The Art of Maintaining a Microwave-Based Internet Link Across an Ever-Changing City Skyline

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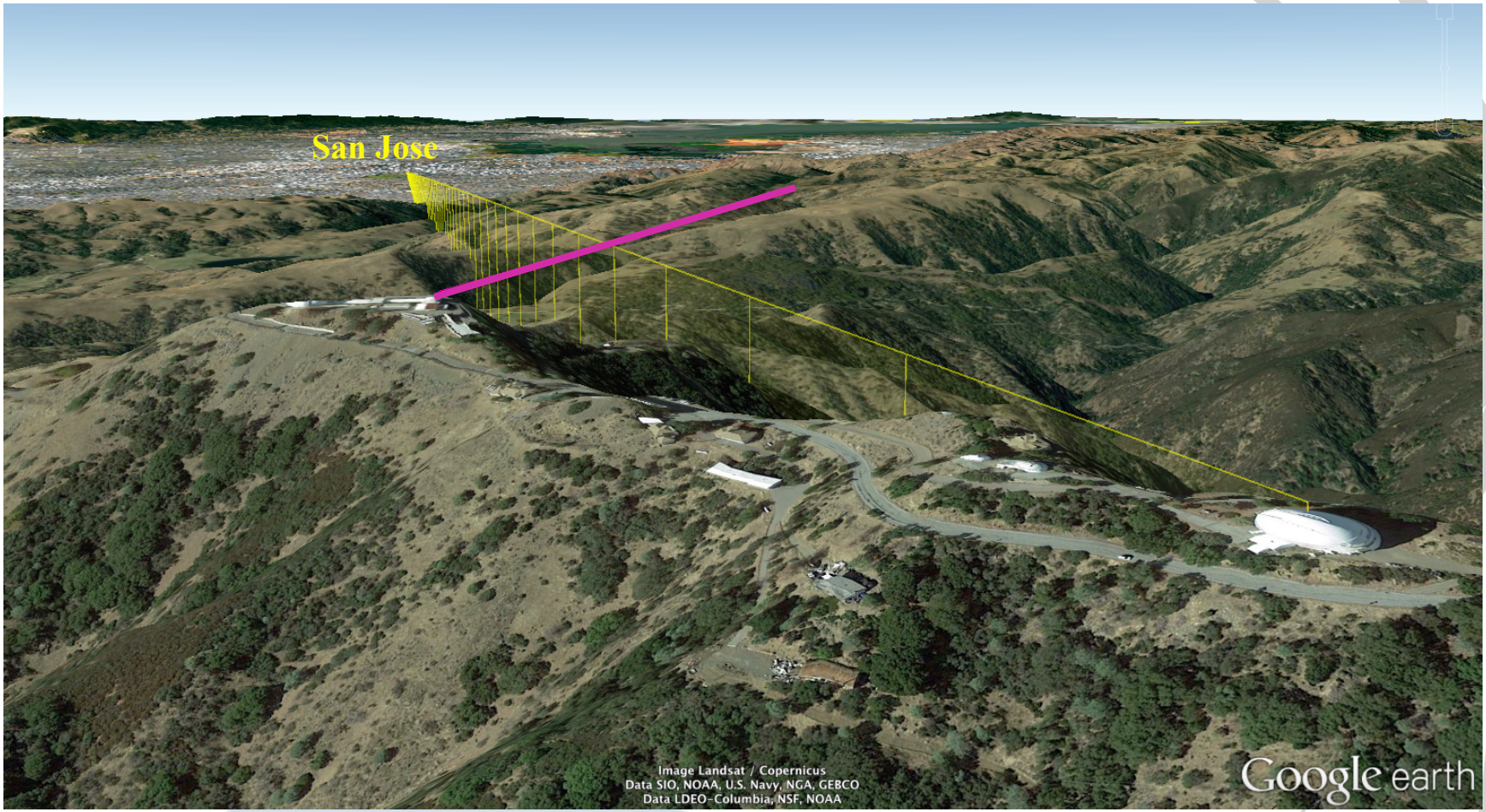
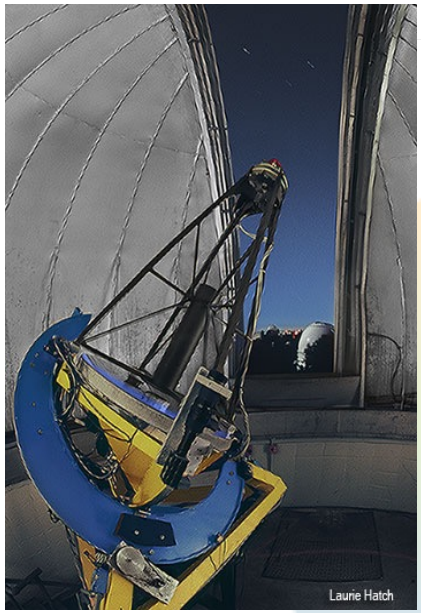
Introduction



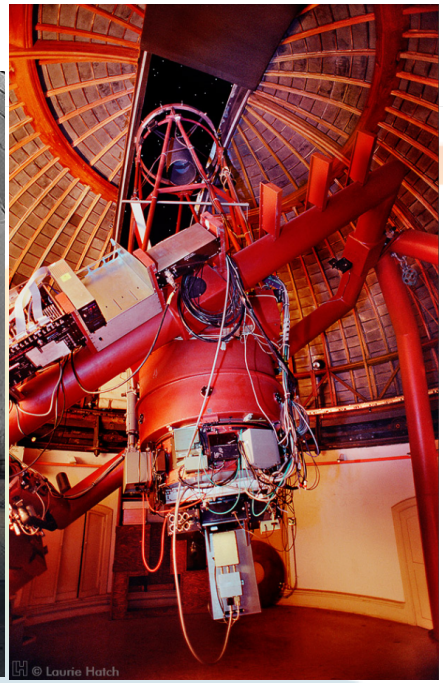
Lick Observatory, Mt. Hamilton, California

