SAE INTERNATIONAL

SILICON VALLEY AIR-TAXI STUDY

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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

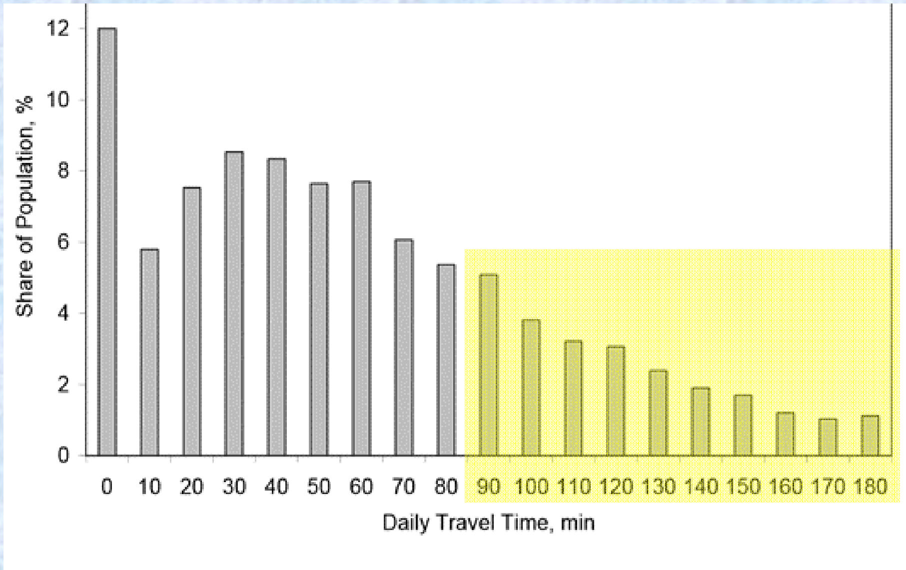
SILICON VALLEY CASE STUDY…

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

#1 IN COMMUTER TRAVEL DISTANCE AND TIME

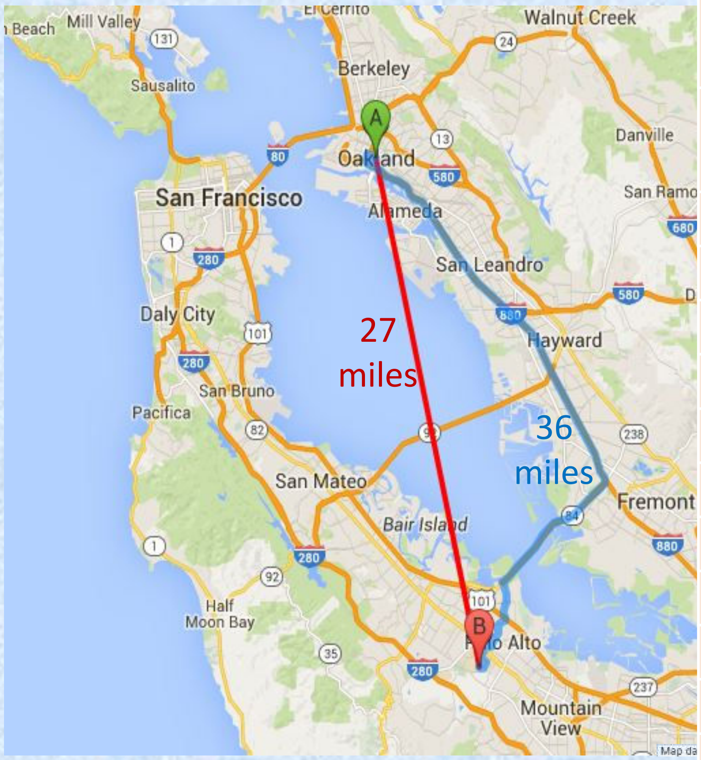
Metro Areas with Highest Mean Distance	Percent Mega Commutes
San Francisco-Oakland-Fremont, CA	2.06
San Jose-Sunnyvale-Santa Clara, CA	1.90
Salinas, CA	1.23
Gulfport-Biloxi, MS	0.94
Hinesville-Fort Stewart, GA	0.93
Lawton, OK	0.82
Fayetteville, NC	0.73
Brunswick, GA	0.64
Anchorage, AK	0.25
Honolulu,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



		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						
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						

