve as a vital component for the eventual widespread deployment of intelligent vehicles that will rely heavily on autonomy to assess their own locations in 3D space relative to adjacent vehicles at elevated speeds. As such, embedded technologies (e.g., Cognitive systems, AI, Machine learning) will be required to establish safe, reliable, and repeatable performance. The notion of "readiness" (i.e., *preparedness*) certainly applies to looking beyond autonomous cars to address the inherent challenges (e.g., over-congestion, infrastructure disrepair) associated with our road Transportation network. With a highly disruptive technology such as Flying Cars, **there will be numerous Regulatory obstacles that will require advanced M&S Test, Experimentation, and Validation - many to be highlighted throughout this paper. Refer to Figure 3, which illustrates the key M&S domains of interest that serve as the foundation for this paper**. With relevance to the fundamental pillars of I/ITSEC (i.e., Training, Simulation, and Education) and for the benefit of the PSMA subcommittee specifically, we now present an overview of numerous M&S domains of interest, and highlight associated barriers to progress - in greater detail.

FLYING CARS - APPLICABILITY TO M&S AND TRAINING

Modern technological developments demonstrate that Flying Cars may be available for commercial use by 2025 (Becker, 2017; Bogaisky, 2018). **Many of the associated challenges to sustain the technology will necessitate Live/Virtual models and simulations (M&S) for testing and validation**. For example, the evolution of Flying Cars will demand new Policies and Standards to regulate transition and handoff periods between manual and autonomous vehicle control and the complex transition between ground and flight dynamics (e.g., for takeoffs/landings). Furthermore, new Policies and Standards will be required to explore the complexities of airborne navigation safety which will necessitate both computational M&S for "virtual" testing (e.g., Figure 4; Roberts and Milford, 2017) and physical M&S performed within a "Live" setting. For the latter, prototyping (e.g., within a "drone dome" enclosure; refer to Figure 5) must be leveraged to emulate a functional miniature-scale infrastructure for forecasted Flying Car transport modes. **Flying Car deployment will likewise have profound impacts on Training**, which will demand novel regulations for safe operational and maintenance procedures. The ongoing development of Flying Car technologies will enable next-generation training methods within related technological domains, including: a) pilot training and certification, b) repair/service/upgrade procedures, c) connected/autonomous vehicles, including advanced robotics and sensor fusion, and d) machine learning and artificial intelligence (AI). Lastly, human response to autonomous features of next-generation transport modes remains uncertain. **Through application of M&S, an improved understanding of the complex human factors associated with Flying Cars** is required to manifest Policies and Standards that will govern future modes of operation. Ultimately - human behavioral patterns ascertained (e.g., via human behavior models and simulations) in conjunction with Live/Virtual testing to explore the human-machine interface can be leveraged to clarify the infrastructure challenges associated with real-world deployment.

Figure 3 – Flying Car M&S Domains of Interest

Figure 4 – M&S for Flying Car Navigation

Figure 5 – (Live) Flying Car drone dome testing

In this paper, we present an extensive overview of emergent Flying Car capabilities and requirements for actionable regulations and governance to advise and dictate future Test, Evaluation, Validation, and Deployment of the technology. **A brief forecast of the primary PSMA issues pertinent to key M&S domains of interest includes**:

- <u>Safety</u> – The most critical segments of Flying Car operation will be ground/air transitions (takeoff/landing), which will demand NAS/FAA regulation, and suitable governance for an integrated (rather than segregated) airspace
- <u>Pilot Training & Certification</u> – For both manual and autonomous Flying Cars, the vehicle the operator (or pilot), and the air/ground-based support systems (maintenance) will require appropriate certifications and governance
- <u>Infrastructure</u> – Flying Cars will necessitate regulations for "vertiports" for land/air transitions, and this will dictate policies and standards for required (vertical takeoffs and landings, or VTOL) operational features.
- <u>Environment</u> – Governance must be mandated (e.g., NASA UAM) to ensure environmentally conscious best practices are instituted for Flying Cars, including electric power, and minimized noise and fuel emissions
- <u>Logistics & Sustainability</u> – Flying Cars will mandate Sustainable legal standards for operation, maintenance, and control, and staged adoption Logistics (e.g., Emergency vehicles, then Industrial Rideshare, then consumers)
- <u>Cybersecurity</u> - Flying Cars will be highly computerized and automated, the systems of which will mandate Policies for guarding against cybercrimes (e.g., malware, denial from Trojans that attempt illegal remote access)

- <u>Human Factors</u> – Human preferences will direct and dictate Flying Car sustenance, including financial (i.e., acquisition expenses; willingness to hire), operational benefits/concerns, and anticipated Use Case scenarios.