Remotely-accessible Lick Telescopes and Instruments

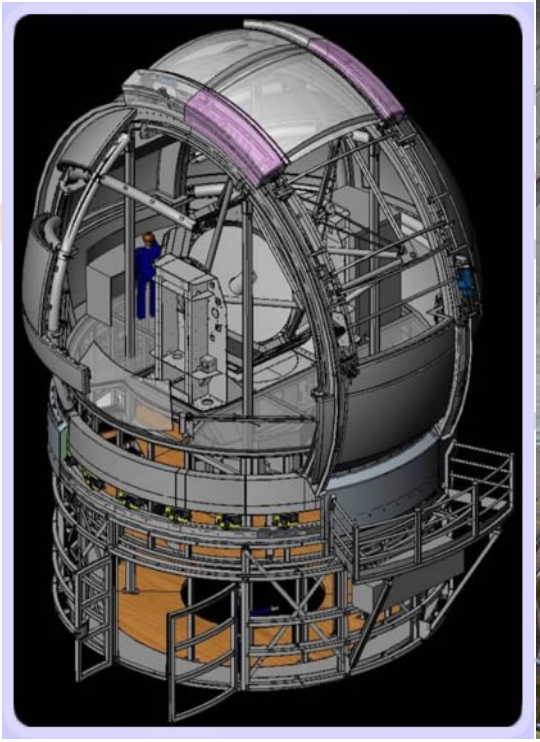
KAIT 0.6-m



Nickel 1.0-m



APF 2.4-m



Shane 3.0-m

Observations conducted from remote control rooms on campus

Mt. Hamilton is one of the highest points in the SF Bay Area

- Lick Observatory (elevation 4235')
- 20 miles east of San Jose

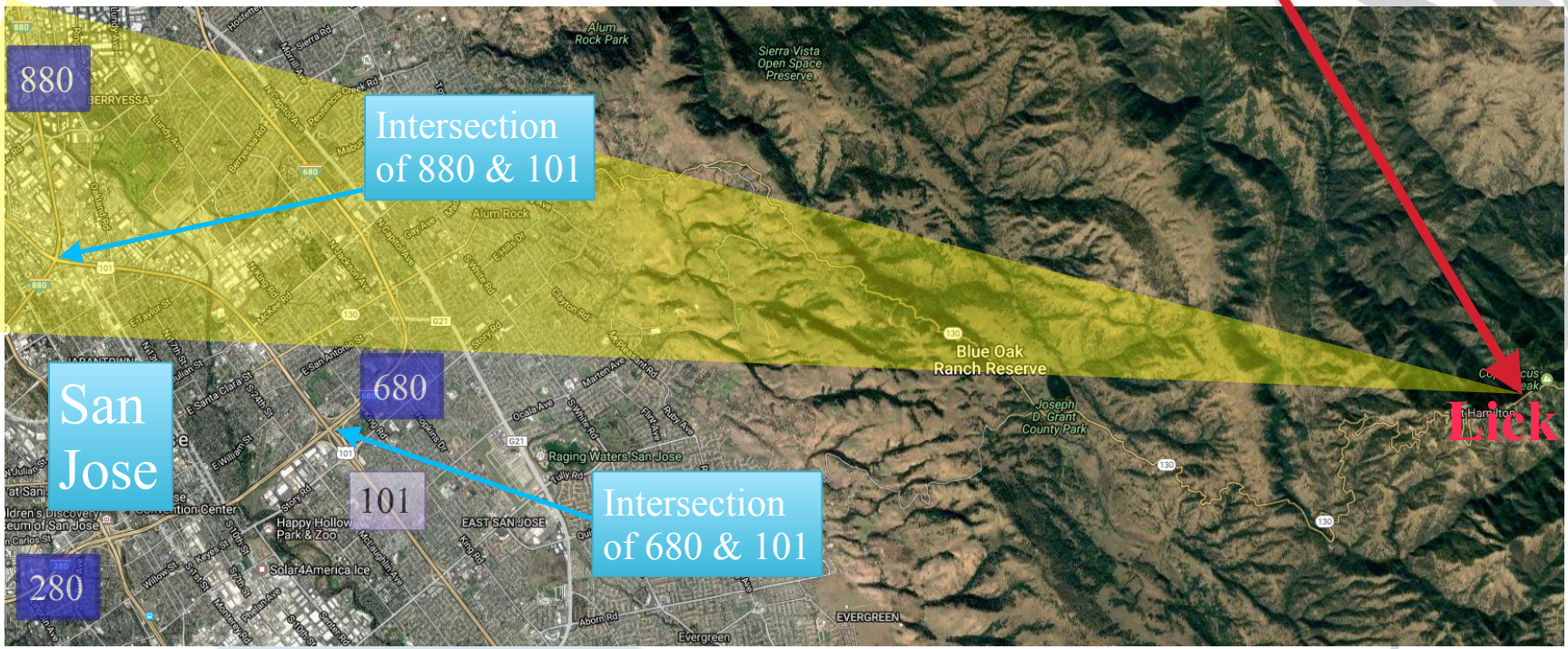
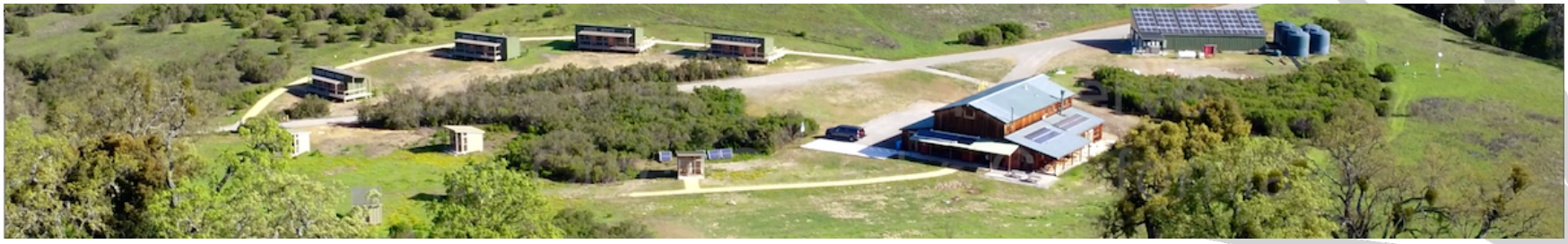


