Robotic Platform for RST: Landing & Takeoff System on Latching Cars

Aristeidis Symeonidis, Michael Chung - Santa Clara, CA. Apr 2017.

<u>Abstract</u>

Using electric cars for runway operations enables extremely-short takeoff or landing (ESTOL) capability for long-range electric fixed-wing aircraft between low-noise highly-localized RST skyparks. Tolerable acceleration of .6 g brings aircraft to 45 mph takeoff speed in 35 meters, enabling skyparks to be comparably land intensive to parking lots.

Part masses of comparable electric-powered aircraft for 2-passenger RST

- 1200 kg aircraft takeoff weight
    - 400 kg base weight
    - 300 kg two occupants
    - 50 kg <260 kW 95% η motor
    - 300 kg Li-ion battery at 140 Wh/kg; 40 kWh; 200km @ 20 kWh depletion/100km
    - 50 kg more structures, carbon fiber framing, Al skin
    - 50 kg more controls/avionics
- 8000 kg car - jacked-up 2x scale Model X with catch latch
- 10^x kg asphalt infrastructure street-integrated gates & skypark

"Regional Sky Transit (RST) is the name applied to a future system of ubiquitous, short-range, on-demand, affordable, point-to-point delivery of people by electrically-powered, autonomous, ultra-quiet Sky Taxis. The RST system will rely upon easily accessible small, "pocket skyparks" adequate for vertical or extremely short take off and landing (V/ESTOL) that allow the public to minimize ground travel time (GTT) on short trips within highly populated mega-regions." -Dr. Brian Seeley [1]

Summary

Aircraft equipped with a small retractable latch would land on self-driving cars velocity matching the aircraft. The cars would provide deceleration to gate taxiing speed, giving extremely-short landing capability and rapid throughput. The same latch can be used for landing, taxiing restraint, and catapult launch. ESTOL capability in fixed-wing aircraft creates a better option for RST due to higher glide efficiency and range, and lower costs and noise compared to VTOL aircraft options. Vertical takeoff requires a thrust/weight greater than 1, and more power increases noise, a primal concern[2].

The power now available in batteries enables an electromagnet on the car's latch hook to magnetize a ferromagnetic aircraft latch rod, inducing attractive force, reducing employment of control surfaces on aircraft for aligning & maneuvering latch hook into slot during landing.

Door-to-door transit time costs [1]

-gate to takeoff, 15 seconds achievable
-**flight cruising: 120 mph**, car avg: ~30 mph, train: ~30 mph
-landing to gate, 15 s achievable
-street to gate, 20 s achievable, TBD skypark design
-skypark to final destinations, target: <6 min, TBD skypark proximity

Energy cost ~ $0.10/kWh

- 2017 Tesla Model S: energy consumption 32 kWh/100 mi = **20 kWh/100km**
- 20:1 L/D 1400 kg Aircraft 70 kgf * 100 km = 7.0e7 Nm = **20 kWh/100km**
    - both have room for future improvement from higher battery energy densities and lower gross weights
    - Range $\propto$ Aerodynamics, battery density, gross weight^{-1}

Features:

- Safety - redundant parallel power, battery, control systems, airbags, 45 mph stall speed, high glide ratio, parachutes
- Convenience - Enter and exit cabin at gates, fast taxi to runway
- Pleasure - panoramic view, low vibration, HUD/laptop/internet productivity
- Noise - target <48 dB continuous noise, distributed electric propulsion
- Piloting: automated in future with simplifying power of electromagnet or robotic hook

Aerodynamics

Range is limited by the aerodynamic performance of aircraft. Lift/Drag ratio is energy efficiency of aircraft's flying surfaces. Achieving L/D over 20 may require wingspans of 15-20 m and great design. Hinged wings possible for tight skypark space.
Purported stable fuselage length (m) = .3 * Wingspan + 2.5

No parasitic drag protrusions for landing/taxiing/takeoff gear; small retractable latch eliminates bulky landing gear/wheels often comprising 10% of gross aircraft weight.