We begin with an overview of Policies and Standards related to ***Safety*** (i.e., operational; mechanical) – a foremost concern for establishing and maintaining Flying Car sustainability.

SAFETY CONCERNS

Beginning with the M400 SkyCar (Moller, 2016), development of Flying Car technologies has been ongoing since the early 1980's, and numerous manufacturer technologies (e.g., Aurora Flight Sciences PAV, 2019; PAL-V, 2019) are already beyond conceptual design. With the popularity of drones and UAV's steadily on the rise, and with associated demand for Policies to support commercial application, Flying Cars are slowly inching towards reality. If critical regulatory obstacles can be overcome, passenger drones and Flying Cars could begin to be realized in the next decade (Lineberger, 2018). Obviating Safety concerns (both human and autonomous) associated with Flying Car technology is therefore of paramount importance. As with autonomous ground vehicles, any publicized adverse safety incidents (e.g., Garsten, 2018) can taint public perception, and limit the growth rate of consumer acceptance.

The most challenging question facing Flying Cars involves suitable procedures for going airborne (takeoffs) and returning to the ground (landings), and a complex safety risk analysis will be required to determine the logistics of how Flying Cars are regulated by the National Airspace System (NAS), the governing entity for United States airspace (Del Balzo, 2016). From a regulatory standpoint, much additional research is required to ensure that novel autonomous systems to operate, navigate, and control Flying Cars are equipped with redundancy, and have "safe mode" capabilities (i.e., "on-the-fly" decision-making) if they encounter unusual situations. Airspace logistics may further dictate that the primary regulatory body (i.e., the FAA) will assign minimum Safety standards, and then each individual State would then mandate its own private air traffic controllers (Niller, 2018). As outlined earlier, <u>advanced models and simulations - in both Live and Virtual contexts - will be required to prototype common modes of Flying Car operation to establish baseline Safety guidelines</u>. Additional notional specifics are offered throughout this paper, and in the next section, we begin by forecasting regulatory requirements for ***Pilot Training and Certification***.

PILOT TRAINING AND CERTIFICATION STANDARDS

As Flying Cars will involve airborne egress (i.e., aviation), regulations will be mandated by the Federal Aviation Administration (FAA) with a conservative Safety Management System (SMS; *FAA 8000.369*) to govern and manage effective risk controls (Del Balzo, 2016). For traditional aircraft, the FAA has a successful regulatory system for pilot licenses, aircraft certification and registration, takeoff and landing sites (airports), and a mechanism for air traffic control. Anticipating Flying Cars, traffic control systems will comprise added complications, and compared to smaller "drones", the path to regulating human flight will be challenging and time consuming (Stewart, 2018). For a ground vehicle, one requires separate driver's licenses to operate a sedan vs. a motorcycle vs. a multi-axle semi-truck. Conversely, a Flying Car operator will require licensure both to *drive and fly*, and will require appropriate vehicle registration and Type Certification. Proposed Flying Car technologies are essentially fixed-wing airplanes (e.g., the Aurora PAV), but others operate more as a motorcycle-gyrocopter hybrid (e.g., the PAL-V). Ultimately, certain proposed vehicles will operate as a *car with wings* (i.e., a Flying Car), while others will effectively serve as an *airplane with wheels* (i.e., a Driving Plane), which complicates regulatory matters relevant to the requisite skill of the Flying Car "operator", as well as matters related to certification, airworthiness, and licensure (Del Balzo, 2015).

A wide range of Flying Car types are forecasted to eventually be allowed to operate within large, metropolitan areas. As such, their sustenance will largely depend on Certification procedures, which will dictate the urgency and tempo of this emergent, and disruptive technology as it evolves. Preliminary versions of Flying Cars will likely have a driver/pilot on board for the flight segment(s) of the journey. However, technologists are already developing concept models for future Flying Car vehicles that will be remotely piloted and supervised either: a) by live humans on the ground, or b) by autonomous systems in the air and/or on the ground. To operate "urban air mobility" vehicles (either with or without passengers) without a pilot would depend not only on the Certification of the vehicle, but likewise on the Certification of pilots and support systems on the ground – for which suitable Policies have not yet been established (Thipphavong et al., 2018). <u>Ultimately, advanced (virtual) M&S will be required to specify appropriate training systems (with suitable fidelity), and design standardized training scenarios for future Flying Car operators – particularly for handling complex ground-air and air-ground transitions.</u> Regulation of air traffic issues across all governing bodies will be a unique and complex challenge. Accordingly, in the next section, we investigate a number of key Policies and Standards issues related to ***Infrastructure and Navigation*** in greater detail.

