SAE INTERNATIONAL

# SILICON VALLEY AIR-TAXI STUDY

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13 April 2016

# INITIAL BENEFIT & FEASIBILITY ASSESSMENT OF ON-DEMAND, URBAN MOBILITY USING 3 DIMENSIONS

# OUTLINE

- My background, briefly
- Silicon Valley air-taxi commuter study
- Why now

# RESEARCH ENGINEER, NASA LANGLEY RESEARCH CENTER

- First “A” in NASA…**Aeronautics**
  - One of 4 NASA Research Centers with significant aero component
- Established 1917, Hampton VA
- 1,976 civil servants
- Engineering research in
  - Aerodynamics
  - Structures and materials
  - Dynamics and control
  - Flight systems and operations
  - Concept and systems analysis



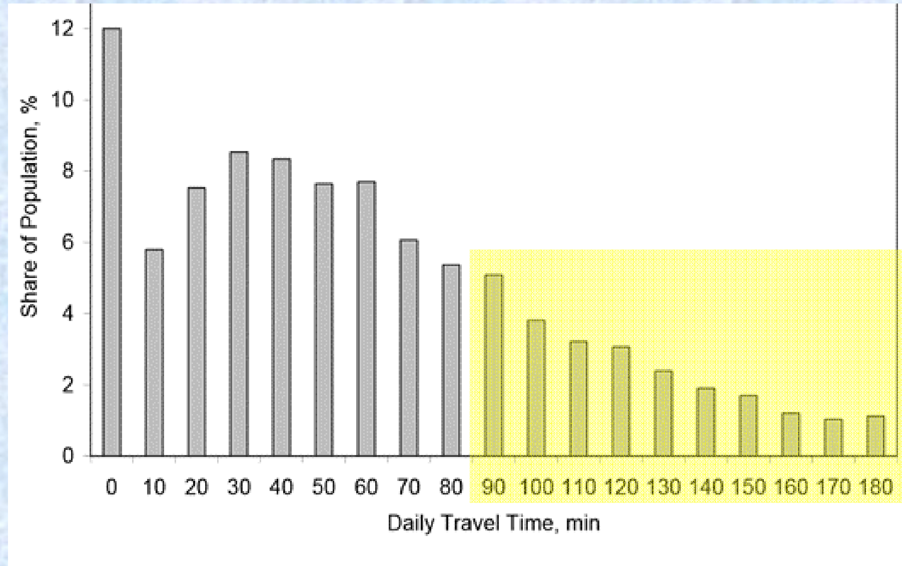
# SILICON VALLEY CASE STUDY…


- High income
- High housing costs
- Terrain challenged transportation network
  - Water & mountains
- Rapid new technology adoption, investment

# #1 IN COMMUTER TRAVEL DISTANCE AND TIME

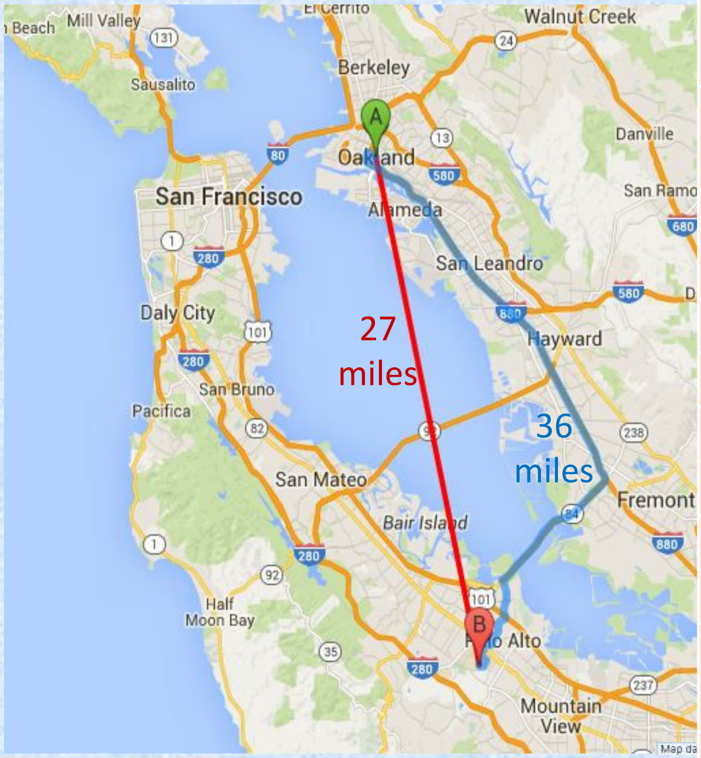
| Metro Areas with Highest Mean Distance | Percent Mega Commutes |
|---|---|
| San Francisco-Oakland-Fremont, CA | 2.06 |
| San Jose-Sunnyvale-Santa Clara, CA | 1.90 |
| Salinas, CA | 1.23 |
| Gulfport-Biloxi, MS | 0.94 |
| Hinesville-Fort Stewart, GA | 0.93 |
| Lawton, OK | 0.82 |
| Fayetteville, NC | 0.73 |
| Brunswick, GA | 0.64 |
| Anchorage, AK | 0.25 |
| Honolulu, HI | 0.08 |