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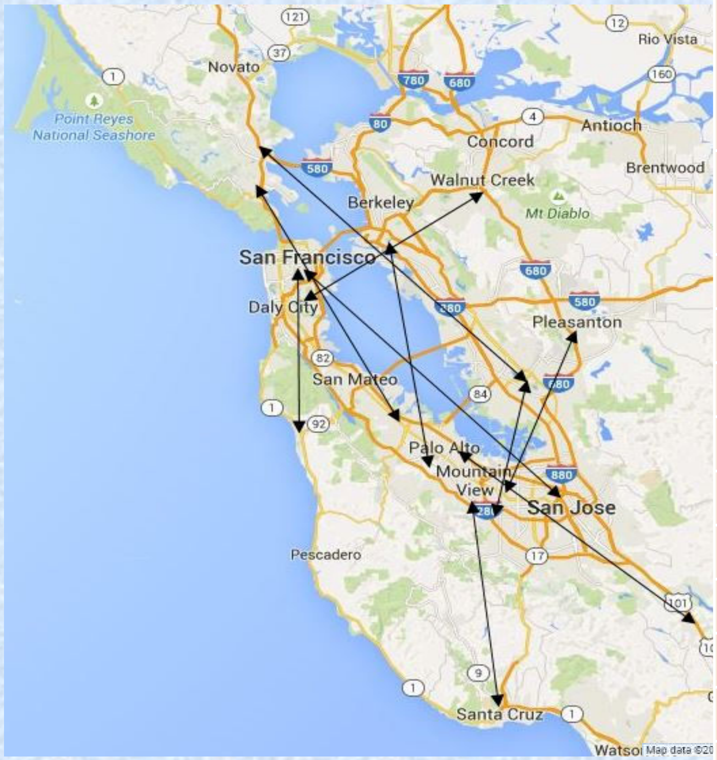
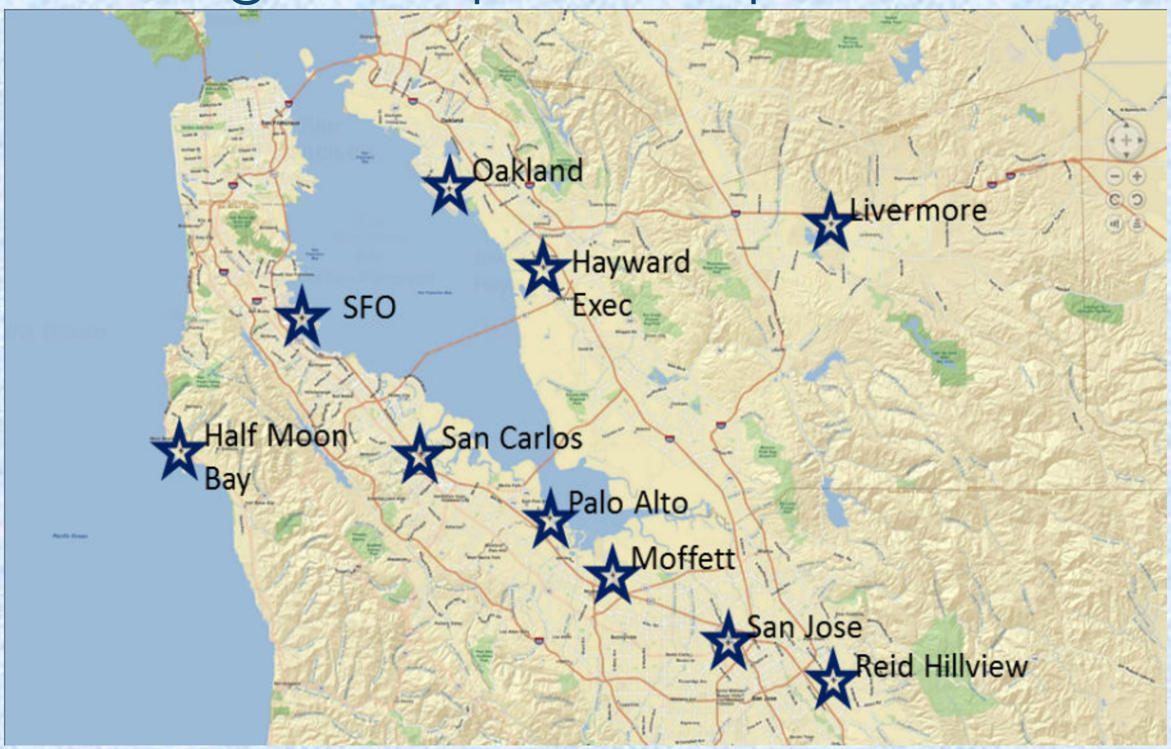


