A Review of Aviation Navigation Systems

… from old W. J. Overholser's barn to NextGen and Metroplex

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Van Nuys Airport Citizens Advisory Council
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Ver 1.0

Summary of this presentation

- This presentation describes various aircraft navigation systems ranging from simple onboard visual navigation, called Pilotage, through to sophisticated Satellite Systems.
- **PART 1** describes Dead Reckoning, Radio Navigation, Electronic Navigation including GPS and Inertial systems.
- **PART 2** describes the FAA's newest NextGen and Metroplex systems under consideration and noise related issues.

PART 1

- Dead Reckoning, Radio Navigation, Electronic Navigation including GPS and Inertial systems

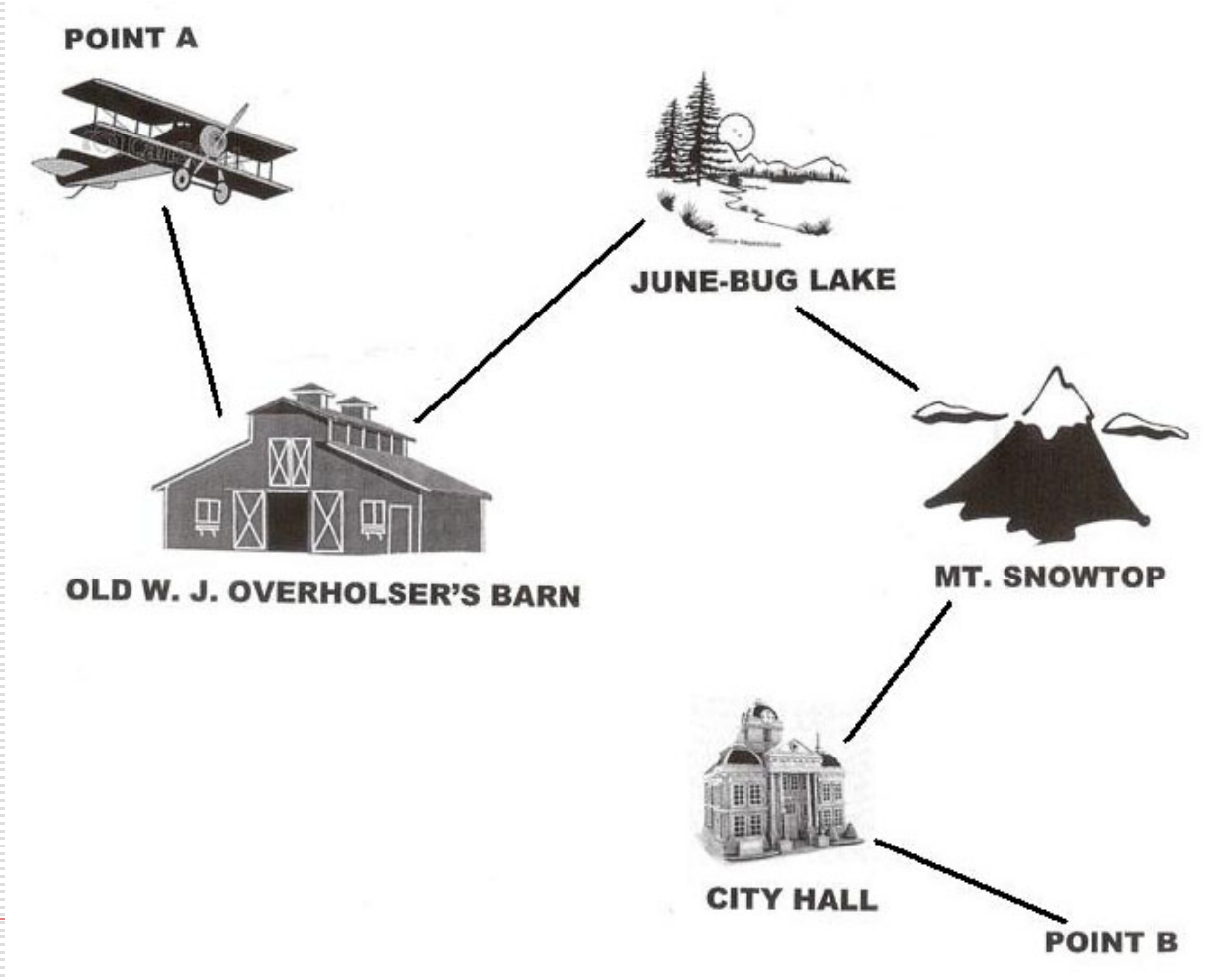
Types of Navigation Systems

- Pilotage
- Dead Reckoning
- Radio Navigation
  - ADF
  - VOR/DME/RNAV
- Electronic Navigation
  - Loran
  - Inertial
  - GPS
- Celestial