**Top 3 Metro Areas with most 1-way commutes greater than 90 minutes are all in the Silicon Valley**



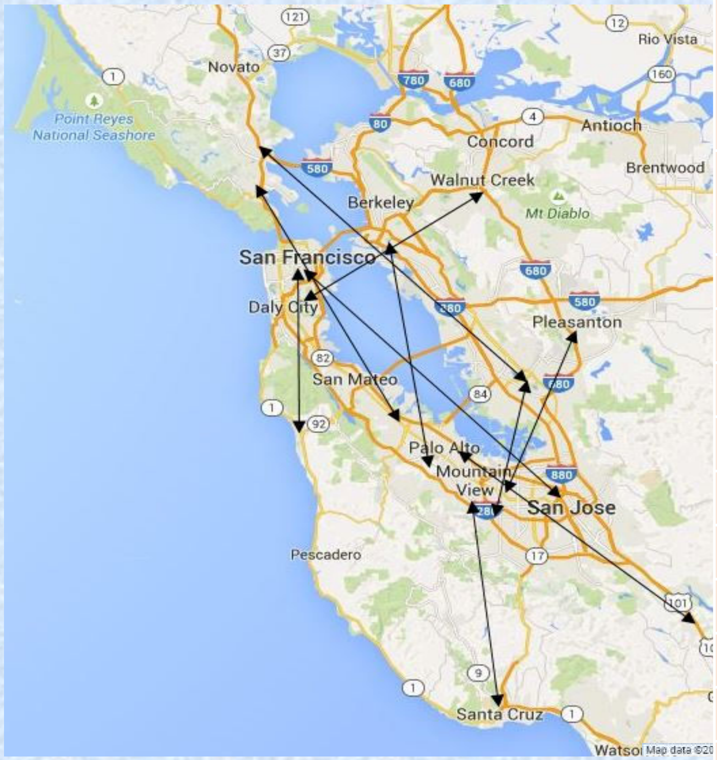

**>25% have Daily Travel Times of >90 min.**

# TRAVEL TIMES FOR URBAN CITY PAIRS




| City 1 | City 2 | Direct Distance (miles) | Driving Distance (miles) | Average Speed (mph) Non-Peak | Average Speed (mph) Peak | Ground Travel Time (minutes) Non-Peak | Ground Travel Time (minutes) Peak |
|---|---|---|---|---|---|---|---|
| Oakland | Stanford | 27 | 36 | 39 | 18 | 55 | 120 |
| Morgan Hill | Palo Alto | | | | | | |
| H.M. Bay | San Fran. | | | | | | |
| Santa Cruz | Mt. View | | | | | | |
| San Fran. | San Jose | | | | | | |
| Fremont | Cupertino | | | | | | |
| Pleasanton | Sunnyvale | | | | | | |
| Walnut Crk. | Daly City | | | | | | |
| San Rafael | Fremont | | | | | | |
| Mill Valley | RW City | | | | | | |
| | **Average** | | | | | | |