City 1	City 2	Direct Distance (miles)	Driving Distance (miles)	Average Speed (mph)		Ground Travel Time (minutes)	
				Non-Peak	Peak	Non-Peak	Peak
Oakland	Stanford	27	36	39	18	55	120
Morgan Hill	Palo Alto	34	38	51	19	45	120
H.M. Bay	San Fran.	22	30	45	24	40	75
Santa Cruz	Mt. View	29	36	48	20	45	110
San 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



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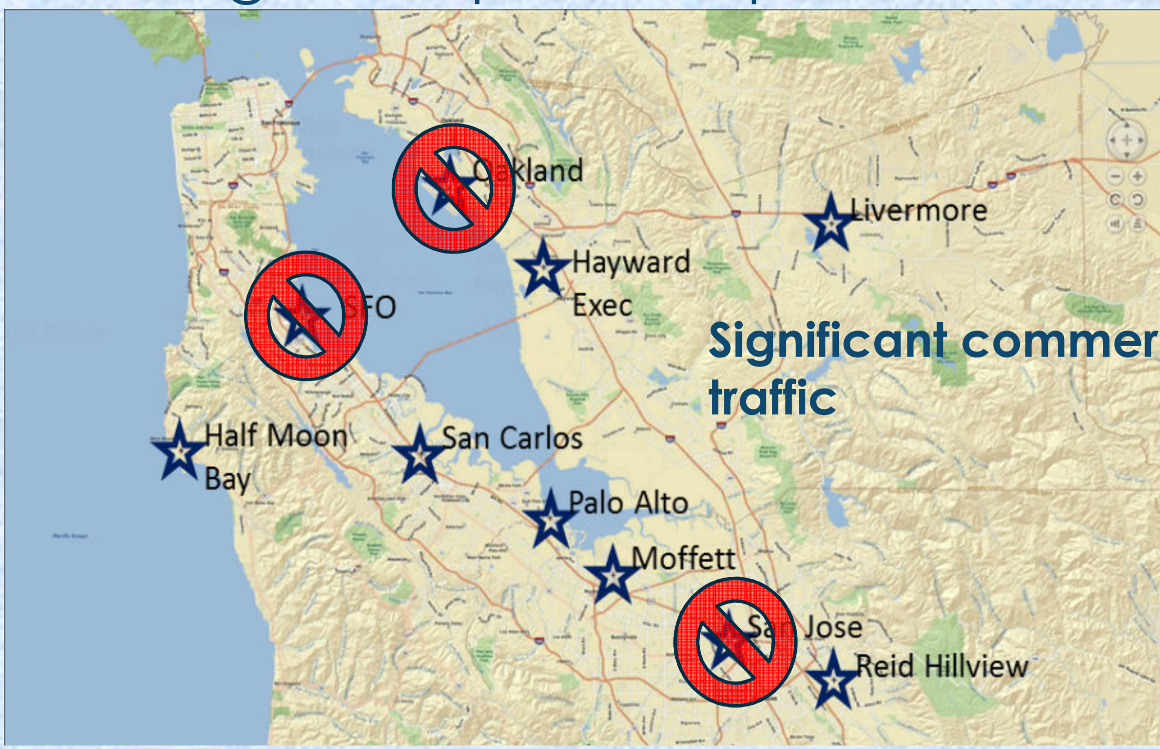


2 ground segments averaging 12 miles each

Significant commercial traffic

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

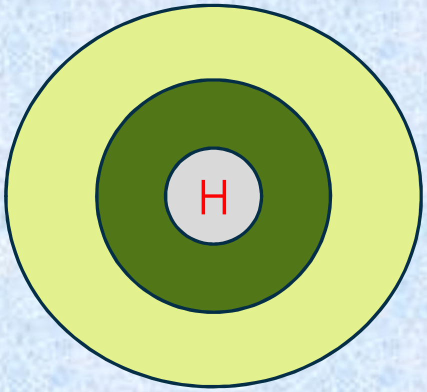
- 2 ground segments to best airports (average 12 miles)
- 5 minutes per transition (optimistic)
- 200 mph in-flight average