INFRASTRUCTURE & NAVIGATION

The navigational benefits of instituting a functional Flying Car network are obvious – a technology that allows civilians to transport from source to destination at a fraction of the overall time required to drive the same distance. Refer to Figure 6, which illustrates a sample journey that compares drive/flight times for a work commute. (*image source:* Roberts and Milford, 2017). Here, the estimated 23 minute drive path (shown in red) is constrained by 2D roads, ground congestion, and the natural limitations of land topography. The flight path (shown in green) obviates these constraints, and reduces the point-to-point straight path travel distance by approximately 2/3 (i.e., to 8 minutes). In this scenario, we presume an Infrastructure to traverse in a manner that would permit safe takeoffs and landings, as well as infrastructure for vehicle storage (e.g., parking). Naturally, such a vast network of "vertiports" (e.g., Filippidis, 2018; see Figure 7) would necessitate standards and certifications for our infrastructure (e.g., helipads installed atop large public buildings; large segments of flat land designated for air-ground transitions) (Lineberger, 2018). <u>Design, layout, and specification of such vertiports will require advanced M&S (e.g., Monte Carlo simulations and advanced heuristic optimization techniques) to guarantee human safety and likewise maximize operational effectiveness and efficiency.</u> Accordingly, transportation authorities must mandate that Flying Car operators are constrained to selected flight corridors, such that a direct route might not always be an option. These corridors would likely be strategically located over reduced-risk areas of land that have minimal population (Roberts and Milford, 2017).
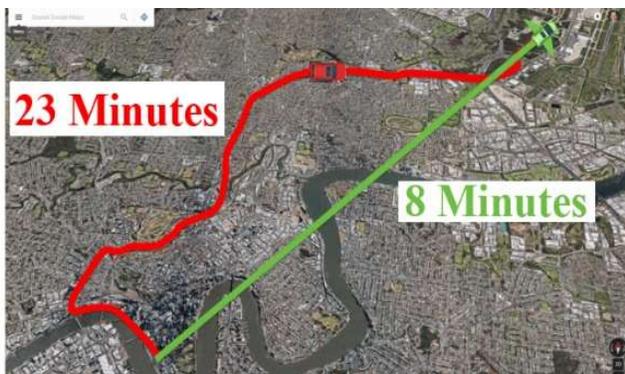

Figure 6 – Navigational benefits of Flying Cars

Figure 7 – Flying Car "vertiport"

A related consideration is the need to regulate and mandate a functional range of motion for a Flying Car. <u>Suitable design specifications will rely upon Live/Virtual testing and M&S to determine technical standards that meet all functional requirements, and are likewise cost effective and sustainable.</u> For example, we presume that in standard operational mode, the bottom of the vehicle is oriented downward (i.e., along the +Z axis), and it can traverse vertically while having the capacity to "hover", and likewise remain stationary while airborne. Furthermore, we presume that Flying Cars would travel longitudinally (i.e., along an X-axis), and laterally (i.e., along a Y-axis) without having to orient the vehicle in that direction. Flying Cars, like aircraft, will thus require rotational motion: to bank (roll), to tilt (pitch), and to revolve (yaw) to establish orientation within a plane parallel to the ground (worldbuilding, 2016). There will likely be situations where extended horizontal runways are not geometrically feasible, and will require a vertical takeoff and landing (VTOL) capability. Rideshare corporations (e.g., Uber and Lyft) are forecasting VTOL vehicles that are easier to fly than helicopters (Stewart, 2018), and have a "segregated airspace" dedicated for and managed by Rideshare entities. However, Federal regulators will likely mandate long-term policies involving a holistic *integrated airspace*, where everyone shares the skies (Stewart, 2018). Accordingly, idealizations of Flying Cars are such that they have the approximate size of a car, can drive on the road like a car, but also have VTOL capabilities.