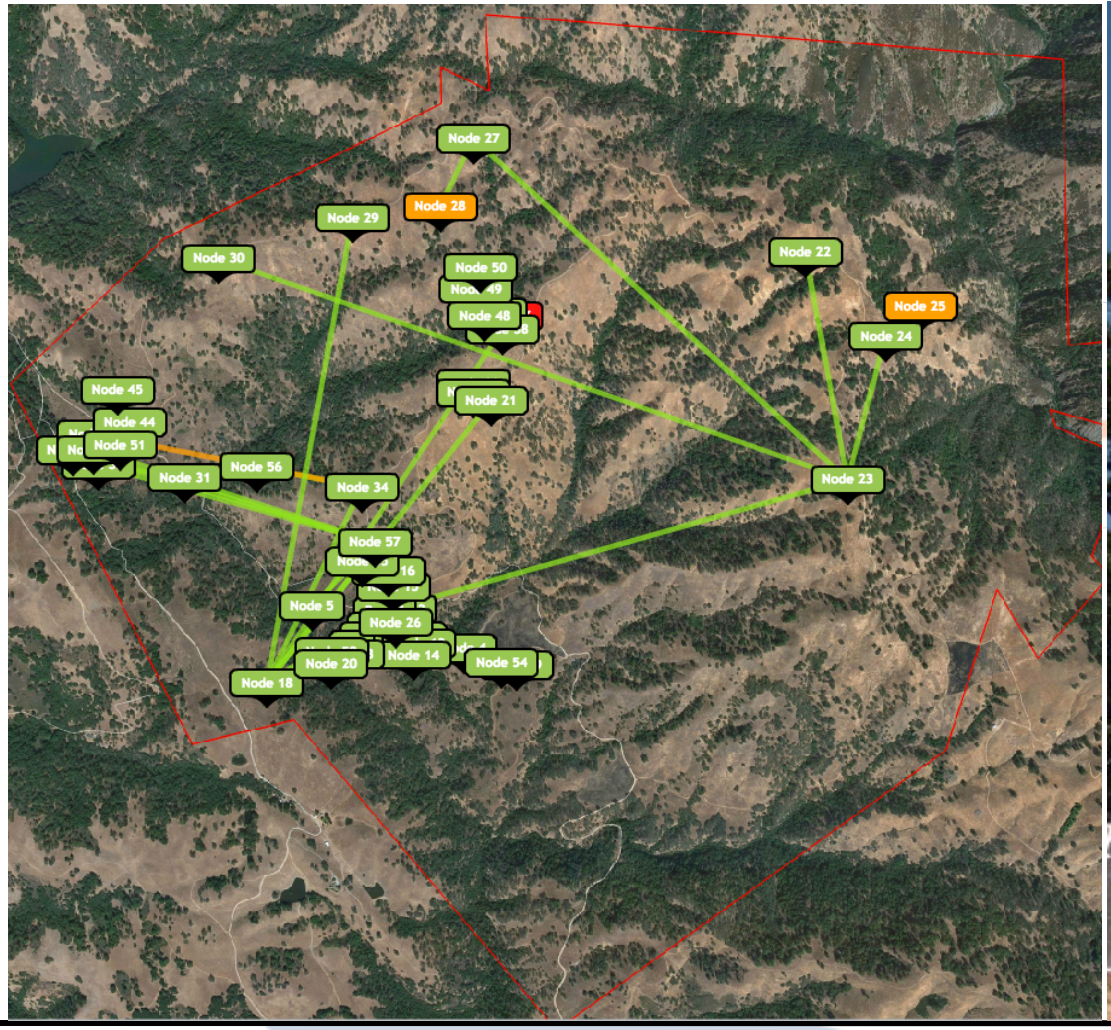
Image from Google Maps

The Blue Oak Ranch Reserve (BORR)

Field station provides lodging, classrooms, offices & labs

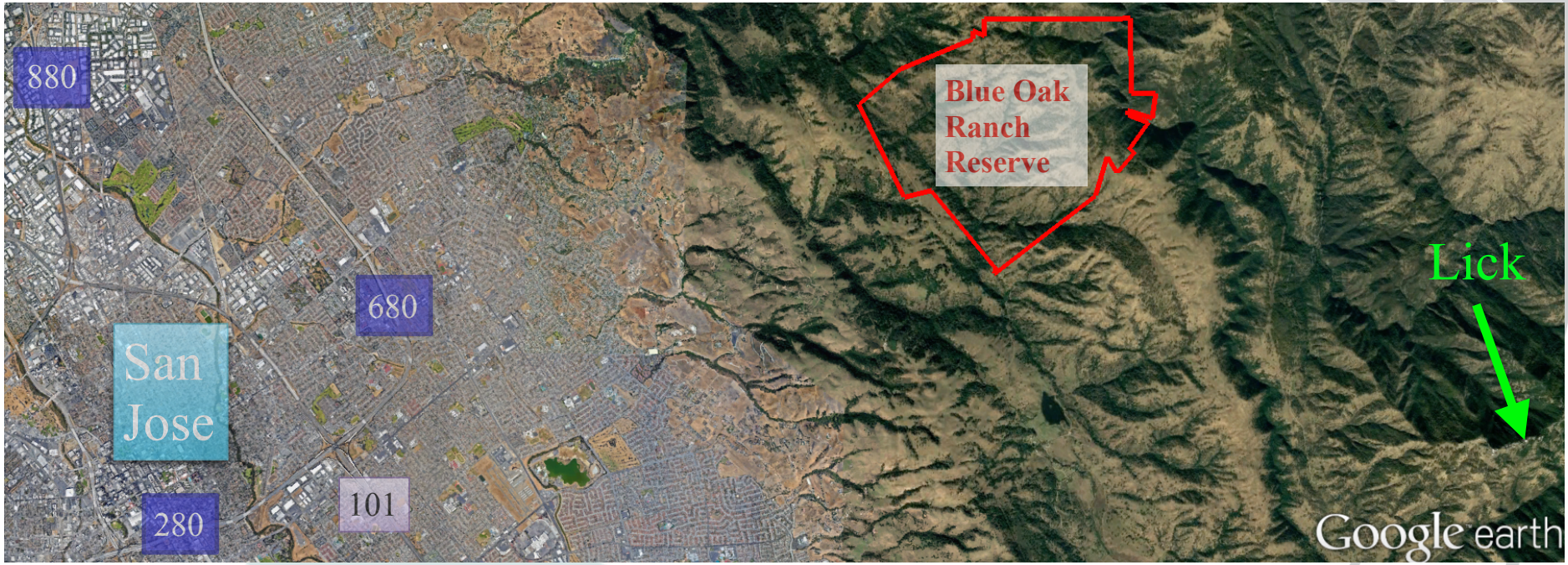


Distributed sensor grid is solar-powered and connected via WiFi mesh



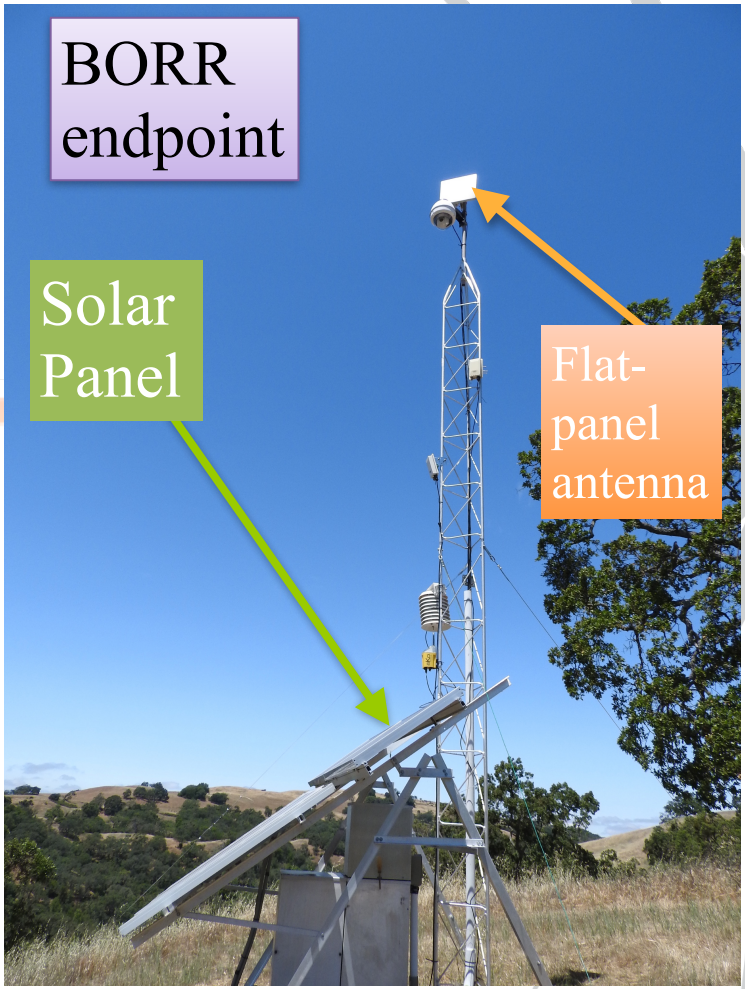
BORR Field Station is 7 miles away and 2350’ below Lick