Aviation navigation dates back to the early 1900's

Pilots flying from point A to point B used recognizable landmarks such as buildings, lakes, rivers, mountain tops and the like. Pilotage was a visual process of calculating one's position by traveling from one recognizable landmark to another. It did not use astronomical observations or electronic navigation methods.

Pilotage Flying from Point A to Point B



Dead Reckoning

- In navigation, dead reckoning is the process of calculating one's current position by using a previously determined position, or fix, and advancing that position based upon known or estimated speeds over elapsed time and course.

Area Navigation (RNAV)

- **Generic name for a system that permits point-to-point flight**
  - Onboard computer that computes a position, track, and groundspeed
  - VOR/DME
  - Loran
  - Inertial
  - GPS

Automatic direction finder ADF

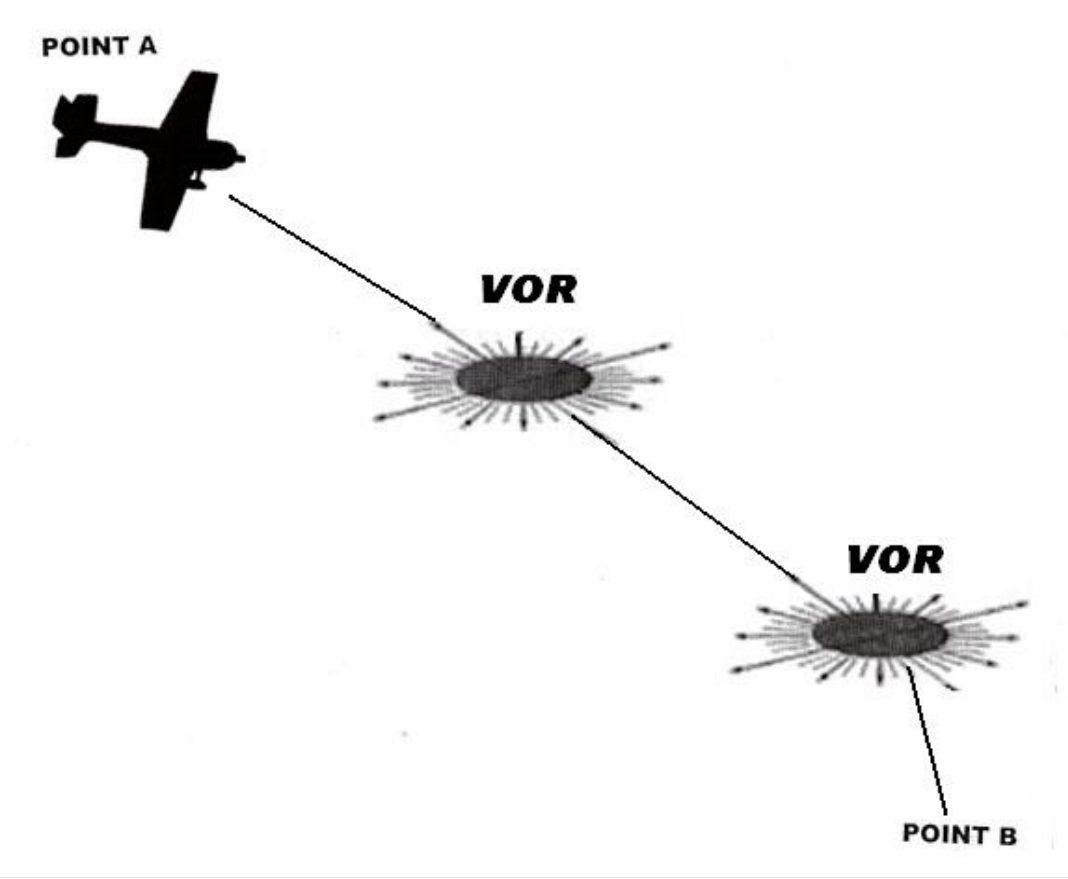
- ADF equipment determines the direction or bearing relative to the aircraft by using a combination of directional and non-directional antennae to sense the direction in which the combined signal is strongest.

