

Scientific Data Drone Research @ The MESA Lab of UC Merced

YangQuan Chen, Ph.D., Director,
MESA(Mechatronics, Embedded Systems and Automation)**LAB**
ME/EECS/SNRI/HSRI/UCSolar, School of Engineering,
University of California, Merced

E: yqchen@ieee.org; *or*, yangquan.chen@ucmerced.edu

T: (209)228-4672; **O:** SE1-254; **Lab:** CAS Eng 820 (**T:** 228-4398)

Jan. 22, 2015. Thursday
FUEGO Symposium @ LBNL

Thanks

- Carl Pennypacker for invitation!



Skip Ad in 3 minutes

UC Merced



- The Research University of the Central Valley
- Centrally Located
 - Sacramento – 2 hrs
 - San Fran. – 2 hrs
 - Yosemite – 1.5 hrs
 - LA – 4 hrs
- Surrounded by farmlands and sparsely populated areas

UC Merced



- Established 2005
- 1st research university in 21st century in USA.
- 6,200 Undergraduates
- 300 Grads (200+ Ph.D)

- Strong Undergraduate Research Presence (HSI, MSI)



The MESA Lab

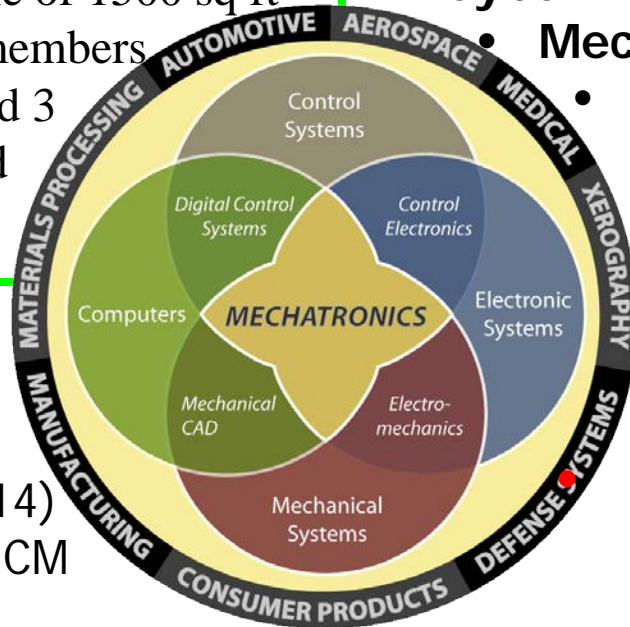
- **Mechatronics, Embedded Systems, Automation Lab**
- <http://mechatronics.ucmerced.edu>
- Lab Director: Prof. YangQuan Chen
 - Lab Manager: Brandon Stark
 - 6 Ph.D. Students
 - 1 MSc Student
 - 20+ Undergrads
 - 5 Visiting Ph.D. Students
 - 7 Visiting Professors/Scholars
- Unmanned Aerial Systems
- Cyber-Physical Systems
- Renewable Energy Systems
- Mechatronic Systems
- **Applied Fractional Calculus**



Mechatronics, Embedded Systems and Automation Lab

Real solutions for sustainability!

Established Aug. 2012 @ Castle of 1500 sq ft
6 Ph.D/1 MS/ 20+ undergrad members
12 visiting scholars || Sponsored 3 capstone projects and mentored 5+2 capstone teams (Sp'14)



Research Areas of Excellence:

(ISI H-index=32, Google H-index=56; i10-index=289)

- Unmanned Aerial Systems & UAV-based Personal Remote Sensing (PRS)
- Cyber-Physical Systems (CPS)
- **Mechatronics**
- **Applied Fractional Calculus Modeling and Control of Renewable Energy Systems**

Education and Outreach Activities:

- Eng Service Learning (Sp14)
- AIAA Student Branch @UCM
- UC Merced Preview Days
- "The Drone Age" @ Castle Air Museum
- Robots-n-Ribs| MESABox! ASME tutorials
- 8 capstone teams (45 seniors!) ...
- **ME142 Mechatronics** (take-home labs)
- **ME280 Fractional Order Mechanics**

Projects Related to San Joaquin Valley:

Energy [Solar energy, CPV, Building efficiency (HVAC lighting), smart grids integration, NG pipelines]