- Blue Oak Ranch Reserve (elevation 1885’)
- Lick Observatory (elevation 4235’)



Many parts of BORR have line-of-sight to Lick

2008: Lick-BORR 5 GHz microwave link (7 mile path, ~50 Mbps)



Comparing Lick Connectivity Alternatives

- Adding more T1 circuits not cost effective
- Dedicated fiber link:
  - High capital cost: > $1M
  - Single, non-diverse path
  - Subject to fiber cuts
- Dual microwave links:
  - Much lower cost:< $100K
  - Frequency diversity

Mt. Hamilton Road, Feb. 20, 2017

2010: Finding funds for a high-speed microwave link

A CalREN-connected downlink site in Santa Clara: UCSC UNEX

June 2012: Primary 11 GHz link endpoints

June 2012: Secondary 5 GHz link endpoints

Link performs well even during harsh winter weather

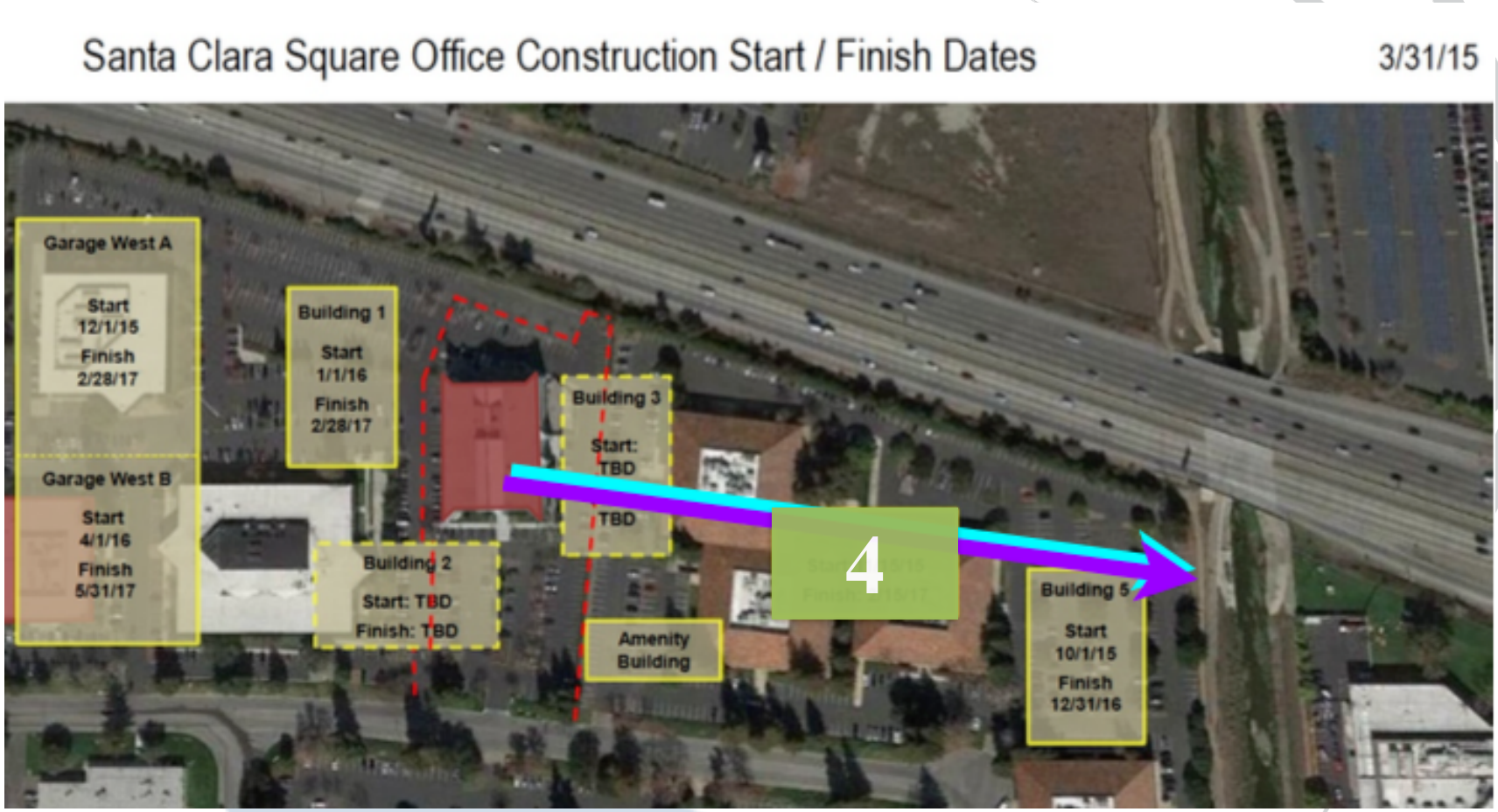
Fall 2014: UCSC UNEX Building is sold, slated for demolition