- This display looks like a compass card with a needle superimposed, except that the card is fixed with the 0 degree position corresponding to the center line of the aircraft.

Radio Navigation - VORs
VHF Omni Directional Radio Range

- VORs derived from the old 4-course radio range from the late 1920's and 1930's
- Gained widespread use for navigation in the 1950's. Made instrument navigation commonplace. Remain the basis for most of the world's air navigation systems- and will be for 5-10 yrs.

VOR Flying from Point A to Point B



VHF Omni Directional Radio Range (VOR)

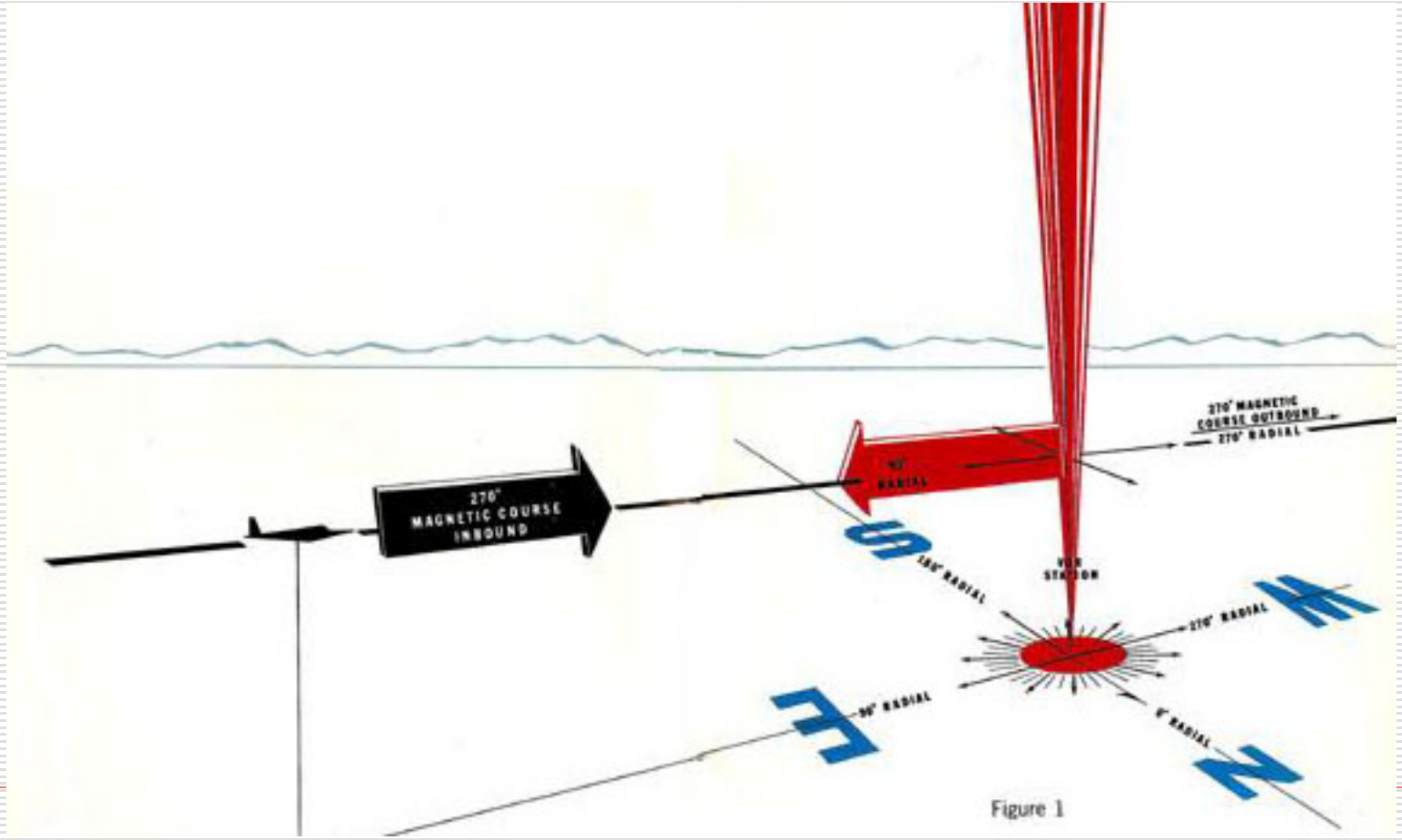
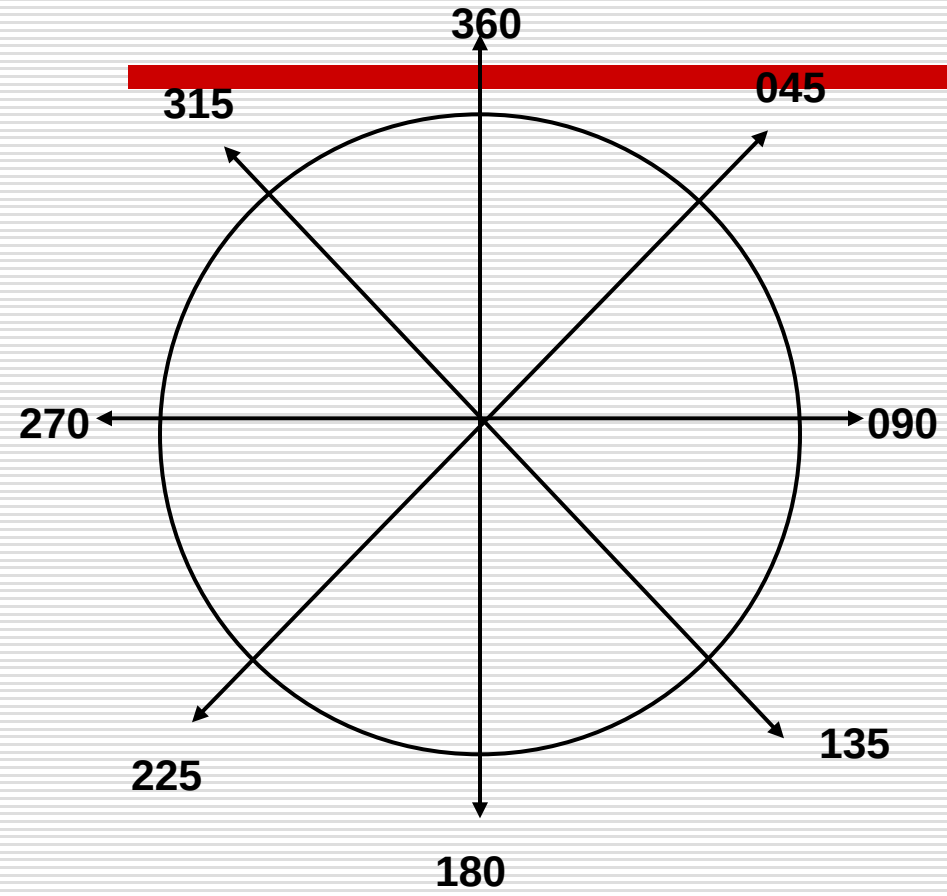
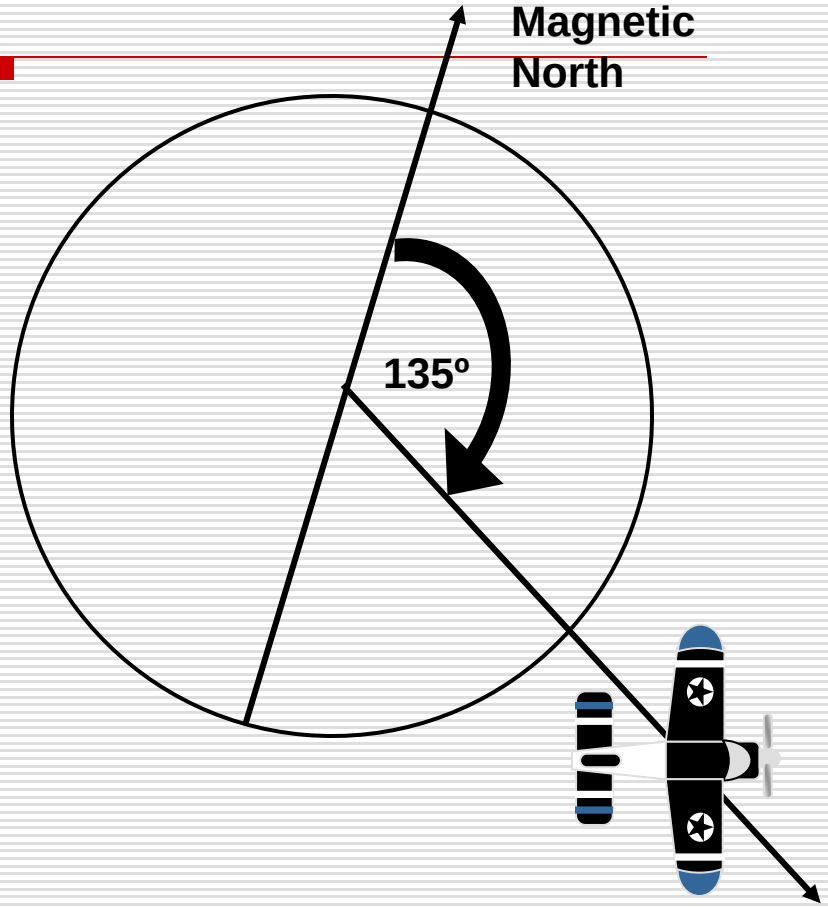