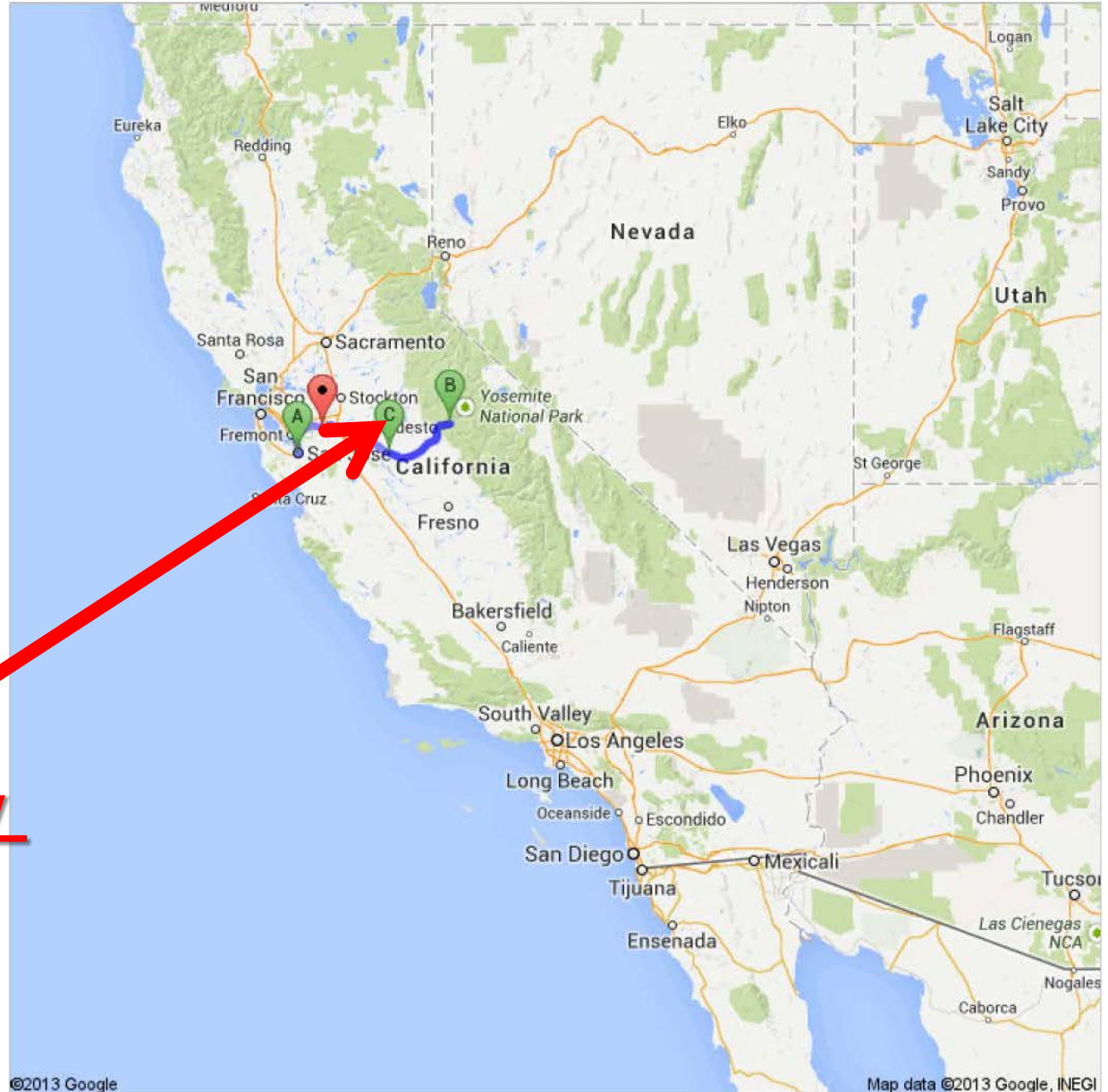
- **Water** (Water/soil salinity management, water sampling UAVs)
- **Precision Ag/Environment** (Crop dynamics, optimal harvest, pest ...)

MESA Lab Philosophy and Ambition

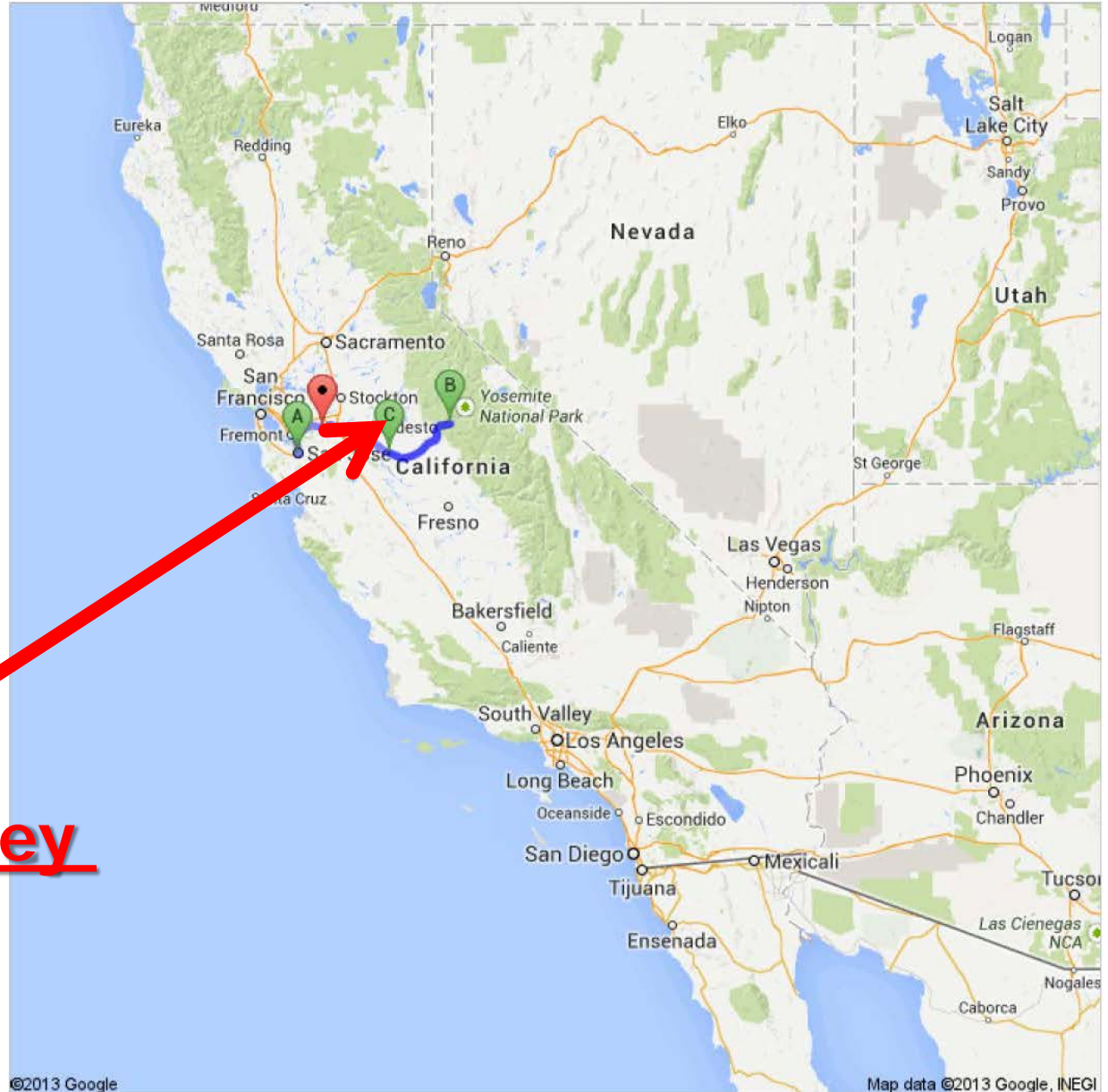
- *"We make real systems that work and others want them."*
- **MESA Lab: Staying on top and for sustainability.**
- Nationally and internationally visible and prominent!