Schedule and footprints for proposed new buildings

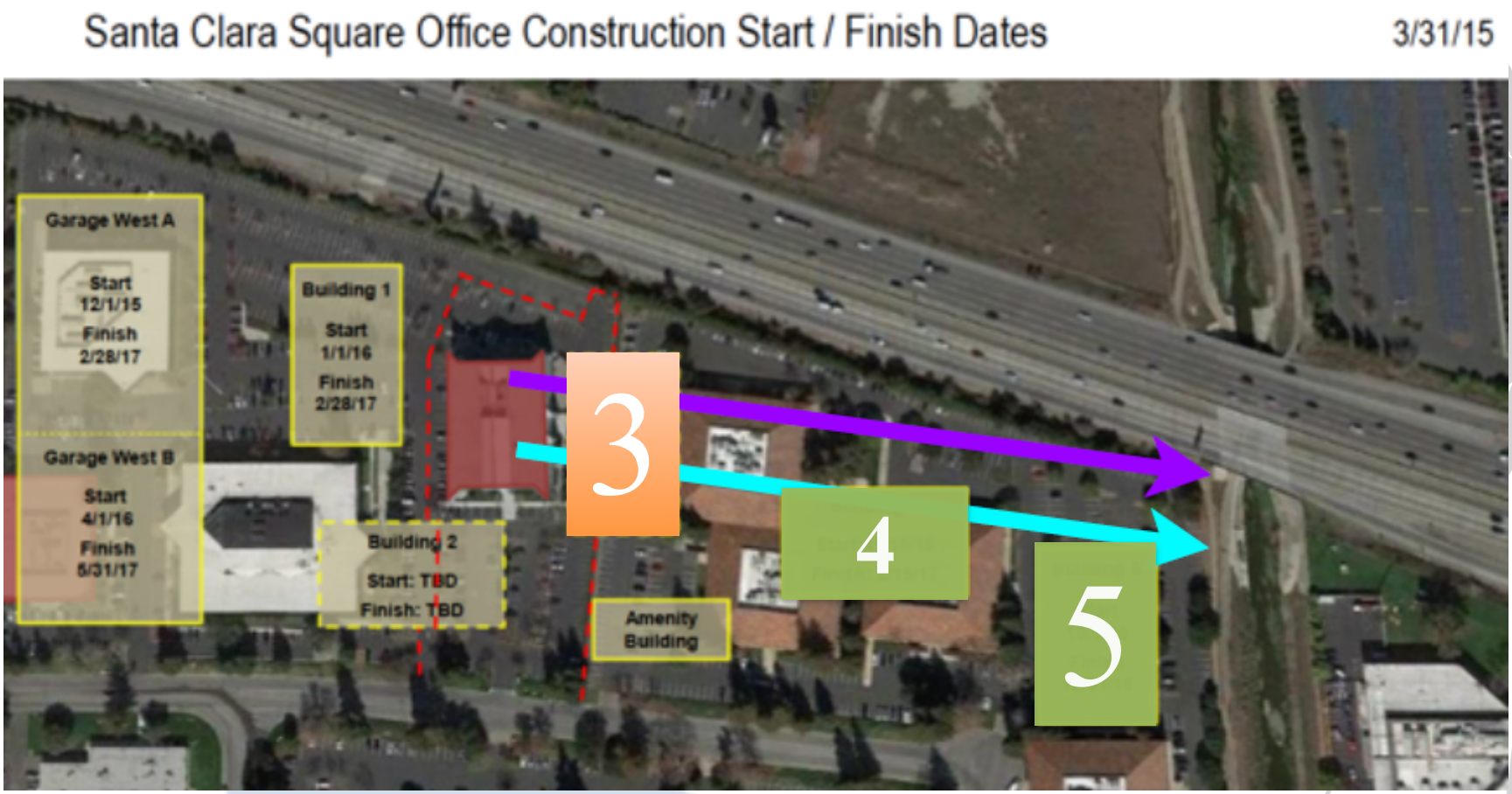
Pile drivers would shake building and sometimes block beam line

Nearby cranes and their payloads would obstruct the beam line to Lick

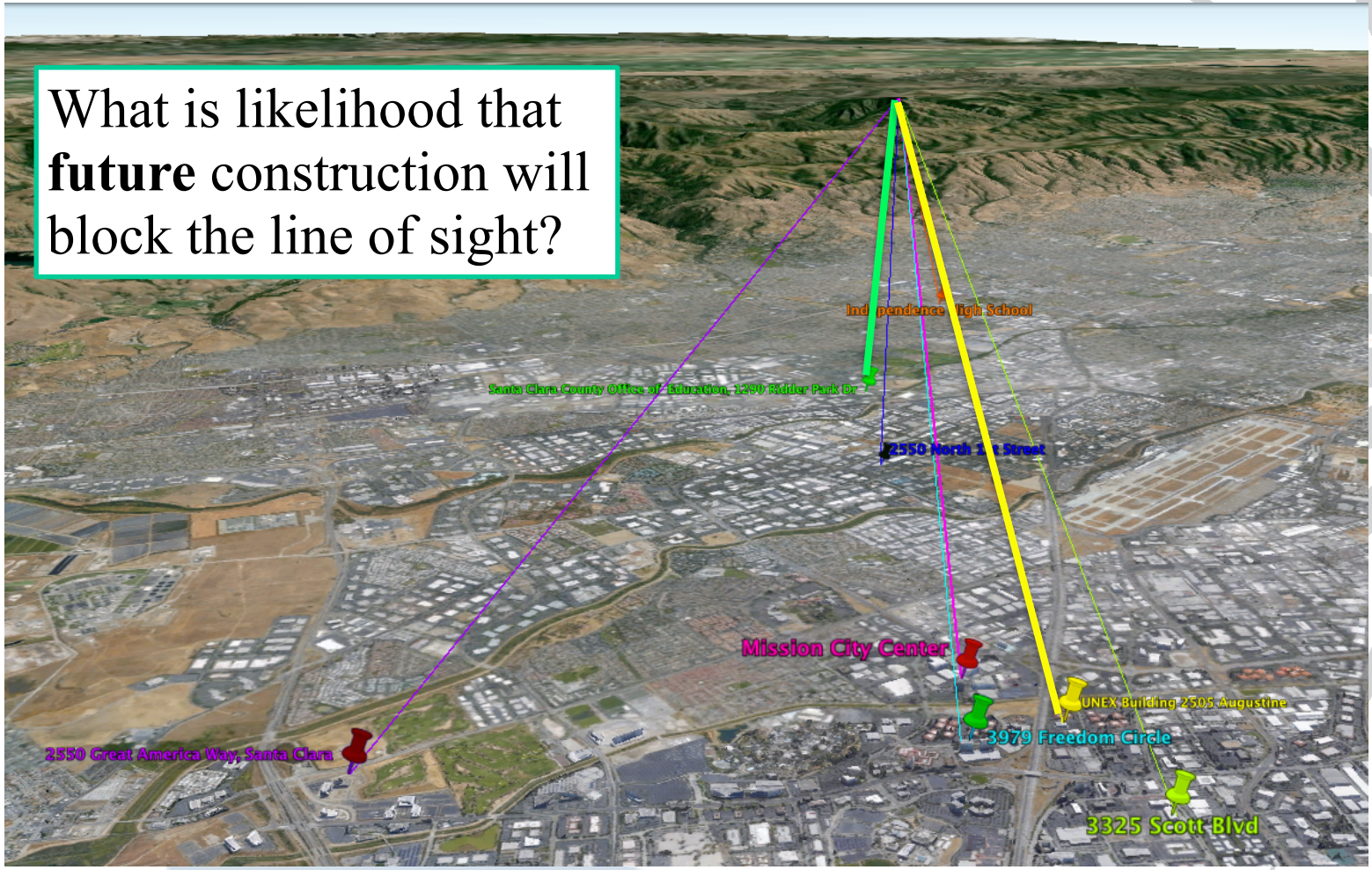
11 and 5 GHz antennas originally installed side-by-side