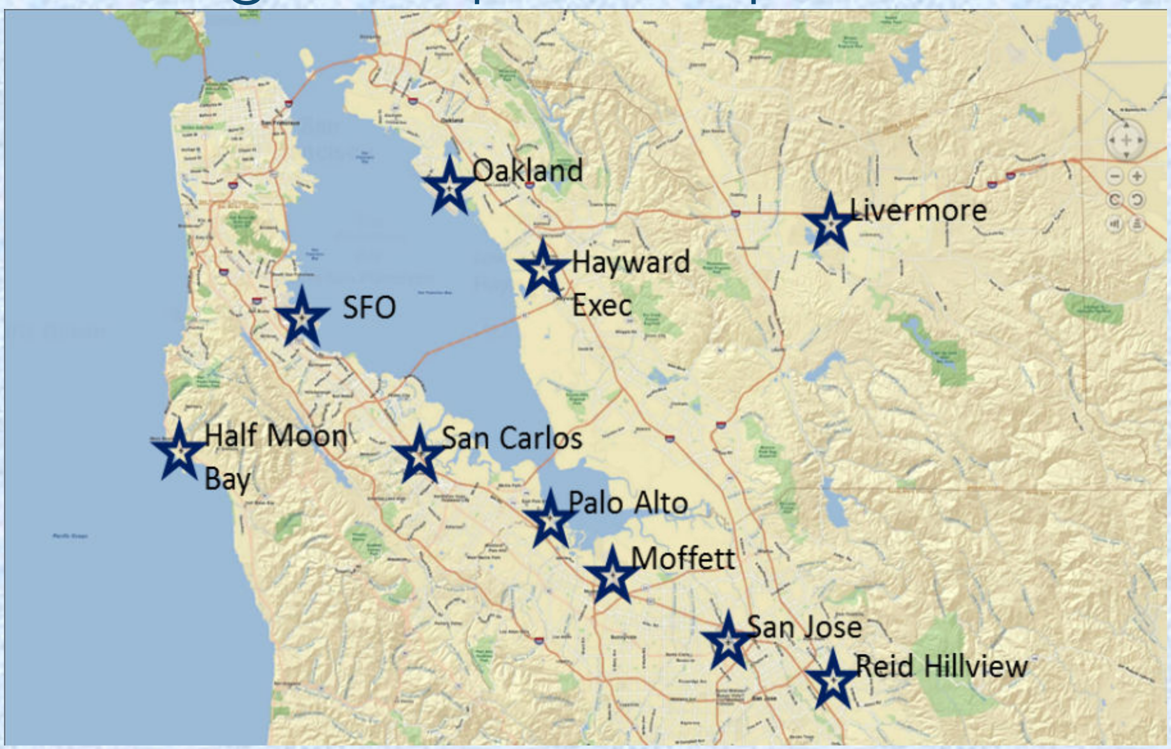
# TRAVEL TIMES FOR URBAN CITY PAIRS




| | | Direct Distance (miles) | Driving Distance (miles) | Average Speed (mph) | | Ground Travel Time (minutes) | |
|---|---|---|---|---|---|---|---|
| City 1 | City 2 | | | Non-Peak | Peak | Non-Peak | Peak |
| Oakland | Stanford | 27 | 36 | 39 | 18 | 55 | 120 |
| Morgan Hill | Palo Alto | 34 | 38 | 51 | 19 | 45 | 120 |
| H.M. Bay | San Fran. | 22 | 30 | 45 | 24 | 40 | 75 |
| Santa Cruz | Mt. View | 29 | 36 | 48 | 20 | 45 | 110 |
| San Fran. | San Jose | 42 | 48 | 53 | 32 | 55 | 90 |
| Fremont | Cupertino | 16 | 25 | 50 | 20 | 30 | 75 |
| Pleasanton | Sunnyvale | 22 | 28 | 43 | 17 | 40 | 100 |
| Walnut Crk. | Daly City | 27 | 32 | 49 | 18 | 40 | 110 |
| San Rafael | Fremont | 42 | 49 | 53 | 27 | 55 | 110 |
| Mill Valley | RW City | 34 | 40 | 40 | 20 | 60 | 120 |
| | **Average** | **29** | **36** | **47** | **22** | **46** | **103** |