Reliance on present-day battery science will be a limiting operational factor, as power constraints will dictate a brief (e.g., 10-20 minute) flight duration prior to re-charge (Rathi, 2018). Uber (2016) likewise concluded that batteries are not yet sufficient in terms of energy density, cycle life, nor cost-effectiveness, but supposes near-term improvement with economies of scale. A successful Flying Car engine is likely to be one that can successfully separate the source of rotational force from the speed of rotation (e.g., a "Split Power" engine – refer to Figure 8 for a preliminary illustration of the concept; Yeno, 2018). Commercial stakeholders, federal/state policymakers, and regional urban planning authorities must likewise envision an infrastructure that fully enables 3D egress within a densely populated (airborne) transportation grid (e.g., see Figure 9). Likewise, to create a unified traffic management system, infrastructure for high-speed data communications and geolocation will be required along predefined flight corridors (worldbuilding, 2016). To this end, suitable policies and regulations will be required to establish guidelines to insure that scalability and operational efficiency are accounted for as a functional Flying Car network evolves.
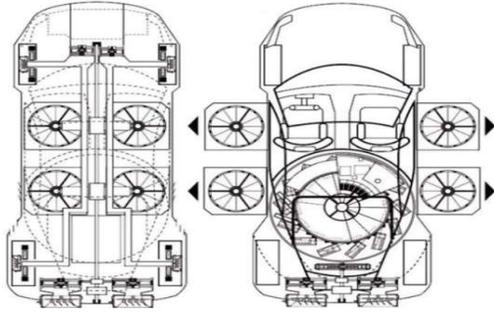
Figure 8 – "Split Power" Engine concept
(*Corporation of Flight*)

Figure 9 – Regulating the Flying Car Infrastructure
(*The Fifth Element*)

Finally, to operationalize Flying Car aeronautics, policymakers and regulators must consider the in-vehicle User Interface that will be required for Flying Car navigation. Instead of "floating" intersections, lane markers, and roadway signage – computer graphics technologists, virtual reality (VR)/Gaming enthusiasts, and M&S subject-matter experts are already forecasting (and prototyping) next-generation standards for Flying Car Heads-Up Display (HUD) navigation systems to support "airborne individual transport" (e.g., Frey, 2006; refer to Figure 10). Here, a supposed navigation system is presented upon a personalized driver display as a 3D "highway" grid. Such interfaces require customizable applications to permit airborne "lane changes", and likewise, the augmented reality (AR) display would feature traffic information that will assist with safe navigation of changes in heading (i.e., "turns"). Policymakers in must therefore establish guidelines for a robust Human-Machine Interface such that on takeoff, the field-of-view will transform seamlessly into a display system appropriate for use in flight mode (AeroMobil, 2019). In the next section, we investigate relevant Policies and Standards related to the ***Environment*** in greater detail.

Figure 10 – Flying Car HUD driver interface
(*zeroG-Autobahn; ZGA*)

Figure 11 – Flying Cars and "on demand" aircraft -
Environmental Impacts (*Salazar, 2018*)

ENVIRONMENTAL AND ENERGY CONSIDERATIONS

Although UAV's were initially marketed as purely recreational devices, the prospect that passenger ("manned") drones might soon be transporting civilians across large cities and vast rural landscapes (Ratti, 2017) has obvious advantages. However, it is difficult to fully comprehend the far-reaching environmental impacts imposed by Flying Car and "on-demand" Rideshare technologies. Although Flying Cars will presumably be a "clean" (i.e., partial- or full-electric power) mode of human transport, a substantial fleet of such vehicles could demand substantial energy resources and appreciably increase the overall amount that humans travel. However, to date, there have been no credible analyses conducted upon Flying Cars that have attempted to quantify their systemic impact on the environment as a whole (Stone, 2017). Refer to Figure 11 (Salazar, 2018), which illustrates how Flying Cars might impact daily existence within highly urbanized environments. Numerous impacts depicted within this futuristic rendering, along with a dialogue concerning anticipated Policy modifications, are explored in this section.