Mitigation strategy: move 5 GHz antenna to north end of rooftop



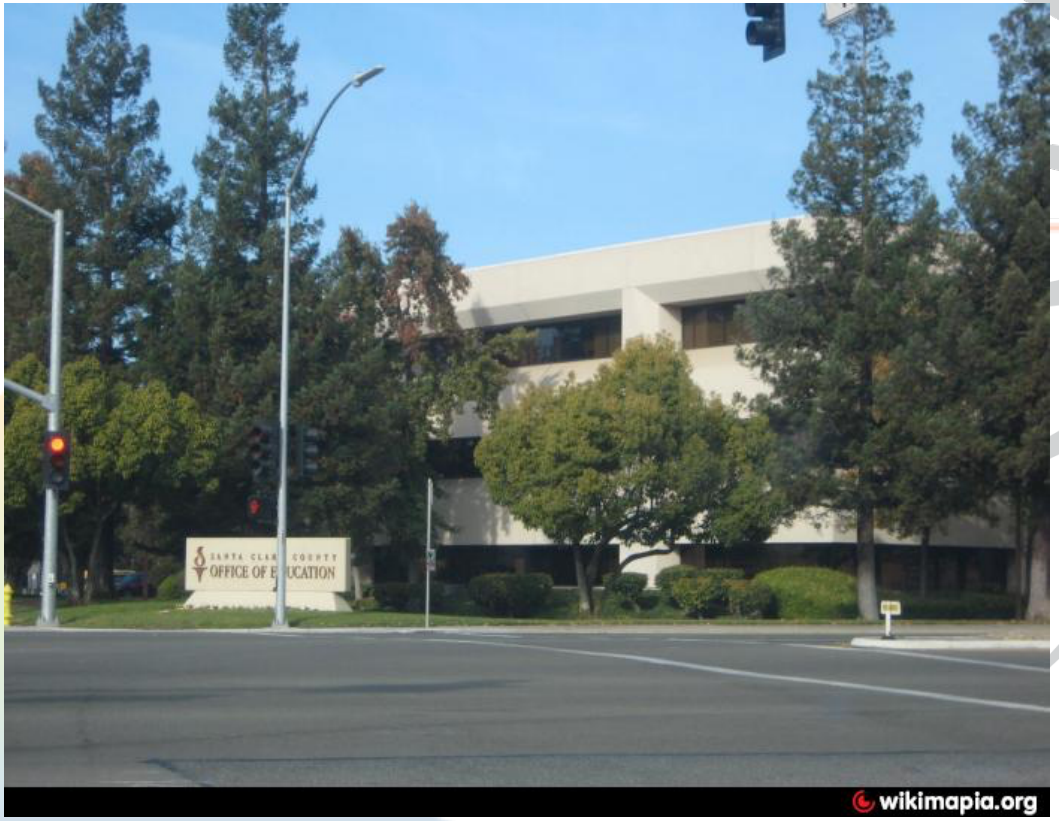
Extensive use of Google Earth to compare lines of sight



Followed up by on-site photographic confirmation

Santa Clara County Office of Education (SCCOE) is 1st choice

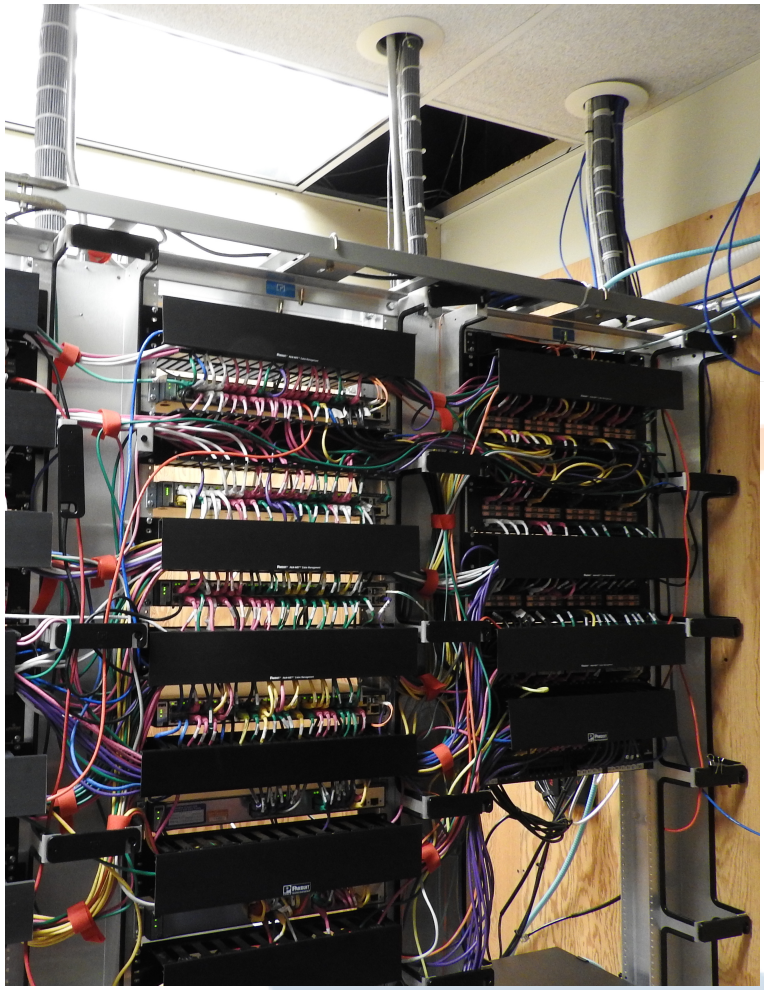
- Well-established government agency
- They **own** the building