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

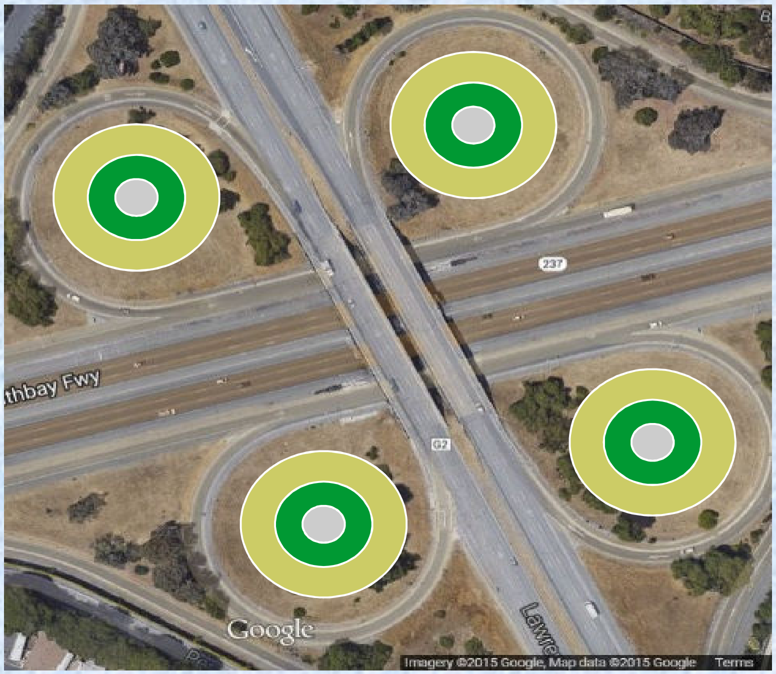
Potential CTOL, STOL, ESTOL, and VTOL infrastructure locations investigated, with a requirement to clear 500 ft above surrounding private property.

- 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

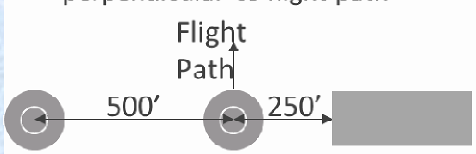


- Available DOT land resource provides approach/departure paths without overflight of private property at <500 ft.
- Existing high noise area that the community accepts with established setbacks
- Distribution that couples to existing ground roads for minimum travel time

POTENTIAL HELIPAD LOCATIONS, URBAN BARGES

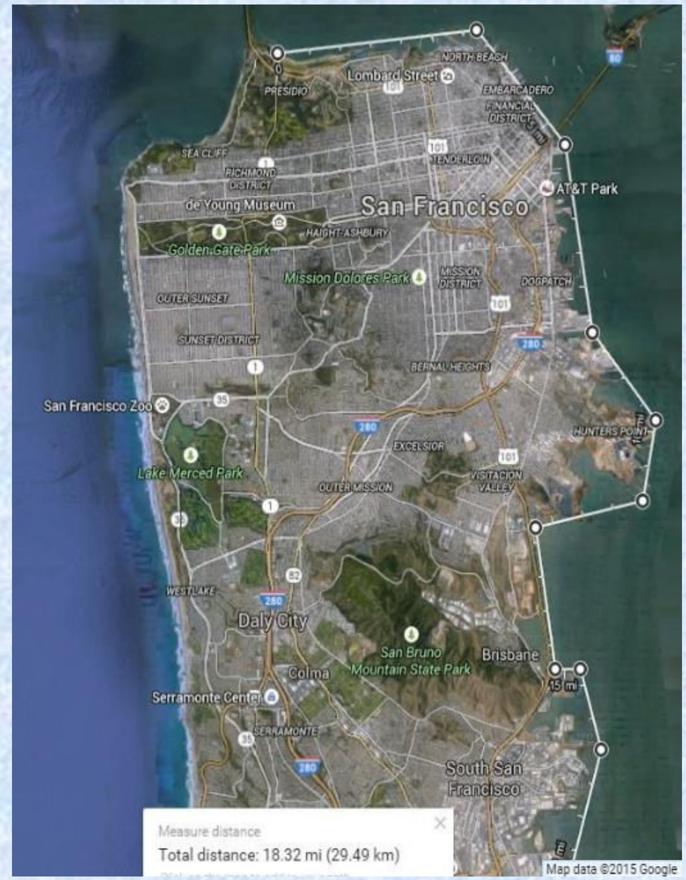
Selection Criteria:

- 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

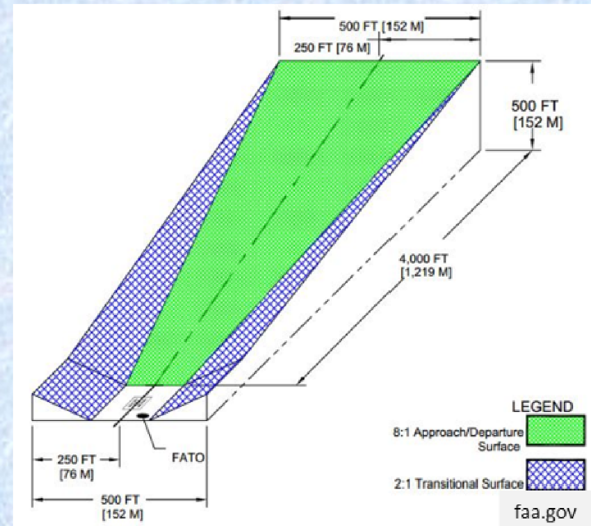


18 Coastal Miles,

50 Potential Helipads



POTENTIAL HELIPAD LOCATIONS, PRIVATE CAMPUS



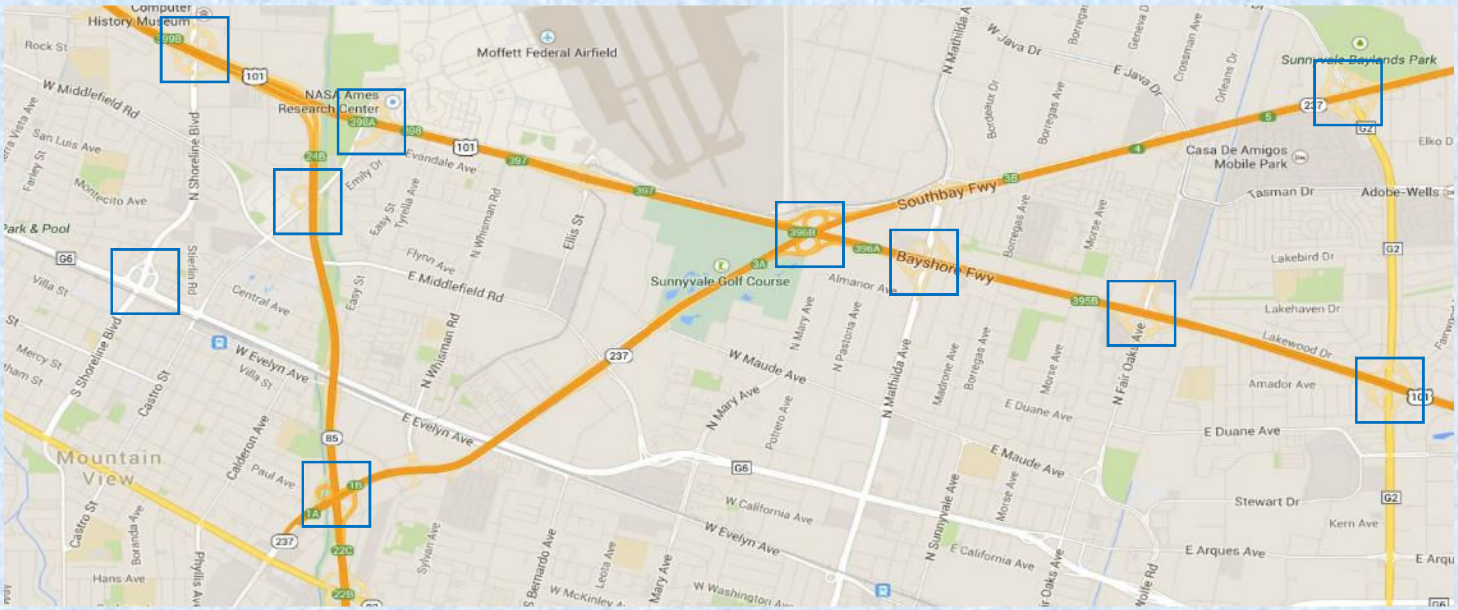
Additional Requirements:

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

AREA-WIDE ESTIMATE

10 Sq. Miles | 10 Intersections | 19 Potential Helipads

2 Miles



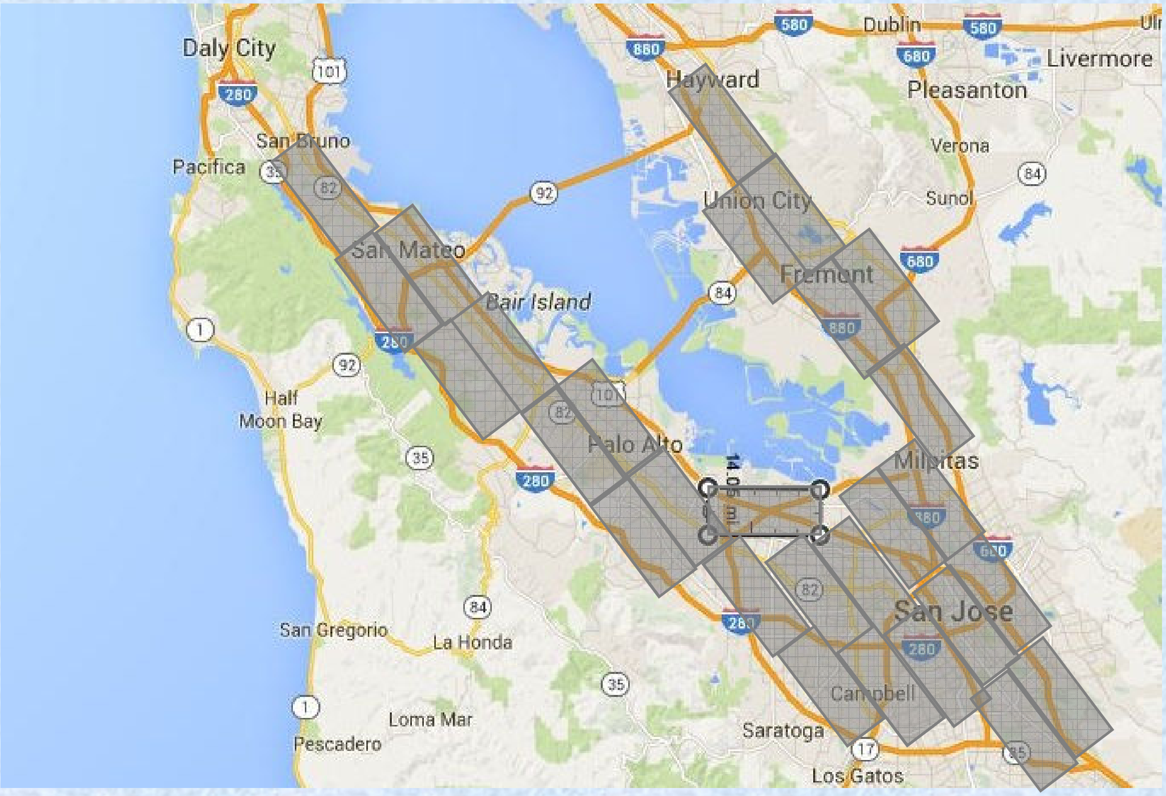
5 Miles

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

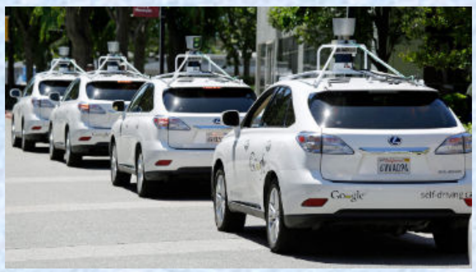
WE'VE HEARD THIS FOR DECADES-- THE BARRIERS ARE TOO HIGH!

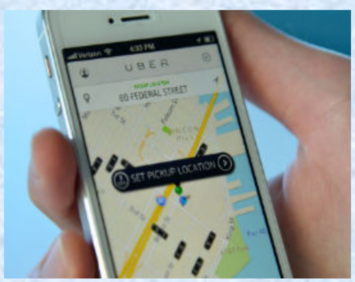
- Too expensive
- Not safe enough
- Community noise
- Hard to use
- Unreliable
- Uncomfortable
- Final mile problem
- Inefficient & high emissions
- Never certify
- Airspace integration
- …

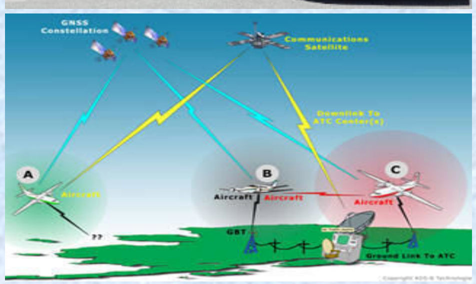
...CONVERGENCE OF DISTRIBUTED ELECTRIC PROPULSION & AUTONOMY IS WHY THIS IS POSSIBLE IN NEXT 10 YEARS

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?