Outline

- Our CIDER dream/vision/reality
- Drone Research Emphasis @ MESA Lab
 - Platform
 - Sensing Payload
 - Actuation Payload
 - Down-stream Processing
 - Smart sensing and actuation policies
- Why us, why here and why now



Ag Drone Valley



Data Drone Valley



Data Drone Valley

UCCE + MESALAB = ?

<http://cemerced.ucanr.edu/>

+ <http://mechatronics.ucmerced.edu/>

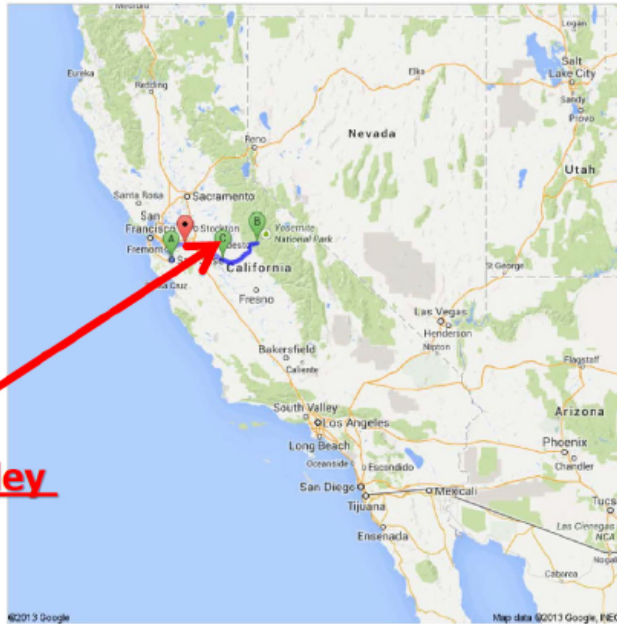
= Ag Drone Valley (~~fractional~~)

We got funded for 5 years!

UC ANR Seed Grant \$279580; (170 to 70 to 15, **competitive**)

CIDER

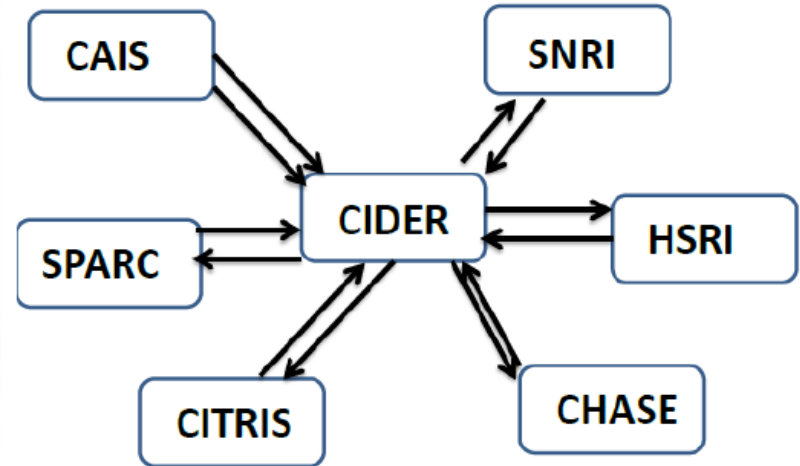
- California Institute of Drone Engineering Research (CIDER)
- Strategic Academic Focusing Initiative
- Our faculty-focused development of a strategic academic vision
- Resulted Funding Proposals
 - NSF NRI
 - CITRIS
 - NSF LTREB



Data Drone Valley

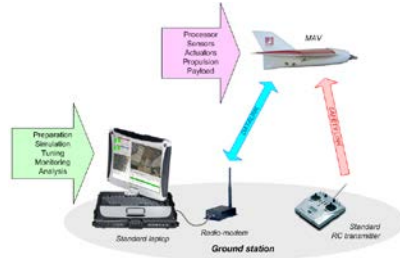
10/05/2013

Robotics&Ribs@MESALAB@UCMerced Symposium



- CIDER:** California Institute of Drone Engineering Research
- CAIS:** Center for Autonomous and Interactive Systems
- SNRI:** Serra Nevada Research Institute
- HSRI:** Health Systems Research Institute
- CHASE:** Center for Human Adaptive Systems and Environment
- CITRIS:** Center for Info Tech Research in the Interest of Society
- SPARC:** Spatial Analysis and Research Center

UC Multi-campus Synergy on CIDER



UCM, UCSC,UCB, UCSD, LLNL

CIDER in Scientific data-drones: platforms, operation, and certification



UCM
UCD
UCSD

CIDER in precision agriculture



UCM
UCD
LBL
SNL
UCSD

1/22/2015

Scientific Data Drone Research
Overview of MESA LAB's Unmanned

CIDER in environmental monitoring: water, fire, soil, air ...

CIDER as an economic amplifier



CIDER as a data-drone workforce foster



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Platforms

- VTOL
 - Y3 rotor
 - Y6 rotor
 - Quadrotor
 - Hexarotor
- Fixed-Wing
 - Battery (AggieAir)
 - Gas engine (MESAKit, MCRC's)

UAS (Remote) Sensing Payloads

- MET (temperature, humidity, wind)
- AQ (PM/CO₂, microbials etc)
- Lidar
- RGB
- NIR
- TIR
- SWIR
- ?? Salinity ?? Valley Fever ??