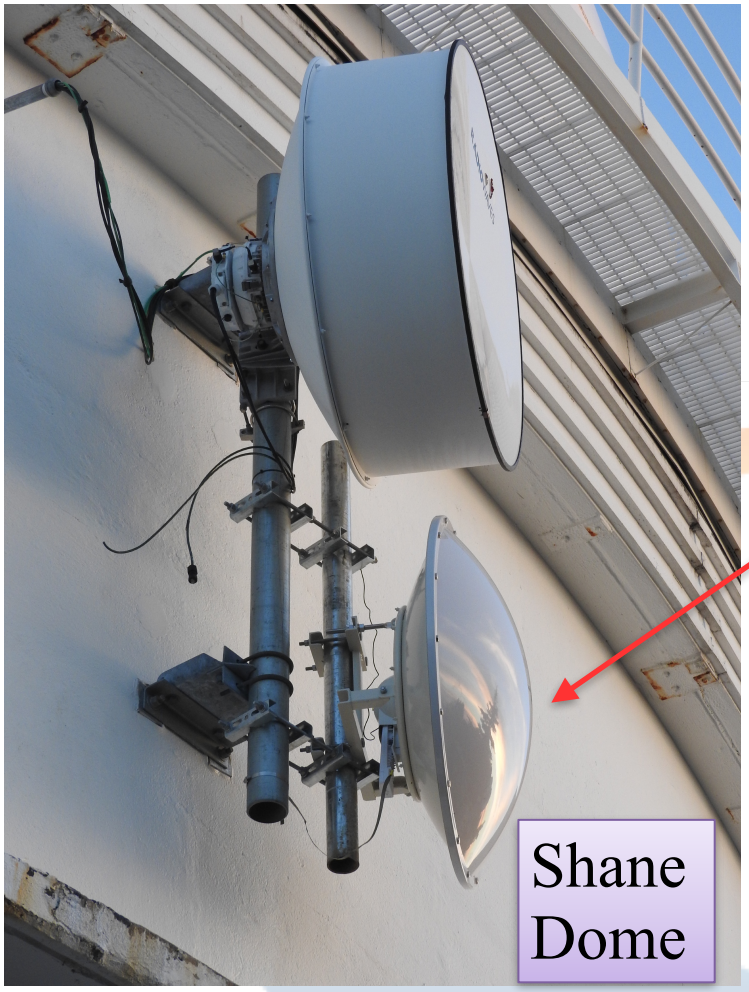
Beam lines from SCCOE rooftop align with nearby roadway