Figure 1

Photograph VOR antenna

The principle of the VOR – Radials





Principles of operation

- VORs broadcast 360 separate radials emanating from the station in all directions.
- VORs broadcast 2 signals- the reference (or 360-N) signal and the rotating signal.

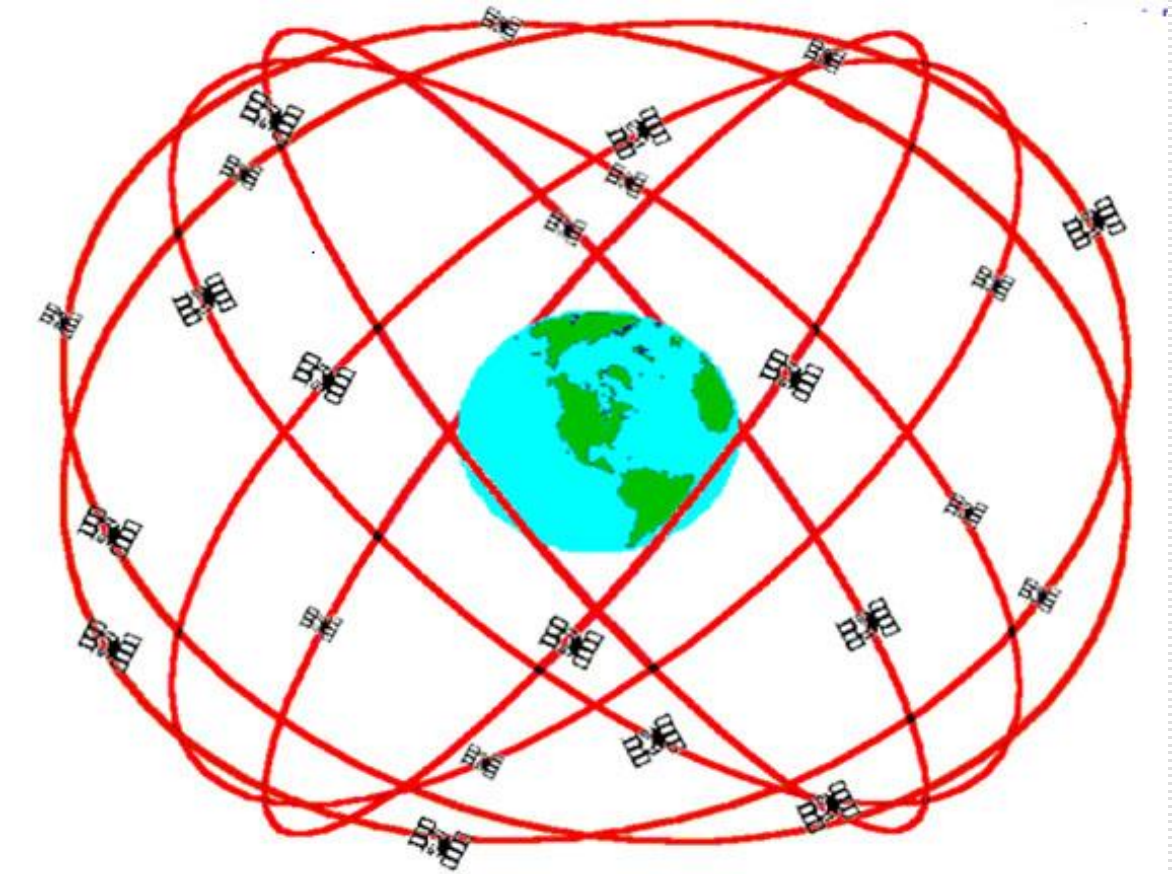
Inertial Navigation System

- Self-contained source of:
  - Position, groundspeed, & heading
  - Does not need a receiver
- Cannot be jammed
  - Applies calibration correction after each flight

Global Positioning System GPS

- System of 24 satellites, 4/5 of which are in view at all times
- Receiver uses 4 of these to determine position of aircraft
- Each satellite transmits code which contains satellite position and GPS time
- Receiver, knowing how fast signal was sent and at what time, calculates position