Based upon the anticipated operational dynamics of Flying Cars, energy requirements are forecasted to be substantial. It is widely assumed that many Flying Car designs will require rotors (e.g., as depicted in Figure 8), which are essentially large fans that force air downward to generate an upward propulsion. It will be difficult or impossible to achieve this lift force without creating air disturbance – and associated noise. As discussed previously, novel and substantial modifications to existing infrastructure must be governed to enable safe takeoffs and landings (with VTOL capabilities), as well as vehicle parking/storage. However -- large, highly urbanized areas (e.g., New York City)

already have substantial problems regulating aircraft noise. Recent noise complaints for residential helicopter tours along the Hudson River have resulted in increased regulation for tour operators (Bellafante, 2014), when prior to this legislation, there were fewer than 5,000 tourist helicopter flights per month. Extrapolating the prospect that Flying Cars could potentially serve as a daily transport mechanism for the ~8 million residents of metropolitan NYC, it becomes readily apparent that appropriate regulations (e.g., maximum sound decibels, at certain times-of-day and days-of-week, and within an appropriate distance of densely populated areas) will be required to inform a comprehensive noise ordinance to advise sustainable Flying Car operation (Ratti, 2017).

In addition to noise concerns, governance and oversight must be established to ensure that a network of Flying Cars will not result in undue burden of our Air Traffic Control (ATC) system. NASA's ongoing Urban Air Mobility (UAM) project (Figure 12) aims to develop an efficient air transportation network for (unmanned) package delivery as well as (manned) passenger taxis within both rural and heavily urbanized regions (Thipphavong et al., 2018). UAM researchers are considering aeronautics issues to mitigate sound issues associated with Flying Car operation, and are partnering with the FAA to develop rules and procedures that can manage the anticipated *low-altitude* Flying Car modes of operation. (Salazar, 2018). Finally, the capability for the technology to embrace "Green" Life Cycle advances (e.g., reduced reliance on fossil fuels; tailpipe emissions measured as "carbon dioxide equivalent", or CO_2e; UCSUSA, 2019) will help to establish the long-term sustainability of Flying Cars. Refer to Figure 13, which illustrates the environmental burden of today's ground-based vehicles based upon energy source (e.g., fossil fuel vs. electricity), relative consumption of resources, and tailpipe emissions. It is reasonable to presume that through the application of e.g., human behavior modeling and discrete event simulation, this transportation analysis infographic is scalable to hybrid-style (Flying Car) vehicles that are capable of both driving and flight. Future Policies and regulations (e.g., those governed by The Environmental Protection Agency, or EPA) will therefore demand that Flying Cars comply with federal emissions and fuel-economy standards (Negroni, 2012). In the next section, we formally investigate regulatory and governance issues related to ***Adoption Logistics and long-term Sustainability*** of Flying Cars.

Figure 12 – Urban Air Mobility conceptualization (***Thipphavong et al., 2018***)

Figure 13 – Green Concerns associated with conventional Ground Vehicles (*Adnan et al., 2016*)

ADOPTION LOGISTICS & TECHNOLOGICAL SUSTAINABILITY

Emergent Flying Car technologies will need to meet the technical and safety standards of BOTH cars and airplanes, and at least initially, will be costly both to acquire and to maintain. In the same manner that complex control devices are currently employed to direct and monitor road safety, allowable flight routes for Flying Cars will need to be mandated and regulated. Likewise, as Flying Cars will exhibit exponential complexity in terms of vehicle design (e.g., propulsion/engine) and achievable speeds that are much faster than standard cars, it will be a major and multi-faceted challenge for policymakers to institute sustainable legal standards (e.g., operation, maintenance, control) for such vehicles (Soffar, 2018).

Technologists (e.g., Templeton, 2018) forecast that adoption logistics for Flying Cars will transpire in a staged manner, initially, to meet our most critical transportation requirements. Driven by regional/national Policies and regulations, one could envision a gradual deployment scenario beginning first with adoption by specialty vehicles (e.g., law enforcement, construction, emergency fire response, ambulances), followed by corporations with niche requirements for airborne egress (e.g., Rideshare entities), and eventually followed by civilians. For example, a limited fleet of (autonomous) "Flying Ambulances" could be effective at quickly teleporting a patient, along with a health professional and essential supplies, in a manner that is non-disruptive to traffic on the ground. Likewise, in certain situations, if the transport was completely without a paramedic onboard to tend to a patient, it might ultimately be a better choice

to fly (i.e., above the traffic) for ~5 minutes than to have the commute consume 15 minutes (by ground) driving in a large vehicle with full gear and support team. Note that despite the idealized and "academic" expectation that Flying Car technologies should originate through emergency responders, a logical argument can be made that preliminary deployment might instead be driven by industry giants with substantial financial interests (e.g., Amazon, for package delivery; Uber, for consumer Rideshare applications). Regardless, proposed vertiports will require design standards (e.g., layout, features, geometries) – as advised by advanced M&S (e.g., multi-resolution models and macro/micro-simulations) to accommodate flying and landing hundreds of aircraft. Likewise, regulations for the associated airspace requirements to enable takeoff and landing patterns (Crosbie, 2017 - refer to Figure 14) will be mandated.