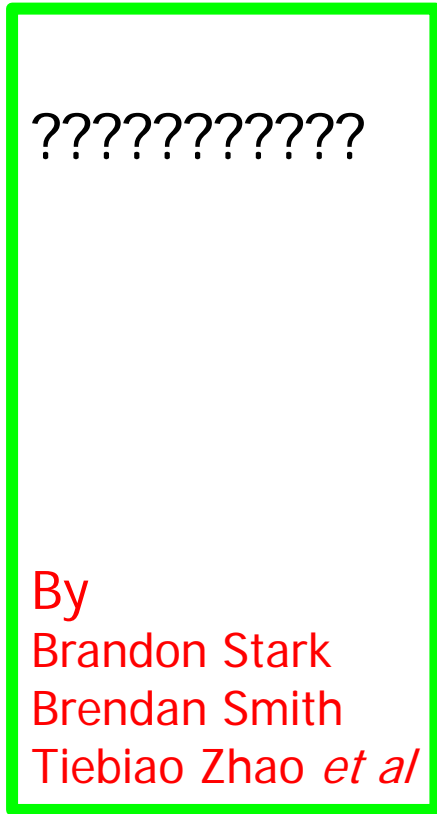
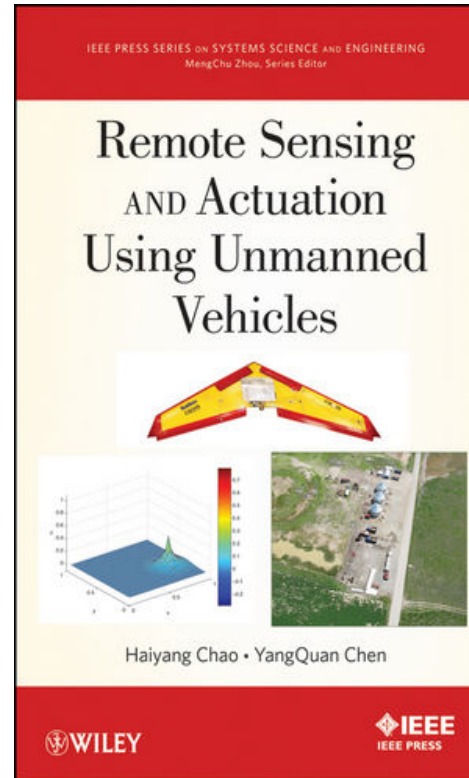
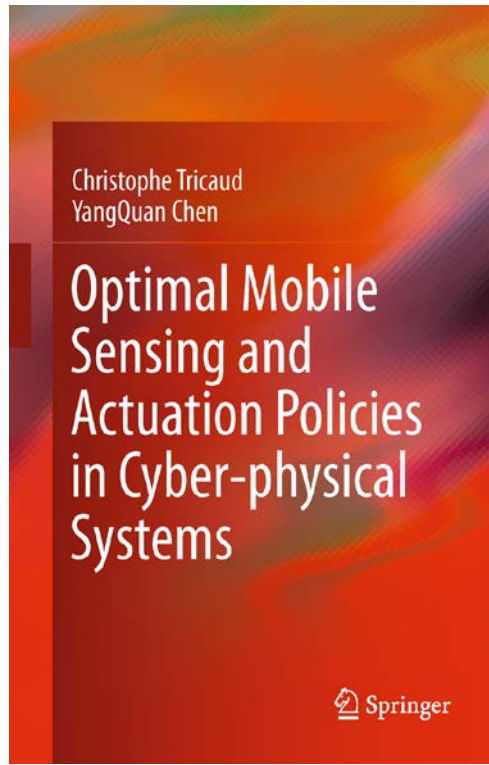
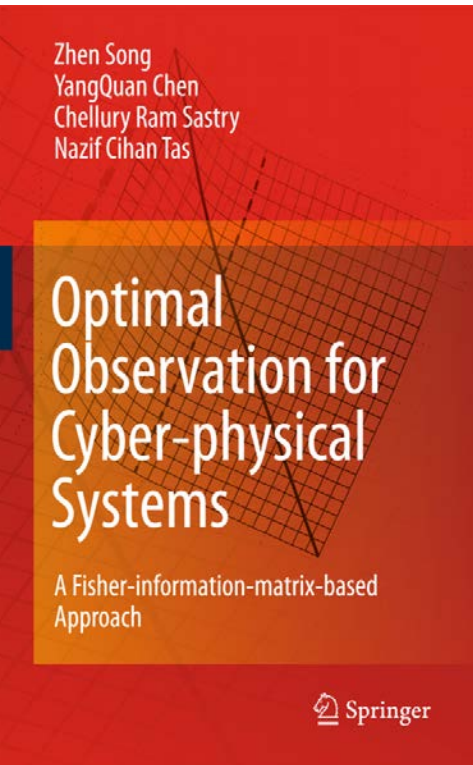
UAS (Remote) Actuation Payloads

- (Precision Spot) Drone Sprayer (crop-dusting)
- Seeding
 - Seeding errors cost extra water + fertilizer + herbicides + pesticides.
- Acoustic deterrent (loudspeaker)
- ?? Remote application
- Variable rate Applications (VRA)

Down-stream Processing

- NDVI
- Other indices
- Crop stress (water, nutrient, frost, heat, pest)
- 3D elevation map
- Variability maps
- VRA (variable rate application)

Smart sensing and actuation policies



Outline

- ▶ Our CIDER dream/vision
- ▶ Drone Research Emphasis @ MESA Lab
 - Platform
 - Sensing Payload
 - Actuation Payload
 - Down-stream Processing
 - Smart sensing and actuation policies
- ▶ Why us, why here and why now

Why us, why here and why now

- ▶ FAA COA (Nov. 2013, 6 approved totally, many pending); NSF RAPID grant (2011-2012)
- ▶ NASA UAS2NAS grant (2011-2014)
- ▶ **UC ANR grant (2014-2019)**
- ▶ AggieAir (2006-2012) commercialization ready
- ▶ ICUAS Executive Committee, ICUAS14 General Co-Chair
- ▶ Unmanned Systems journal founding AE
- ▶ JINT (Springer) Senior Editor; IEEE AR UAV TC Co-Chair
- ▶ FAA UASTSS proposal team member
- ▶ FAA COE proposal team member
- ▶ UAV Handbook (Springer): two chapters from MESA LAB.
- ▶ UAV Engineering Service Learning @ UC Merced (2014-)
- ▶ Past two capstone projects with PG&E sponsorship (2013)

Why us, why here and why now

- ▶ UC Merced: 1st research university in the 21st century in US
- ▶ Strong institutional support (CIDER vision, UC Merced 2020)
- ▶ Strong community support (UCCE, MCRC)
- ▶ Strong student base (mechatronics, robotics, ME/CS)
- ▶ Strong research track record with leading roles in the field
- ▶ Strong engineering hands-on and team work spirit
- ▶ Strong partnership with Utah State's AggieAir
- ▶ Strong vision towards democratic data drone use
- ▶ Idea testing sites (UC NRS, Vernal Pool NR of UC Merced, 2nd FAA COA approved!!)