System of 24 satellites, 4/5 are in view at all times



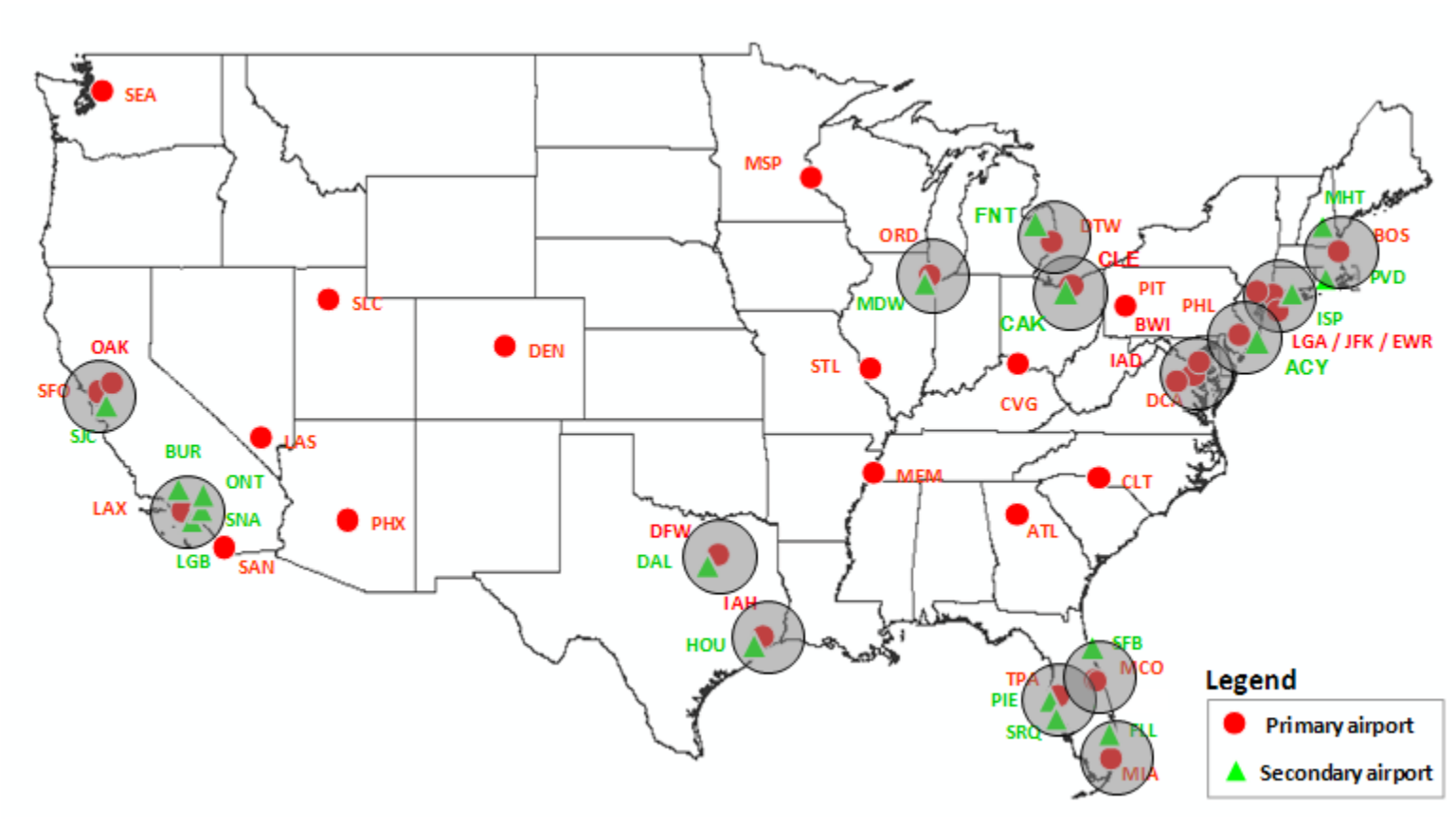
PART 2

- The FAA's newest NextGen and Metroplex systems and noise related issues.

INTRODUCING NEXTGEN

- **The purpose is to improve airspace efficiency and reduce complexity**
  - Focus on major metropolitan areas
  - Optimize flight paths and climb/descent profiles
  - Institute collaborative teams to broadly proliferate existing PBN* experience and expertise
  - Promote RNAV “everywhere” and RNP (Required Navigational Performance) “where beneficial”
  - Integrate airspace and procedure design
  - Decouple operations arriving and departing adjacent airports
  - *Performance Based Navigation is area navigation or RNAV. RNAV is a method of navigation which permits aircraft operation on any desired flight path within coverage of station-referenced navigation aids

Primary and secondary airports within multi-airport systems in the United States



Six NextGen Programs

- **Reshaping operations in the National Airspace System (NAS):**

1. Automatic Dependent Surveillance–Broadcast (ADS-B)
2. Data Communications (Data Comm)
3. En Route Automation Modernization (ERAM)
4. Terminal Automation Modernization and Replacement (TAMR)
5. NAS Voice System (NVS)
6. System Wide Information Management (SWIM)

1. Automatic Dependent Surveillance–Broadcast

- Automatic Dependent Surveillance–Broadcast (ADS-B) is the successor to radar that uses onboard avionics to broadcast an aircraft's position, altitude and velocity to a network of ground stations, which relays the information to air traffic control displays and to nearby aircraft equipped to receive the data via ADS-B In.

- ADS-B In provides operators of properly equipped aircraft with traffic position information delivered directly to the cockpit. Aircraft equipped with a Universal Access Transceiver (UAT) will also receive weather and Notices to Airmen (NOTAM) via the Flight Information Services–Broadcast (FIS-B) service.

2. Data Communications