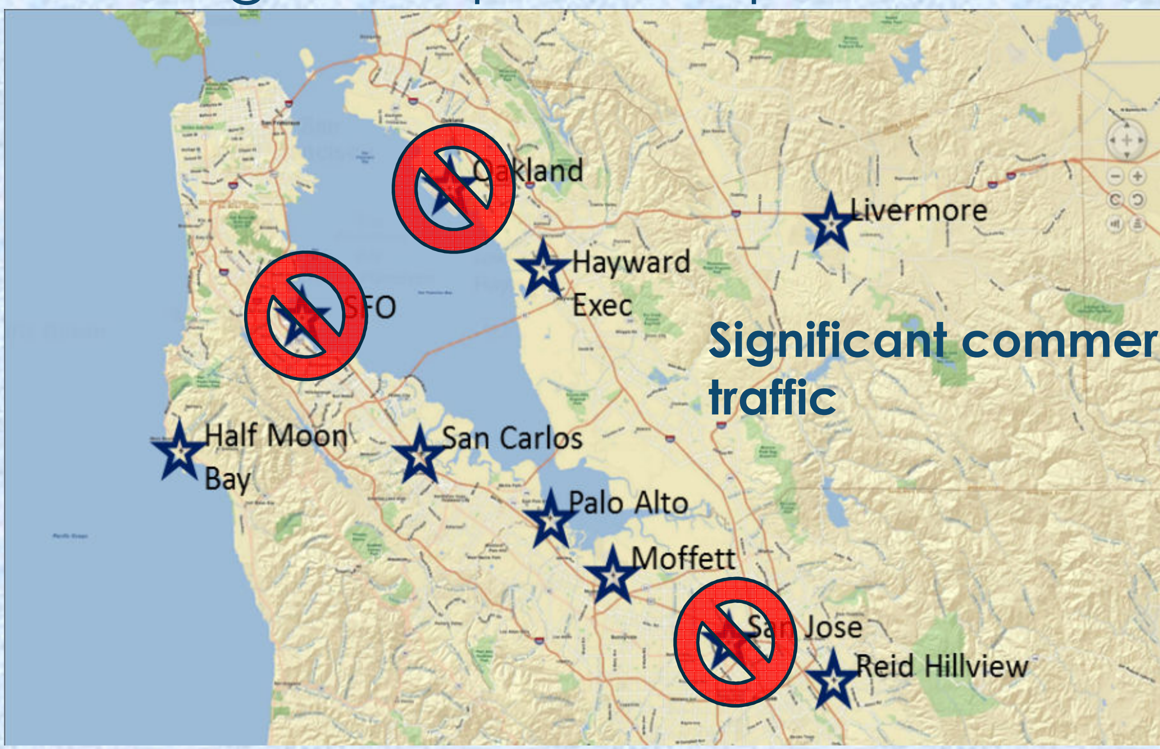
# WHAT ABOUT USING AN AIRPLANE?

- **Restricted to airports**
  - Origin > airport > airport > Destination



# WHAT ABOUT USING AN AIRPLANE?

- **Restricted to airports**
  - Origin > airport > airport > Destination




**Significant commercial traffic**

2 ground segments averaging 12 miles each

# CONVENTIONAL AIRPLANE - CAR COMPARISON

| | | Total Travel Time (minutes) | | | |
|---|---|---|---|---|---|
| | | Non-Peak | | Peak | |
| **City 1** | **City 2** | **Car** | **Plane** | **Car** | **Plane** |
| Oakland | Stanford | 55 | 54 | 120 | 64 |
| Morgan Hill | Palo Alto | 45 | 38 | 120 | 46 |
| Half Moon Bay | San Francisco | 40 | 65 | 75 | 75 |
| Santa Cruz | Mountain View | 45 | 55 | 110 | 64 |
| San Francisco | San Jose | 55 | 81 | 90 | 103 |
| Fremont | Cupertino | 30 | 63 | 75 | 85 |
| Pleasonton | Sunnyvale | 40 | 46 | 100 | 57 |
| Walnut Creek | Daly City | 40 | 57 | 110 | 67 |
| San Rafael | Fremont | 55 | 50 | 110 | 87 |
| Mill Valley | Redwood City | 60 | 50 | 120 | 57 |
| **Average travel time** | | **46** | **58** | **103** | **73** |
| **Average airplane benefit (minutes)** | | | **(12)** | | **30** |

**Airplane**

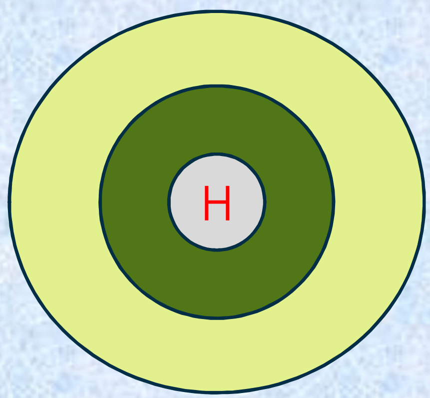
- 2 ground segments to best airports (average 12 miles)
- 5 minutes per transition (optimistic)
- 200 mph in-flight average