Why us, why here and why now

- ▶ Wright Brothers 2.0; drone age
- ▶ 2015 FAA will open NAS for commercial use of drones
- ▶ Low cost and high reliability is both possible
- ▶ Privacy aware practice is maturing;
- ▶ MESA LAB has established now as a drone research hub in Central Valley and nationally and internationally visible.
- ▶ New Ph.D. students are going through the learning curves and ready to contribute to new challenges.

UCMERCED

University of California,
Merced

Brief Description of MESA Lab's Scientific Data-Drone Platform Capacities

10/20/2014

Contact: Prof. YangQuan Chen, yqchen@ieee.org

Lab Web:

<http://mechatronics.ucmerced.edu/research/unmanned-aerial-systems>

Fixed-Wing Platform (AggieAir)

Total Weight	12 lbs
Wingspan	8 ft
Max Flight Time	60 minutes
Typical Flight Altitude	300 - 1500 ft
Max Altitude	3200 ft
Typical Flight Area Coverage	700 acres
Max Flight Area Coverage	2000 acres
Typical Payload	VIS Camera NIR Camera
Max Payload Capacity	2.5 lbs
VIS-NIR Resolution	2.5" - 12"
Thermal Resolution	12" - 60"



Multi-Rotor UAS Platforms

- Single or dual camera mobile sensing platforms
- Best utilized for small areas



Flight Time	10-15 minutes
Max Payload	1 lb
Max Flight Altitude	150 ft
Typical Flight Coverage	20 acres
VIS-RGB Resolution	< 1/4"

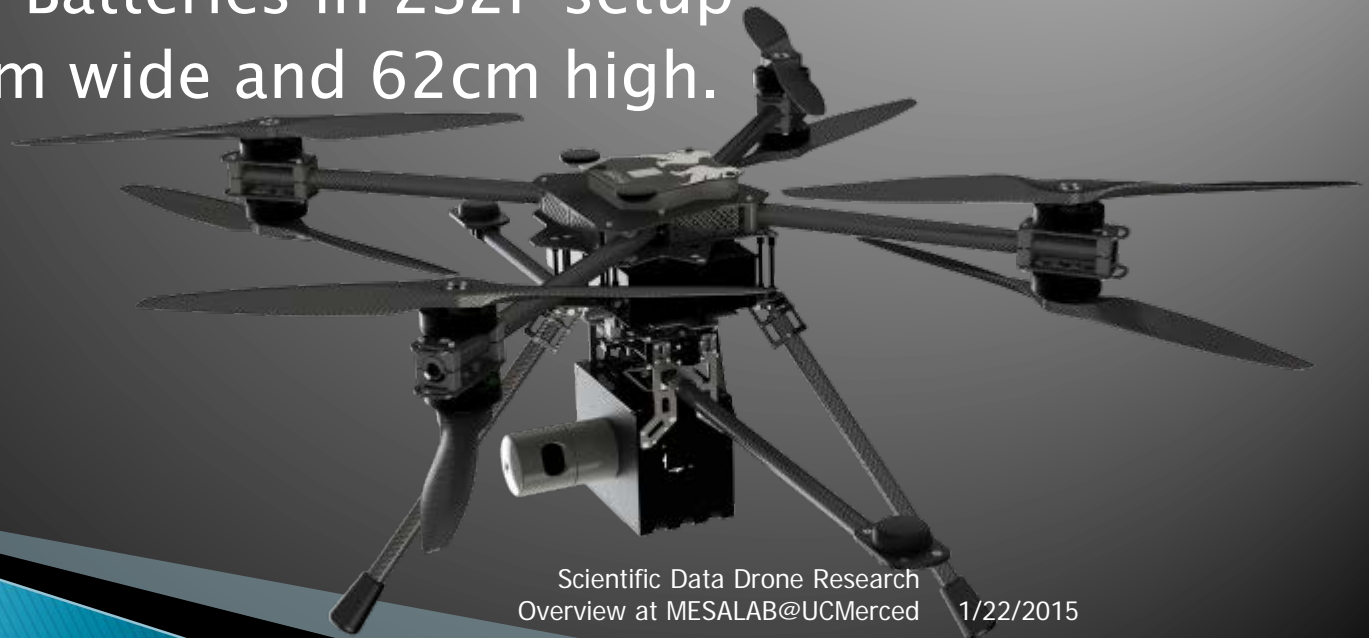
Other UAS Platforms @ MESA LAB (Water drone, soil co-physicist)



Imaging Systems	Point Sampling Systems
Thermal Camera ⁺	Water Collection Sampler*
Narrow-Band Imager*	Air Quality Sampler*
SWIR Imager	Soil Collection Sampler*

Lidar Remote Sensing Drone Platform (since 2014 Oct.)

- ▶ Aerial LIDAR2 (AL2). (5.8Kg payload package)
- ▶ UAV platform (7Kg + 8 Kg batteries)
 - 70cm (28 in) propellers for a highly efficient propulsion, improving payload vs. flight-time characteristics
 - 4 6S 16Ah Batteries in 2S2P setup
 - 150*150cm wide and 62cm high.