- Data Communications (Data Comm) enables controllers and pilots to communicate with digitally delivered messages, rather than rely solely on radio voice communications. With the push of a button, controllers can electronically send routine instructions, such as departure clearances and weather avoiding reroutes, directly to the flight deck.

- Messages appear only on the cockpit display of the aircraft to which they apply, reducing the potential for miscommunication that can occur from radio voice exchanges.

3. En Route Automation Modernization

- En Route Automation Modernization (ERAM) is one of the foundational programs of NextGen. It is a more capable and flexible platform than the decades-old HOST legacy system it replaces. ERAM is now online at the 20 en route traffic control centers in the contiguous United States.

- It performs core functions at the FAA centers where high-altitude air traffic is controlled. ERAM processes flight and surveillance radar data, enables efficient controller-pilot communications and generates detailed display data to air traffic controllers.

4. Terminal Automation Modernization and Replacement

- The Terminal Automation Modernization and Replacement (TAMR) program upgrades multiple air traffic control technologies to a single, state-of-the-art platform: the Standard Terminal Automation Replacement System (STARS). STARS is a foundational NextGen technology that enables Automatic Dependent Surveillance–Broadcast (ADS-B) and other NextGen programs.

- Controllers use STARS to provide air traffic control services to pilots in terminal airspace — the airspace immediately surrounding major airports.

5. National Airspace System (NAS) Voice System (NVS)

- The National Airspace System (NAS) Voice System (NVS) will replace decades-old analog technology with secure, digital Voice over Intranet Protocol (VoIP) technology. Current point-to-point voice-switching technology allows controllers to speak to aircraft within range of their nearby radio site.