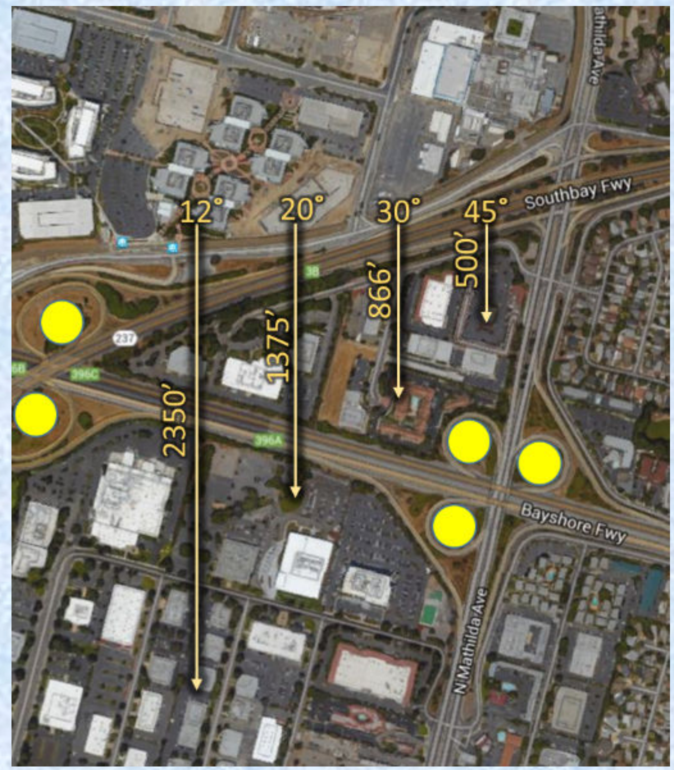
# ARE SHORT OR VERTICAL TAKEOFF & LANDING OPTIONS?
## (Short, Extremely-Short, and Vertical Takeoff and Landing)

Potential CTOL, STOL, ESTOL, and VTOL infrastructure locations investigated, with a requirement to clear 500 ft above surrounding private property.

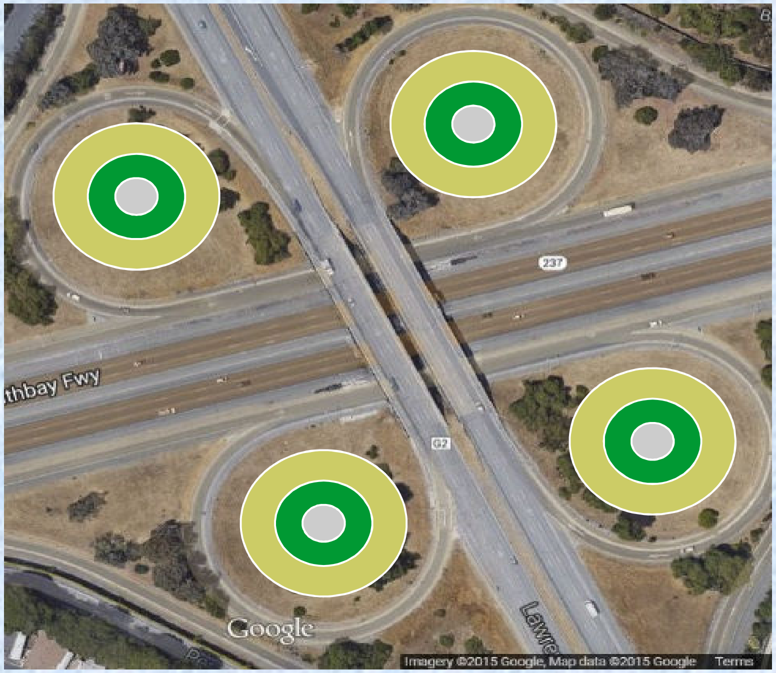
- CTOL with 3˚ glideslope, 9550’ (not shown)
- STOL with 12˚ glideslope, 2350’ field length
- ESTOL with 20˚ glideslope, 1375’ field length
- ESTOL with 30˚ glideslope, 866’ field length
- ESTOL with 45˚ glideslope, 500’ field length
- VTOL with 90˚ glideslope, 0’ field length, but FAA guidelines for setbacks require a 200’ circle