Aircraft Structure

- Strength/weight materials, carbon fiber composite frame & aluminum skin
- Rapid interchangeable appx. 24 kWh battery packs
- Appx. yield loads = 1.5 (safety factor) * 4.5 g acceleration (by gusts)
- Ferromagnetic material latch rod for high magnetic attraction
- Traditional semimonocoque frame, wing spars, ribs, skin
- Battery near wing box for center of lift near center of mass

Aircraft Controls

Extremely short landing prefers descent maneuverability steeper than cruise-flight glide slope. Gimbaling electric fans for thrust vectoring is a flight control possibility. Tradition is set of ailerons, elevators, and rudder on tail stabilizer empennage.

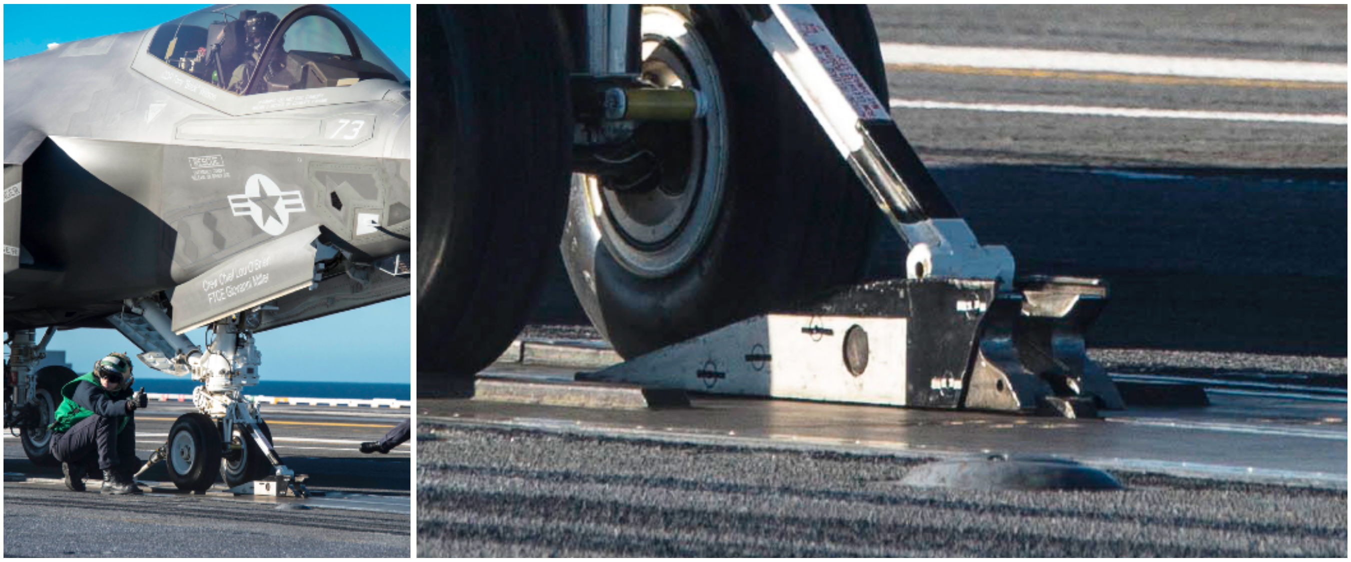
Aircraft Propulsion

Noise generation with thrust generation. Additional fans reduce peak noise output at cost of more parts. Siemens makes a 50 kg, sustained 260kW output electric-aircraft-dedicated motor, solving propulsion for electric aircraft eventually beyond 4-6 passengers. Distributed propulsion over several motors & fans may be needed to lower noise.