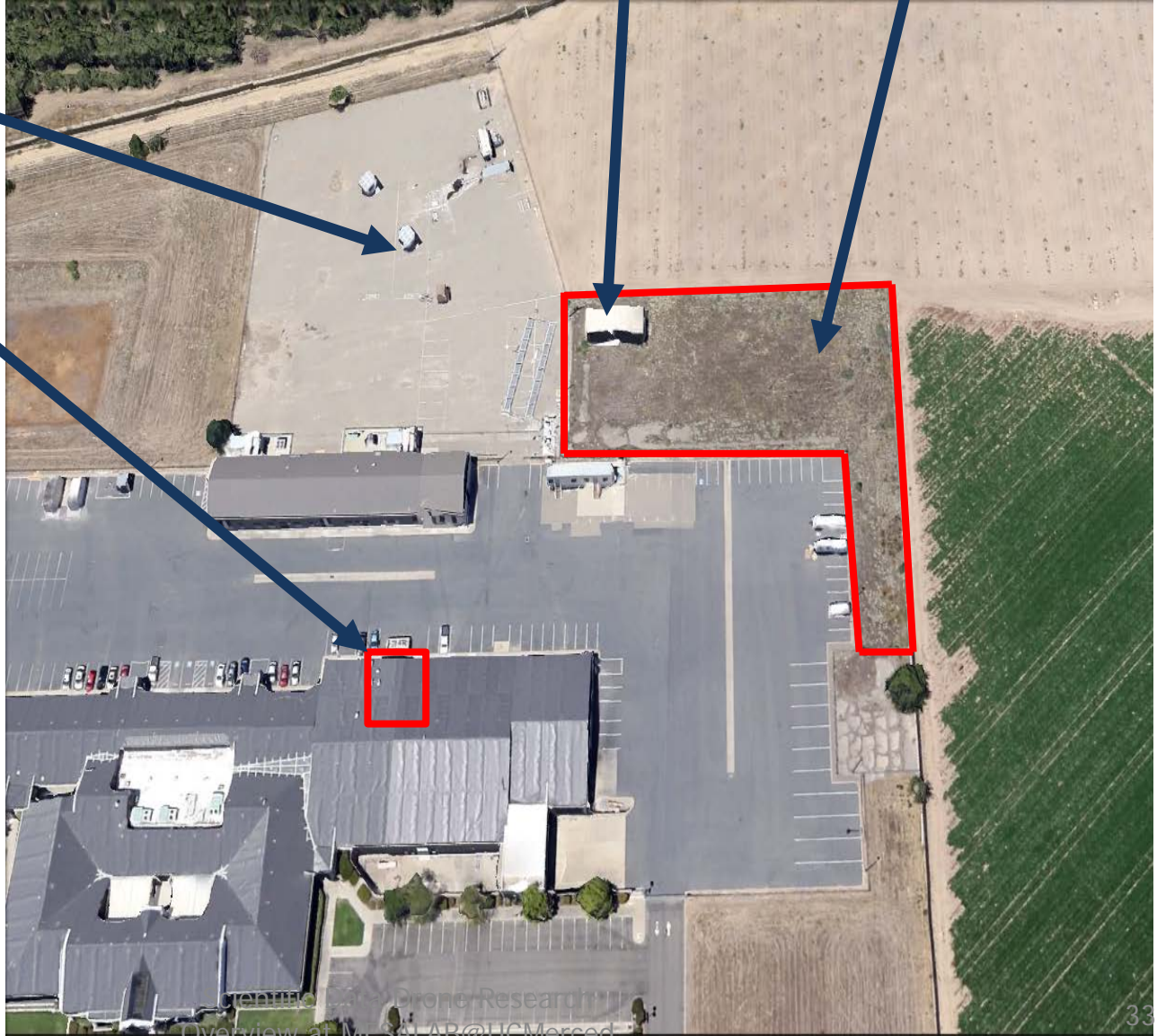
UC Merced Castle Research Facility

Scientific Data-
drone Hangar

MESA Lab @ UC Merced
Scientific Data-drone Test
Site (official since 7/24/14)