***Touchdown/Lift-Off Area*** **50’ Diameter LLA**
**LLA = Level Landing Area**
**115’ Diameter Final Approach and Touchdown Area (FATO)**
**200’ Diameter Public Safety Area (PSA)**



# POTENTIAL HELIPAD LOCATIONS, CLOVERLEAF



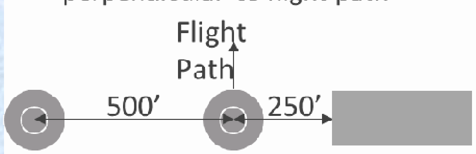


- Available DOT land resource provides approach/departure paths without overflight of private property at <500 ft.
- Existing high noise area that the community accepts with established setbacks
- Distribution that couples to existing ground roads for minimum travel time

# POTENTIAL HELIPAD LOCATIONS, URBAN BARGES


**Selection Criteria:**

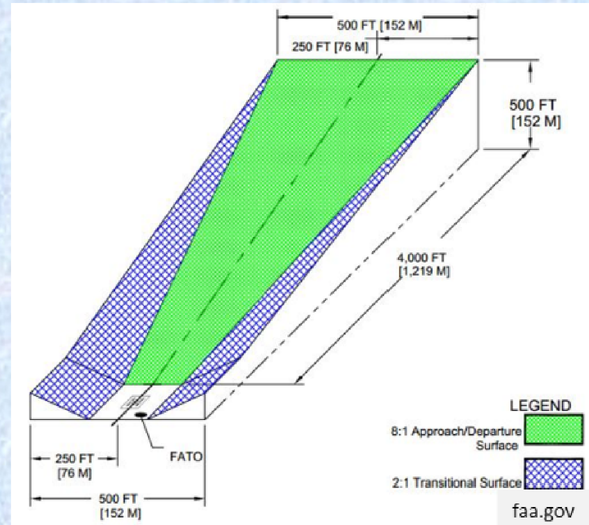
- Direct Roadway Access
- 500’ distance between two helipads perpendicular to flight path
- 250’ distance from center of helipad to other obstruction perpendicular to flight path