-20:1 L/D 1400kg 2-passenger craft in steady, level, unaccelerated flight:
- 70 kgf/490 N drag matched by thrust
- 120 mph/193 kph/54 m/s optimal efficiency cruise speed
- 700 N * 54 m/s = 38 kW constant engine output

-Low-noise, high-efficiency propellers preferred
-Redundant parallel battery, motor, computer, & control architectures

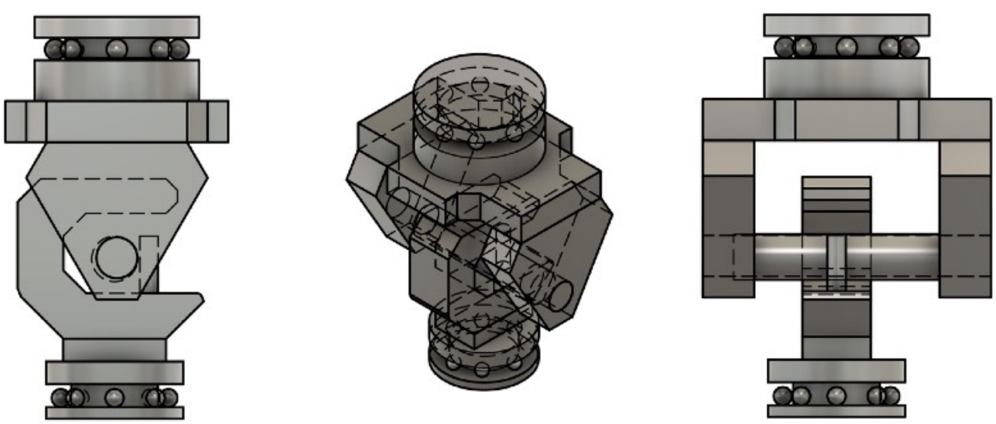
Achieving a steep descent for shorter landing paths may be assisted by reversing thrust direction, an advantage of electric motors.

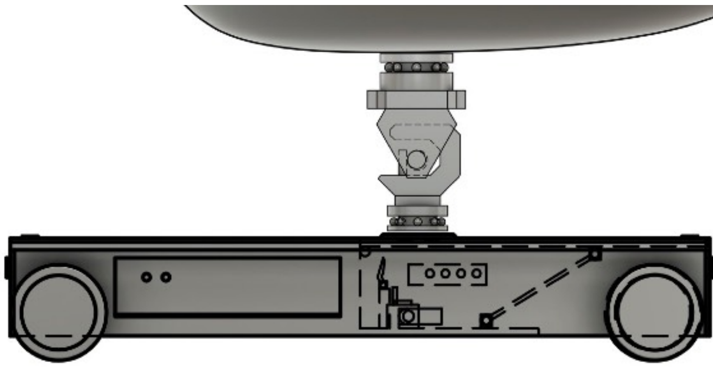


US Navy aircraft carrier launch catapult & F-35 front hook.

F-18 with tail hook extended, landing.

Hook + Latch: For Landing, Takeoff, & Taxiing





It will be seen how effectively the self-driving car can be programmed to work together with the control surfaces of the plane to perform highly reliable and safe hook-latch landings. The latch could be very light, small, and retractable given the low forces involved with small aircraft. Electromagnetic attraction of a ferromagnetic latch could also produce hundreds of pounds of attractive force once the latch is within ~6-12" of the car electromagnet.

.6 g acceleration from 0-45 mph spans 35 meters. In landing, the car must speed match the landing aircraft in its glide, latch and lock it, and provide deceleration to the taxi speed towards the gate for a rapid disembarking, battery swapping, and new passenger docking.

If both the plane's belly latch and car hook can rotate, a hook used for landing can spin around to face forward, ready to release the aircraft in an accelerated takeoff. By securing the docked aircraft, the aircraft's latch would be spun while the aircraft remained docked on the car.

Conclusion

Ever-increasing battery energy densities will compel innovative new aircraft designs. By providing takeoff acceleration with instant-torque wheel motors on a car, the shortest takeoff is made possible, with none of the motor, wheel, or brake mass needing to be retracted into the belly of the aircraft. The significant effect of aircraft gross weight on range demands elimination of all non-essential mass from the flight phase. The system described increases aircraft ranges, enables high speed of skypark operations, decreases size requirement of skyparks, and decreases noise caused by aircraft with lower power/weight ratio than vertical takeoffs.

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