UCSolar.org

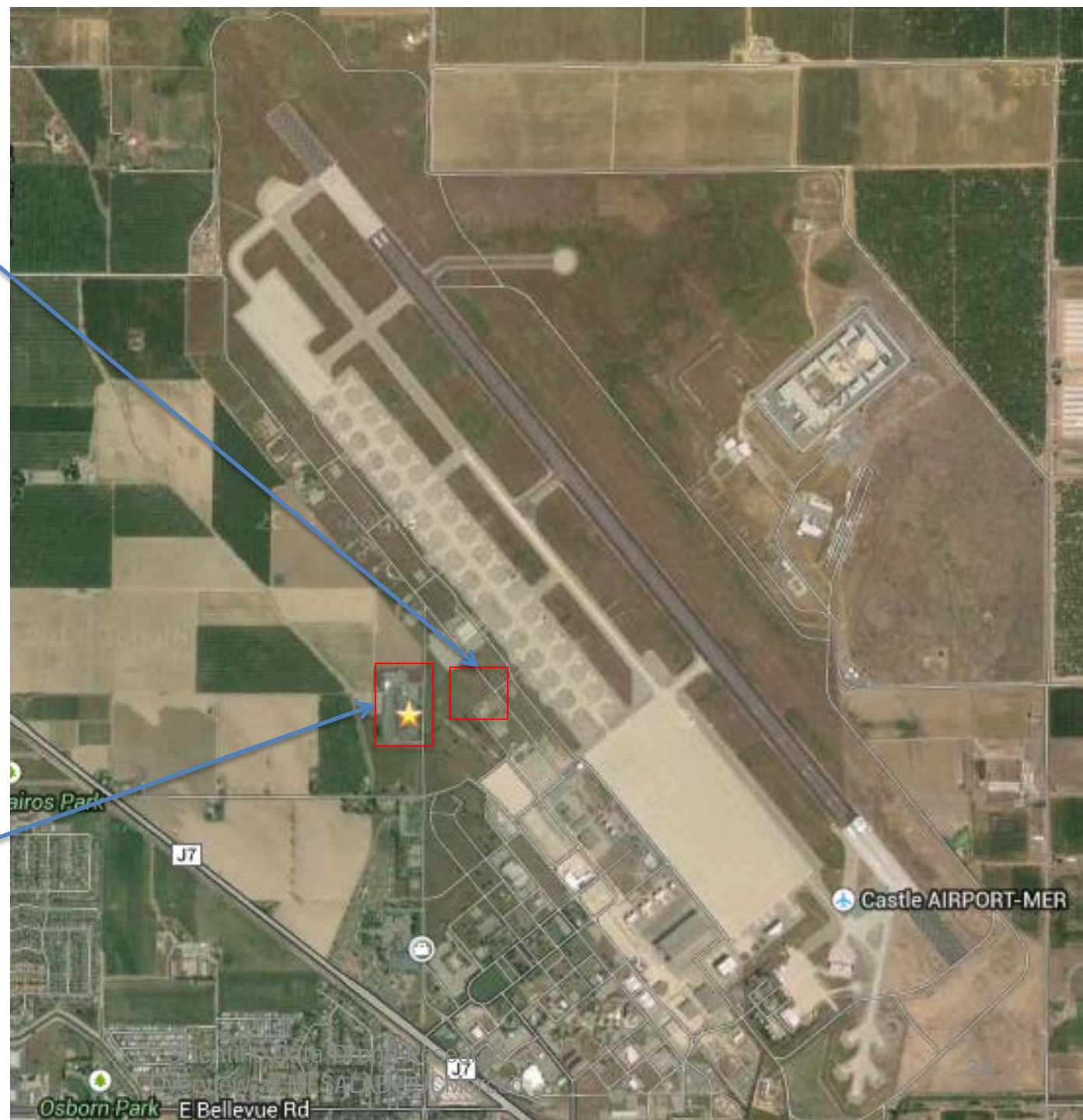
MESA Lab



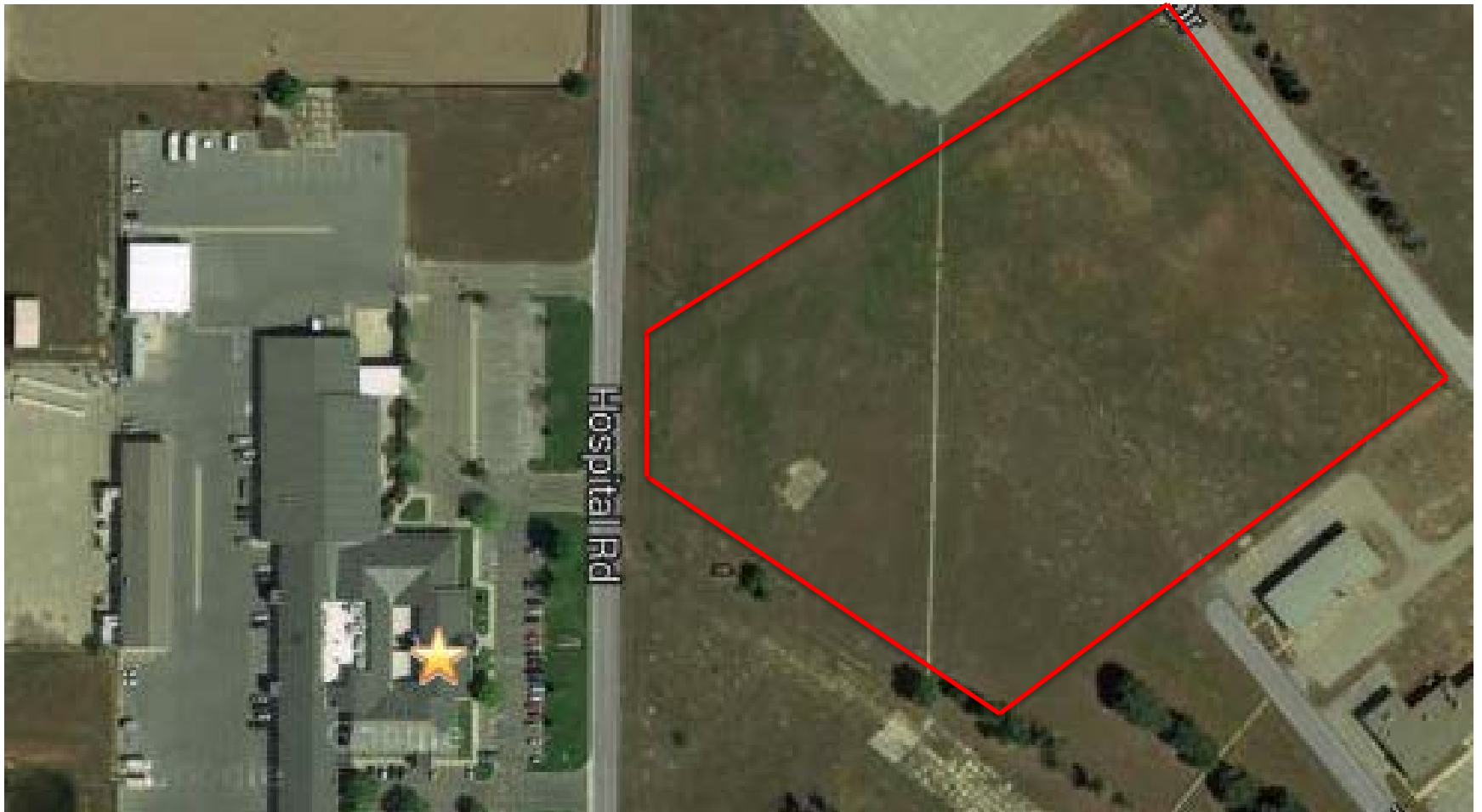
Castle Park Flyer Zone

**UC Merced Castle
Research Facility**

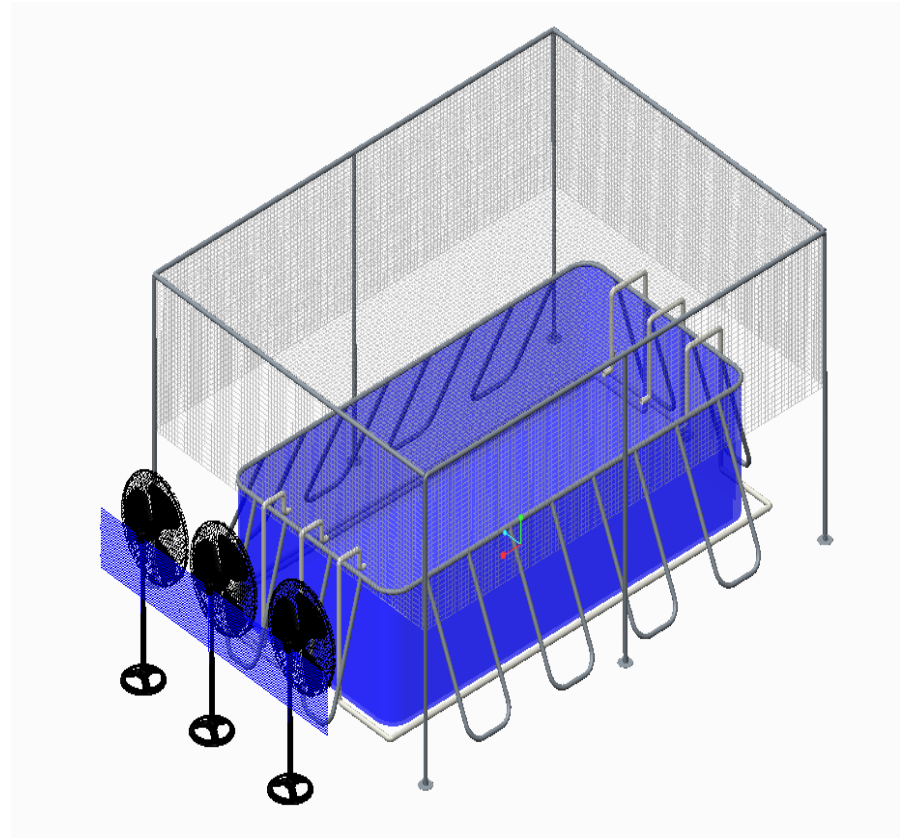
**Addr: 4225 Hospital
Road, Atwater, CA
95301**



Castle Park Flyer Zone



CITRIS funded scientific water quality (eDNA) drone Test Platform Design - Assembly

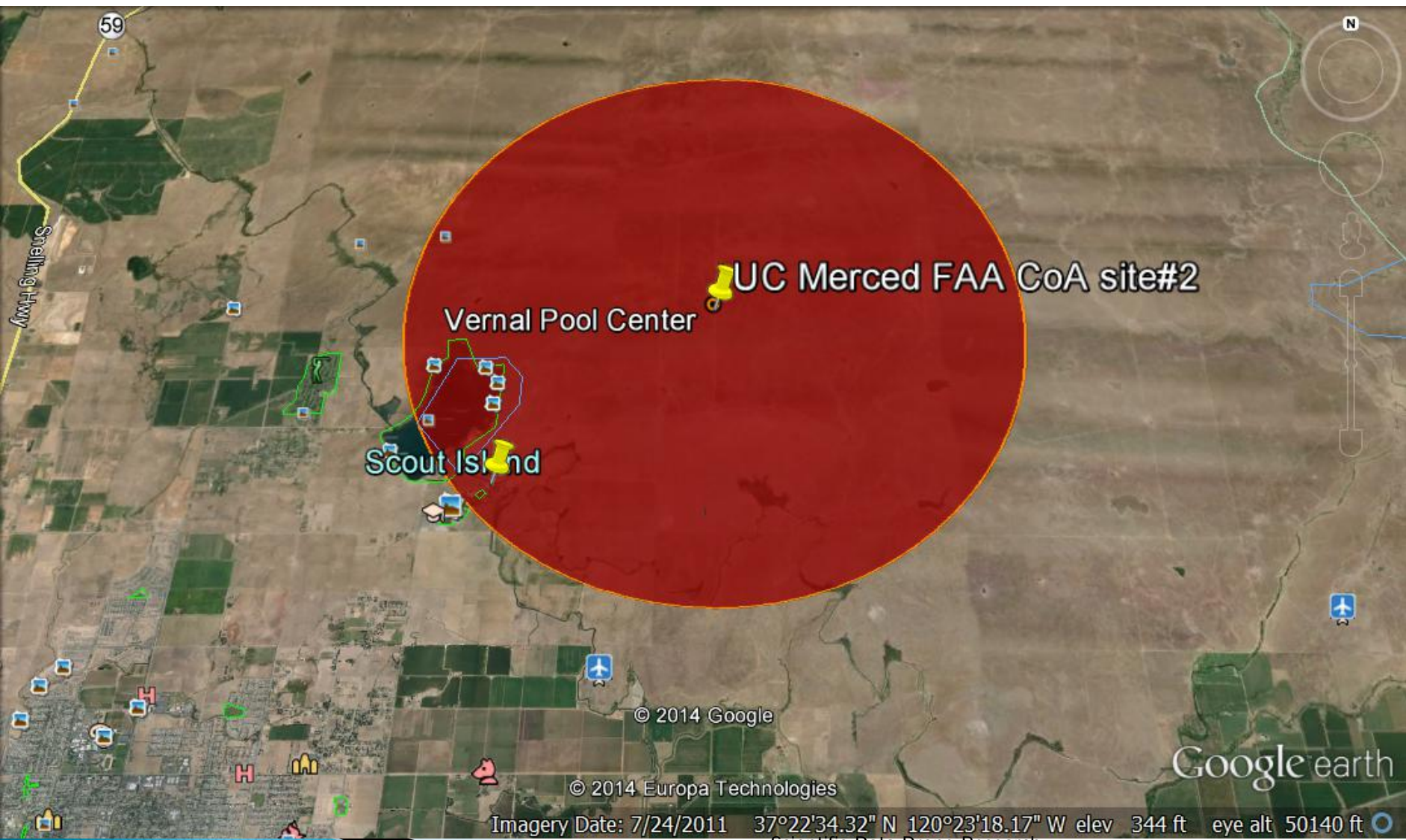


1st FAA CoA Site – UC Merced



2nd FAA CoA Site – UC Merced

(26 square miles in red, 2.5 nautical mile in radius)



© 2014 Google
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Imagery Date: 7/24/2011 37°22'34.32" N 120°23'18.17" W elev 344 ft eye alt 50140 ft

MESA Lab @UC MERCED's Role in FUEGO

- ▶ Optimal multi-resolution information fusion
 - Dynamic-resolution on demand (?)
- ▶ Groundtruthing
 - Payload studies: TIR/SWIR/NIR
 - FAA COAs, Drone test-site
- ▶ UAS operation
 - training/certification/risk assessment
- ▶ FUEGO Workforce/Outreach