18 Coastal Miles,

50 Potential Helipads

# POTENTIAL HELIPAD LOCATIONS, PRIVATE CAMPUS

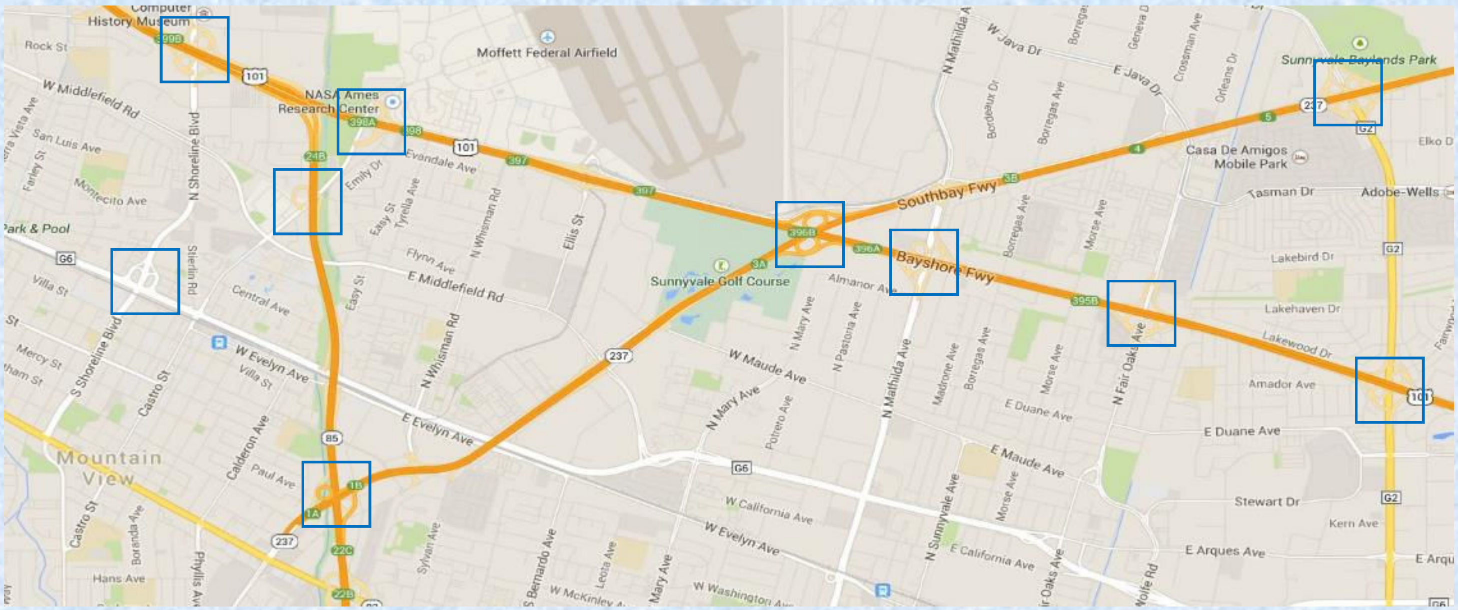




## Additional Requirements:

- Min: 45 deg. crosswind
- 500 ft. private ground clearance

# AREA-WIDE ESTIMATE

10 Sq. Miles | 10 Intersections | 19 Potential Helipads




2 Miles

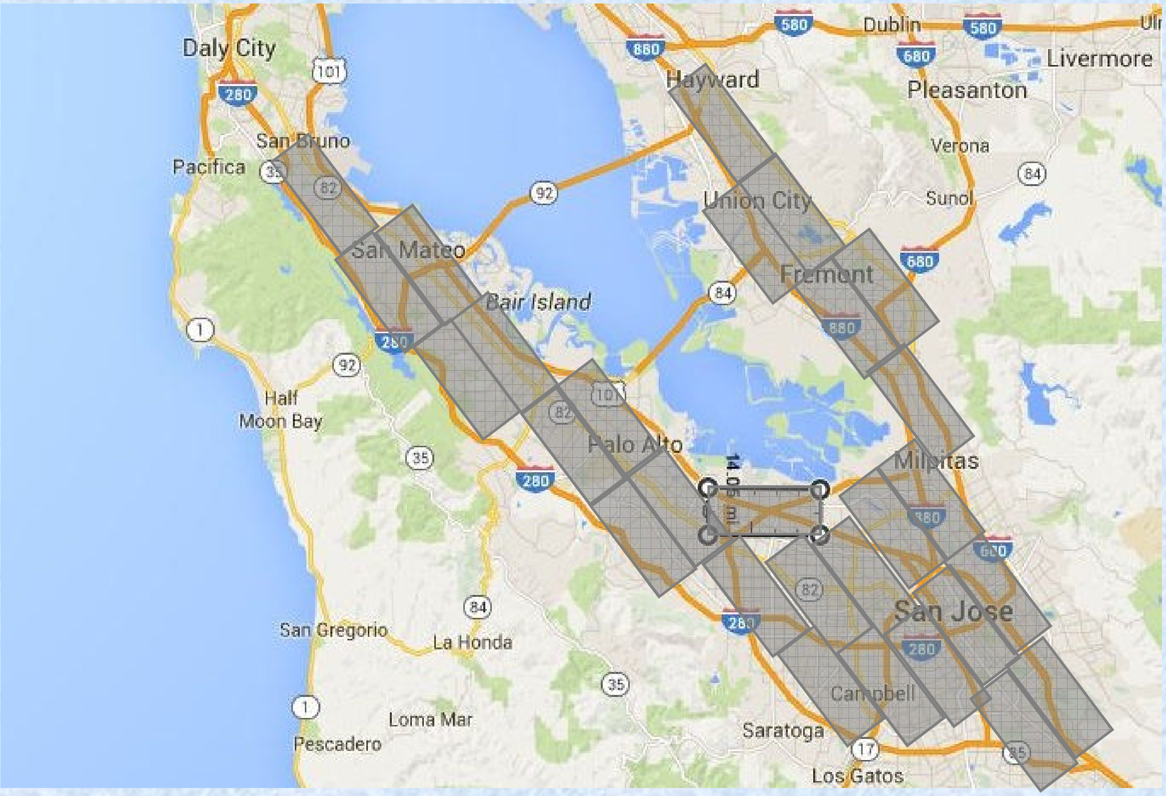
5 Miles

**Selection Criteria:**

- > 200 ft. diameter cloverleaf
- No obstructions

# AREA-WIDE ESTIMATE

280 Sq. Miles | 105 Intersections | 200 Potential Helipads




~1 mile average to nearest helipad

Note: nodal rather than path-based network resilient to local disruption

# VTOL - CAR URBAN COMPARISON

| | | Total Travel Time (minutes) | | |
|---|---|---|---|---|
| | | Car | | VTOL |
| **City 1** | **City 2** | **Non peak** | **Peak** | **Both** |
| Oakland | Stanford | 55 | 120 | 30 |
| Morgan Hill | Palo Alto | 45 | 120 | 34 |
| Half Moon Bay | San Francisco | 40 | 75 | 28 |
| Santa Cruz | Mountain View | 45 | 110 | 32 |
| San Francisco | San Jose | 55 | 90 | 34 |
| Fremont | Cupertino | 30 | 75 | 28 |
| Pleasonton | Sunnyvale | 40 | 100 | 30 |
| Walnut Creek | Daly City | 40 | 110 | 32 |
| San Rafael | Fremont | 55 | 110 | 36 |
| Mill Valley | Redwood City | 60 | 120 | 34 |
| **Average travel time** | | **47** | **103** | **32** |
| **Average VTOL benefit (minutes)** | | **15** | **71** | |

**VTOL assumptions**

- 1 ground mile at each end
- 5 minutes per transition
- Vertical departure and arrival transitions
- 200 mph cruise segment

**Longer trips**

Converges to >3.5x time reduction for longer trips