Lastly, manufacturing challenges might serve to inhibit the sustainability of Flying Cars as economies of scale will demand "many" aircraft flying as soon as possible. Leveraging advanced (e.g., lightweight, strong composite) volume-based manufacturing methods from automotive to aviation is required, however, it is anticipated that this transition will be a gradual process over time (Adams, 2018). Likewise, due to the complex engineering nature of Flying Cars, safety-certified, passenger-carrying flying vehicles will heavily rely on computers and autonomy. However, autonomous systems tend to lack the judgment, situational awareness, and "creativity" often required by live human pilots – and will demand an extended period for development of regulatory standards. To this end, in the next section, we outline anticipated requirements for **Cybersecurity** governance associated with Flying Cars.

Figure 14 – Vertiport design standards for Flying Car Sustainability

Figure 15 – Forecasting and Regulating Cyber Crimes within Flying Car autonomous Interfaces

CYBERSECURITY

Forecasted future modes of Flying Car operation will rely heavily upon computational AI for Detect and Avoid (DAA) technologies to recognize, distinguish, and track other aircraft, predict conflicts, and take corrective action as required. To realize such functionality will demand cognitive systems and computing; platforms that encompass machine learning/reasoning, human-machine interaction/automation, and network sensors for seamless and real-time vehicle-vehicle and vehicle-infrastructure communications (see Figure 15). Beyond the prevailing safety concerns associated with a major system malfunction while flying over a densely populated area, we still lack a comprehensive understanding of how Flying Cars can be protected from hackers, terrorists, or other "cyber" criminals (Ratti, 2017). The establishment of cybersecurity policies and standards will be a major requirement for fully realizing Flying Cars sustainably.

Many present-day Communications, Navigation, and Surveillance (CNS) systems will require expansion to cover additional airspace requirements for Flying Cars. Fortunately, NASA (and other agencies) are developing emergent operational Policies for Urban Air Mobility (UAM) related to aircraft, airspace, and hazards, and to include provisions for security. As Flying Cars will drastically enhance the overall mobility of persons and goods within metropolitan regions, our Air Traffic Management system must assign protocols for cybersecurity to assure reliable exchange of data (e.g., vehicle, navigation, command/control (C2) link, weather), and novel authentication mechanisms will be required to detect intrusions and data leaks (Thipphavong et al., 2018). Instatement of cybersecurity standards will be required to protect vehicle interfaces from attacks (both physical and electronic) to the networks that control Flying Cars. Stochastic M&S (e.g., Pokhrel and Tsokos, 2017) will be mandated to predict, quantify and assess risks to the overall network which will help to inform appropriate countermeasures. Cyber criminals have previously demonstrated the relative ease with which ground vehicles can be compromised after identifying access to its internal operating system (i.e., the Controller Area Network, or CAN bus). Accordingly, cybersecurity specialists for Flying

Cars must impact Policies for guarding against malware, and denial from Trojans that attempt illegal remote access to its Electronic Control Unit (ECU) (Tabora, 2018). In the next section, we diverge from details found in the literature, and conclude this paper with a brief presentation concerning the critical ***Human Factors*** that interrelates to all of the PSMA-relevant subdomains discussed thus far, and will drive and dictate the near-term adoption of Flying Cars.

EXPLORATORY HUMAN FACTORS TO INFORM FUTURE FLYING CARS POLICY
In addition to the various technological Policy and regulatory requirements summarized thus far, we must forecast the critical human element associated with our relationship with Flying Cars (i.e., the Human-Machine interface). For the technology to sustain, humans will be required to overcome psychological barriers that are associated with the concept of "flying" a car, or longer-term, being transported within a pilotless and fully autonomous flying vehicle. Furthermore, for Flying Cars to be widely accepted and adopted, they will have to be as flexible and convenient for daily transport as a modern-day automobile and quickly establish well-documented safety records (Lineberger et al., 2018). Recent subject matter experts have performed exploratory studies (e.g., N=692 surveys issued on Survey Monkey) to investigate the Human Factors associated with Flying Car technologies. Here, we briefly summarize and illustrate these key issues, as they will directly influence future Policies and regulations associated with emergent technological advances.