SCCOE building rooftop has infrastructure for antennas

Nearby closet inside building has rack space and E-power



2016: New 5 GHz link between Lick and SCCOE goes online



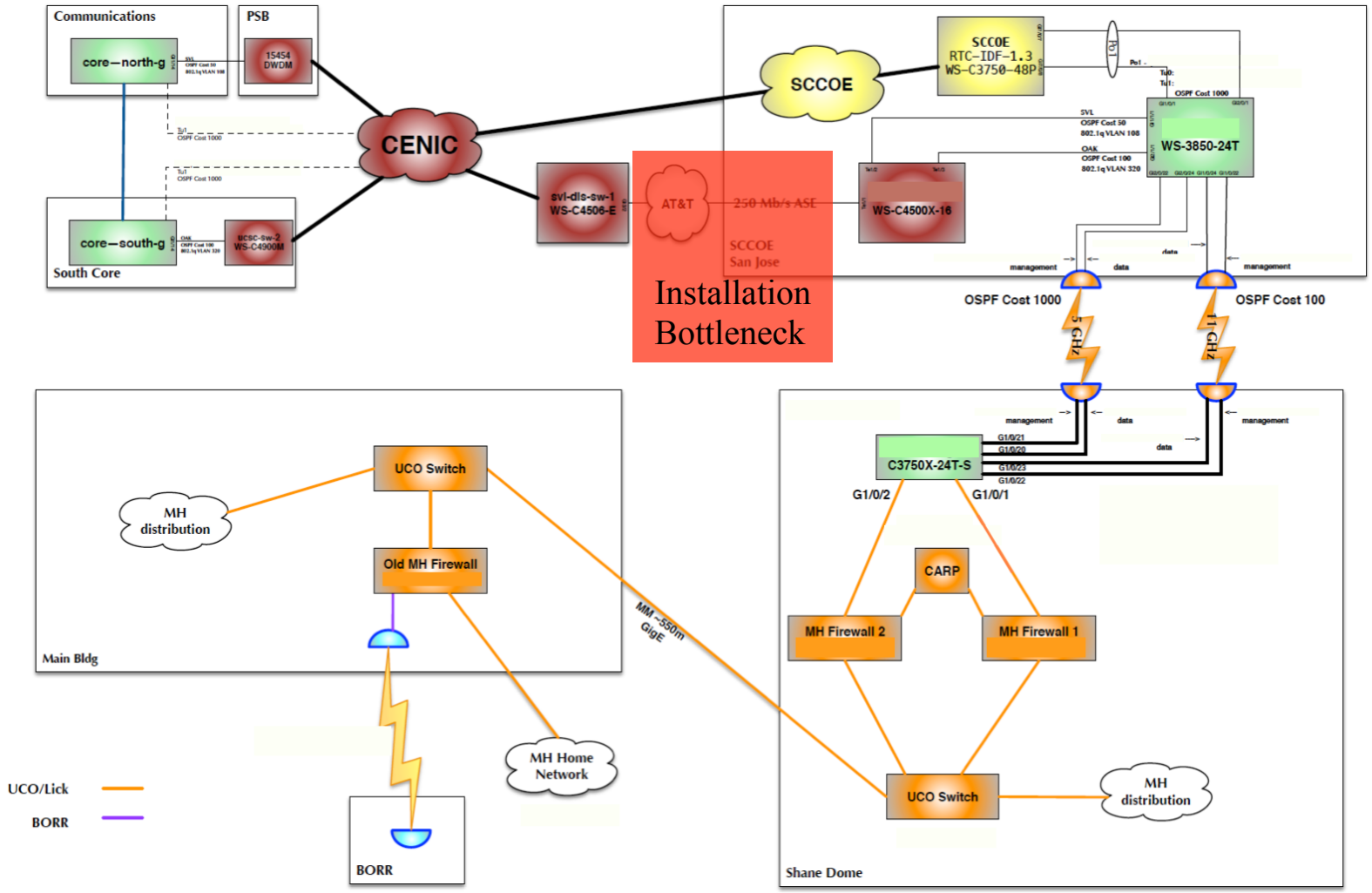
New
5 GHz
link

~100
Mbps

11 GHz link remained operational even with blocked line of sight!

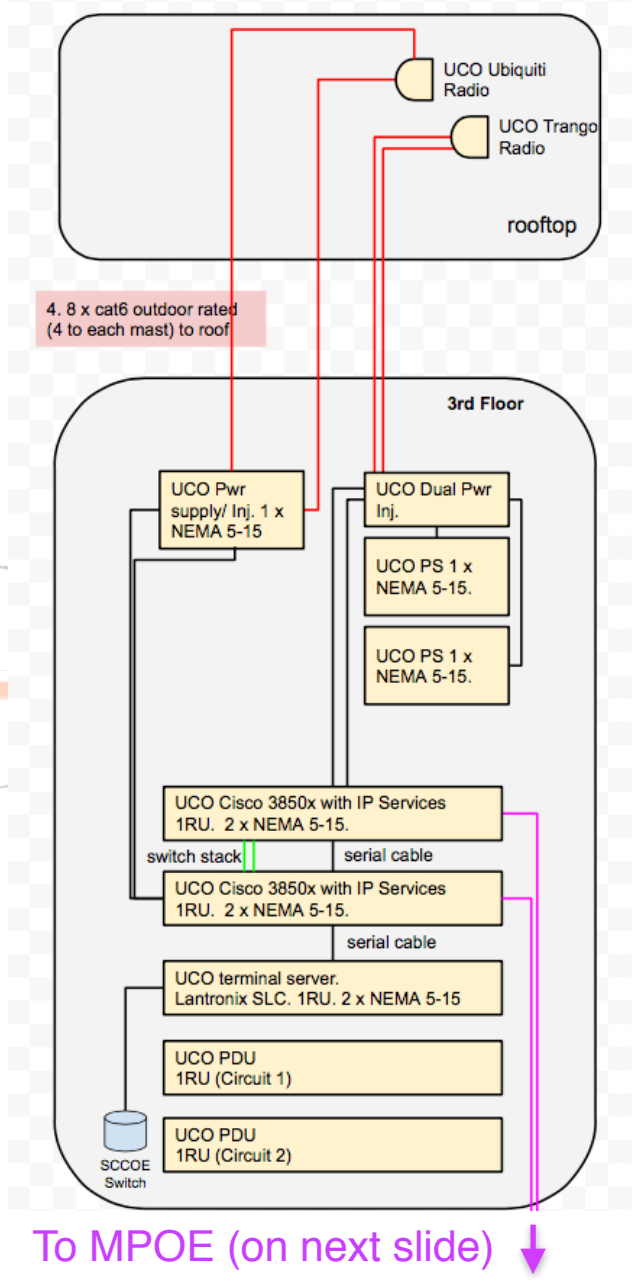
2016: Moving the 11 GHz link from UCSC UNEX to SCCOE

Overall Network Topology



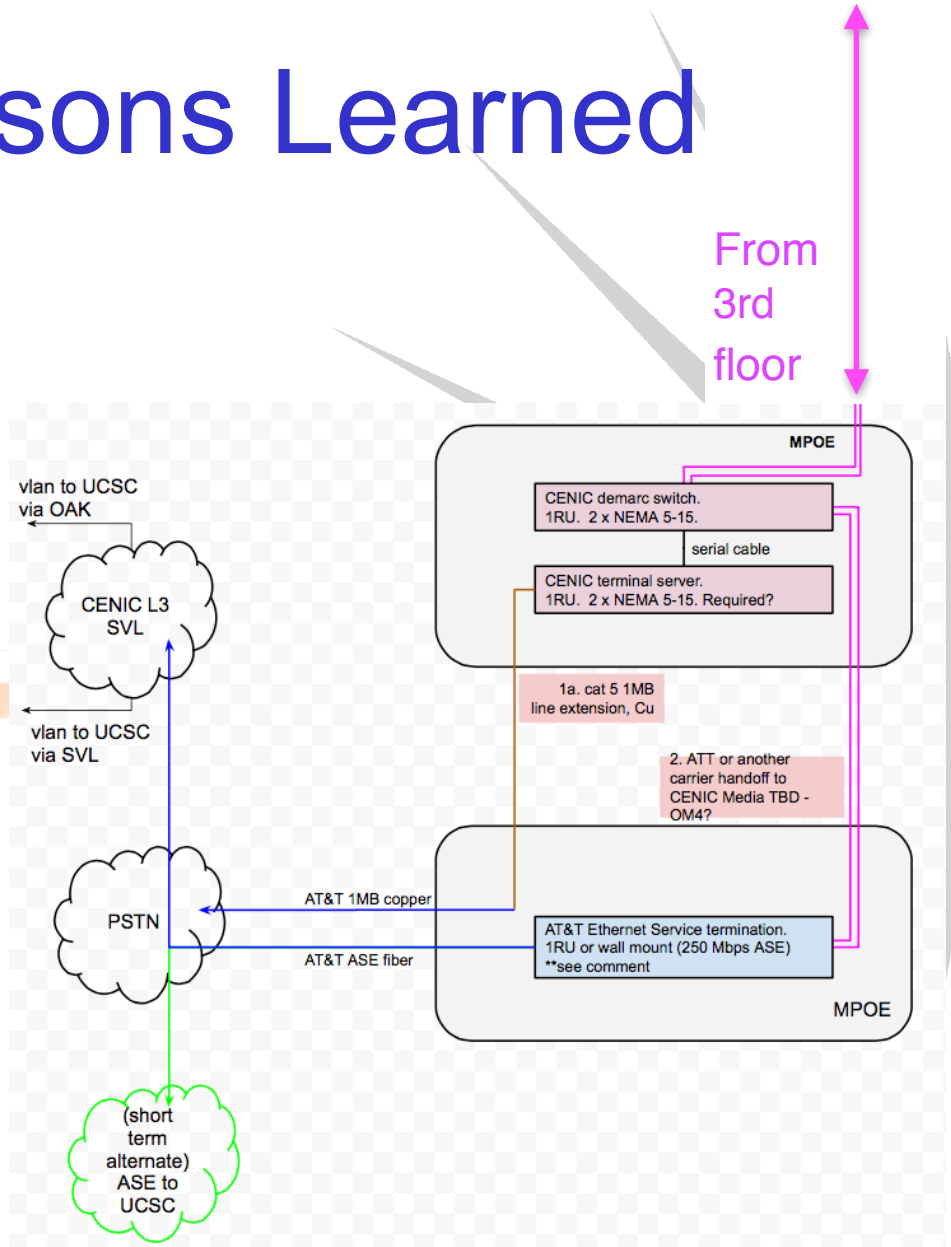
Time's Up

- Carrier circuit at SCCOE delayed
- Must leave UCSC UNEX Bldg. soon
- Needed route to SCCOE radios
- Used GRE tunnel via SCCOE



Network Lessons Learned

- Using GRE?
  - Configure correct MTU!
    - ip mtu 1476
    - ip tcp adjust-mss 1436
    - tunnel path-mtu-discovery
- Need faster failover?
  - Use BFD
- Troubleshooting performance?
  - Use iPerf / PerfSonar
  - Install iPerf host as needed



Conclusions

- The 5 GHz secondary link helped us cope:
  - Small size/weight made it easy to relocate
  - Provided spatial diversity / redundancy
- Legal / regulatory issues were the hardest
- Need to plan for how skyline might change

Conclusions

Collaborations between CENIC members can achieve effective solutions.

Natural Reserve System
UNIVERSITY OF CALIFORNIA

Santa Clara County
Office of Education

UNIVERSITY OF CALIFORNIA
SANTA CRUZ

CENIC

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- UC-REO: Lisa Akeson, Wallace Whittier
- UCOP: Peggy Fiedler, Connie Geraghty
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