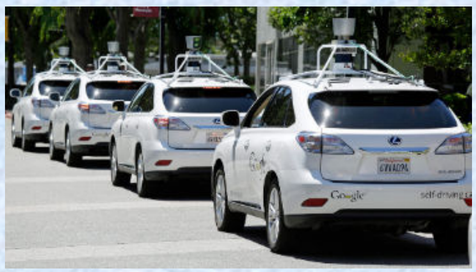
# WE'VE HEARD THIS FOR DECADES--
# THE BARRIERS ARE TOO HIGH!

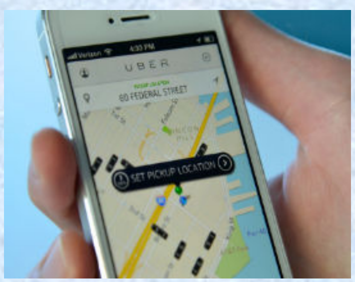
- Too expensive
- Not safe enough
- Community noise
- Hard to use
- Unreliable
- Uncomfortable
- Final mile problem
- Inefficient & high emissions
- Never certify
- Airspace integration
- …

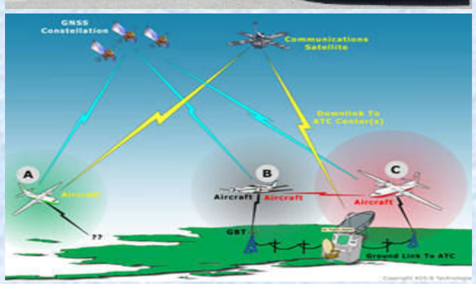
# ...CONVERGENCE OF DISTRIBUTED ELECTRIC PROPULSION & AUTONOMY IS WHY THIS IS POSSIBLE IN NEXT 10 YEARS

**Autonomy**
- Simplified vehicle operation
- High-density airspace
- Air & ground vehicle sharing

**Electric Propulsion**
- Scale-free
- Highly Redundant
- High power/weight
- Efficient configurations




# CURRENT & NEXT STEPS

**NASA**

- Partnering with MIT to investigate Los Angeles as another specific early adopter market
- More detailed demand model with validation from aggregate cell phone location data..
    - Assess the effects of the flown trajectories on existing air traffic using airspace simulation to determine airspace capacity limits for the region.
- FAA, Industry, NASA roadmapping to identify technology and certification requirements and gaps
- SCEPTOR Distributed-Electric Propulsion X-Plane
- Developing design for ultra-quiet VTOL and sub-scale prototype
- Facilitate leveraging of air and ground-vehicle technology, standards, research

**Industry**

- Early helicopter ride-sharing experiments
- Multiple, well-funded electric VTOL concepts currently in development including flight test
- VTOL X-Prize competition under development

# QUESTIONS?