The first analysis (Eker et al., 2018a), provides a preliminary investigation of individual perception regarding the future adoption of Flying Cars. Figure 16 illustrates willingness to pay for Acquisition of a Flying Car for personal use, forecasting what is expected to be common price points for this mode of transport. Just over 40% expressed an interest in acquiring a Flying Car vehicle at a ~$100k purchase value, and these numbers decline sharply with increased dollar amounts. In Figure 17, we explore the anticipated Use Cases for Flying Cars across three subcategories: activity, duration of travel, and time-of-day. The Figure illustrates the forecasted use of Flying Cars most often for entertainment and work activities; respondents seem more likely to use the technology for trips of LONGER duration (i.e., hundreds of miles) as opposed to short trips, and perhaps not surprisingly, remarked as being slightly more likely to use Flying Cars during daylight (i.e., morning/afternoon) periods than during darkness.
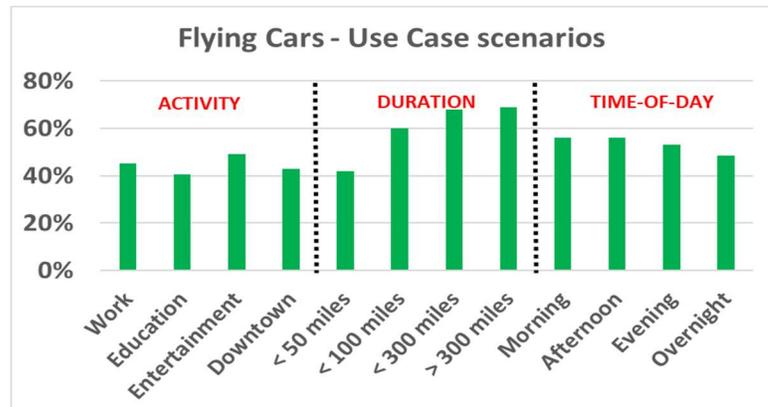

Figure 16 – Willingness to Acquire

Figure 17 – Flying Car Use Case Scenarios

The second analysis (Eker et al., 2018b) provides a preliminary investigation in to the public perception of forecasted Flying Car technologies. Specifically, this effort explores the fact that the future adoption of Flying Cars is directly associated with individual perceptions of the *benefits and concerns* arising from key operational characteristics related to this complex and technologically disruptive technology. Figure 18 investigates the anticipated benefits of Flying Car technologies, where respondents anticipated the value of reduced travel time, and increased travel reliability (e.g., reduced traffic), while being comparatively less anticipatory of the possible gains resulting from reduced fuel expenses and vehicle emissions (e.g., fully electric Flying Cars). Likewise, Figure 19 investigates the fundamental concerns for eventual Flying Car deployment, where respondents seemed most apprehensive about weather conditions, and more concerned about airborne (compared to ground) interactions with other vehicles, while somewhat surprisingly, expressing reduced concern regarding the forecasted requirement to "pilot" one's own (Flying Car) vehicle.

Finally, the third analysis (Ahmed et al., 2018) explores human willingness to hire next-generation Rideshare modes of transport. In this manner, this effort investigates public perceptions and expectations involving Flying Cars with specific regards to shared mobility services, previously unexamined within travel demand literature. Figure 20

previews human preferences towards forecasted operational modes of next-generation Flying Car Rideshare. The graph illustrates slight willingness towards vehicles that allow for human-piloted operation in favor of fully autonomous transport. Likewise, Figure 21 surveys human expectations that Flying Car Rideshare will cost more than ground-based travel, and that humans are willing to pay slightly more than current (ground) rates for transport. However, the current threshold for tolerated increase is slight – i.e., a "few dollars more" per brief excursion, as indicated by the 4th order polynomial "trend line" displayed on the plot.
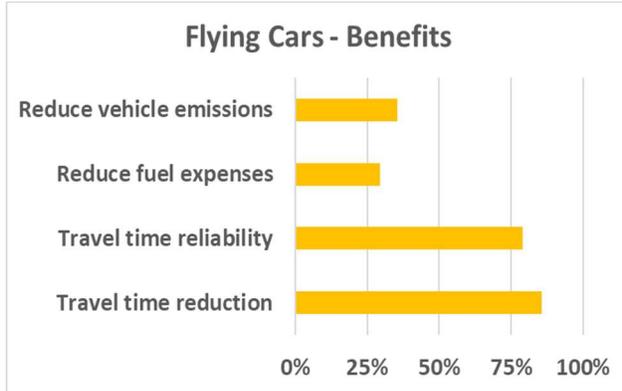
Figure 18 – Benefits of Flying Cars
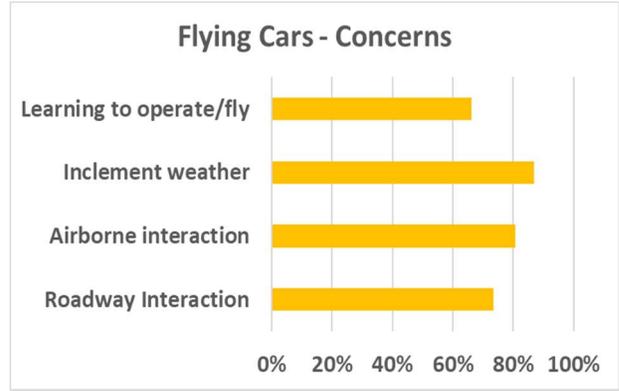
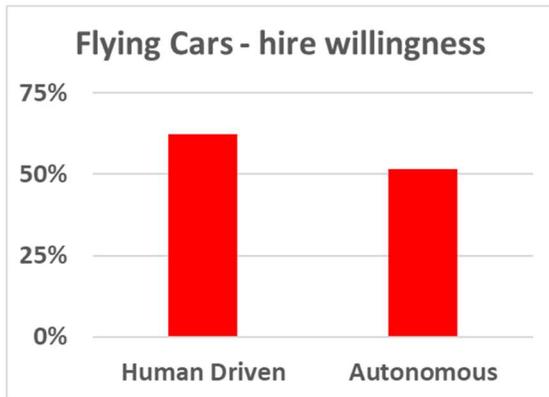**Figure 19 – Concerns related to Flying Cars**
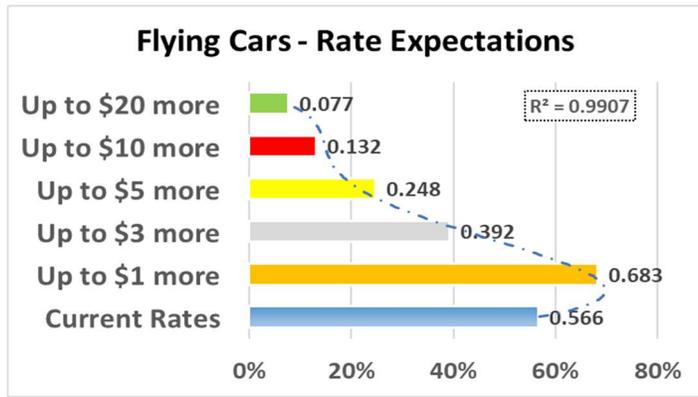
Figure 20 – Willingness to Hire

Figure 21 – Willingness to Pay (services)

In conclusion, we present a concise Summary of the primary M&S-relevant Policies and Regulations that will be required to advance Flying Cars towards long-term sustainability.

SUMMARY AND NEXT STEPS

As our surface transportation infrastructure continues to suffer from overuse, congestion, disrepair, transportation scientists are already investigating the feasibility of passenger drone and Flying Car technologies. For these reasons, we have presented an extensive literature-based overview of emergent Flying Car capabilities, and critically – their requirement for actionable regulations and governance to advise and dictate future Test, Evaluation, Validation, and Deployment. **In this paper, we emphasized seven key M&S domains of interest (Safety, Training, Infrastructure, Environment, Logistics/Sustainability, Cybersecurity, and Human Factors) critical to the forecasted advancement of Flying Cars, explicitly noted topical relevance to the prevailing I/ITSEC 2019 conference themes (readiness & cognition), and for the benefit of PSMA -- explored how these technologies will influence future policies, regulations, certifications, and governance**. Moving forward, the authoring team aspires to develop a high-fidelity M&S framework – including both Live and Virtual testing aspects - to examine the emerging operational feasibility of Flying Cars. Such a capability will allow technologists and subject matter experts to prototype and validate ground/air traffic Simulation-tools., and enable researchers to model and analyze complex egress scenarios within diverse operational settings. We forecast that companion (scaled) Live physical test environments will be necessary to perform advanced scenario prototyping, once baseline feasibility has been achieved through Virtual Simulation. The outcomes of such M&S frameworks will further serve to influence policymakers towards achieving sustainable technological policies and standards.

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