- By contrast, NVS works over a secure FAA digital network and is not limited by geography. With the flip of a switch, NVS will allow voice traffic to move from one location to another, anywhere in the country.

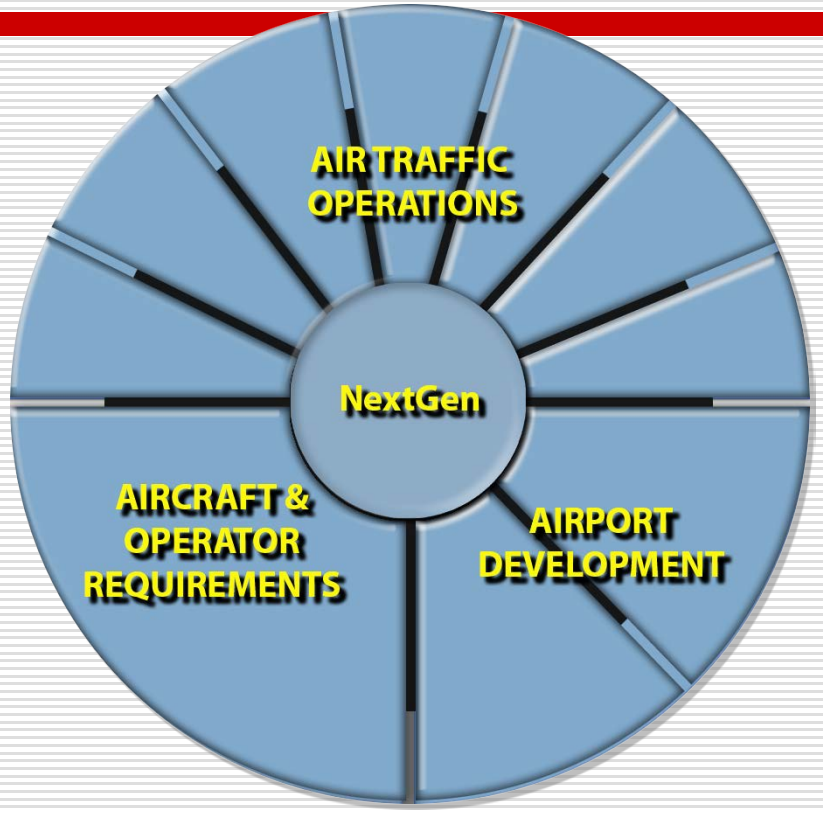
- Infrastructure (FTI) network. FTI's multi-layered security prevents unwanted access to the system while also providing a NAS-wide connection for voice systems.

6. System Wide Information Management

- System Wide Information Management (SWIM) is the digital data-sharing backbone of NextGen. SWIM infrastructure enables air traffic management-related information sharing among diverse, qualified systems.
- The platform offers a single point of access for aviation data, with producers of data publishing once and users accessing the information they need through a single connection.
- It enables increased common situational awareness throughout the National Airspace System (NAS) and improves the FAA's ability to securely deliver the right information to the right people at the right time.

FAA's NextGen Implementation Plan

Our focus is on integration and execution



Airport Development

- OEP Airports
- OEP Metro Areas

Air Traffic Operations

- Initiate Trajectory-based Operations
- Increase Arrivals and Departures at High Density Airports
- Increase Flexibility in the Terminal Environment
- Improve Collaborative Air Traffic Management
- Reduce Weather Impact
- Improve Safety, Security and Environmental Performance
- Transform Facilities

Aircraft & Operator Requirements

- Avionics

NextGen: *Delivering safety, sustainability, flexibility and economic viability*

Today's National Airspace System		NextGen
Ground-based Navigation and Surveillance	→	Satellite-based Navigation and Surveillance
Air Traffic Control Communications By Voice	→	Routine Information Sent Digitally
Disconnected Information Systems	→	Information More Readily Accessible
Cognitive-Based Air Traffic "Control"	→	Automation, Decision Support Tools
Fragmented Weather Forecasting	→	Forecasts Embedded into Decisions
Airport Operations Limited By Visibility Conditions	→	Operations Continue Into Lower Visibility Conditions
Forensic Safety Systems	→	Prognostic Safety Systems
Focus on major airports	→	Focus on metropolitan areas
Inefficient routes & fuel consumption	→	Shorter flight paths/ fuel saving procedures; alternative fuels; reduced noise

→

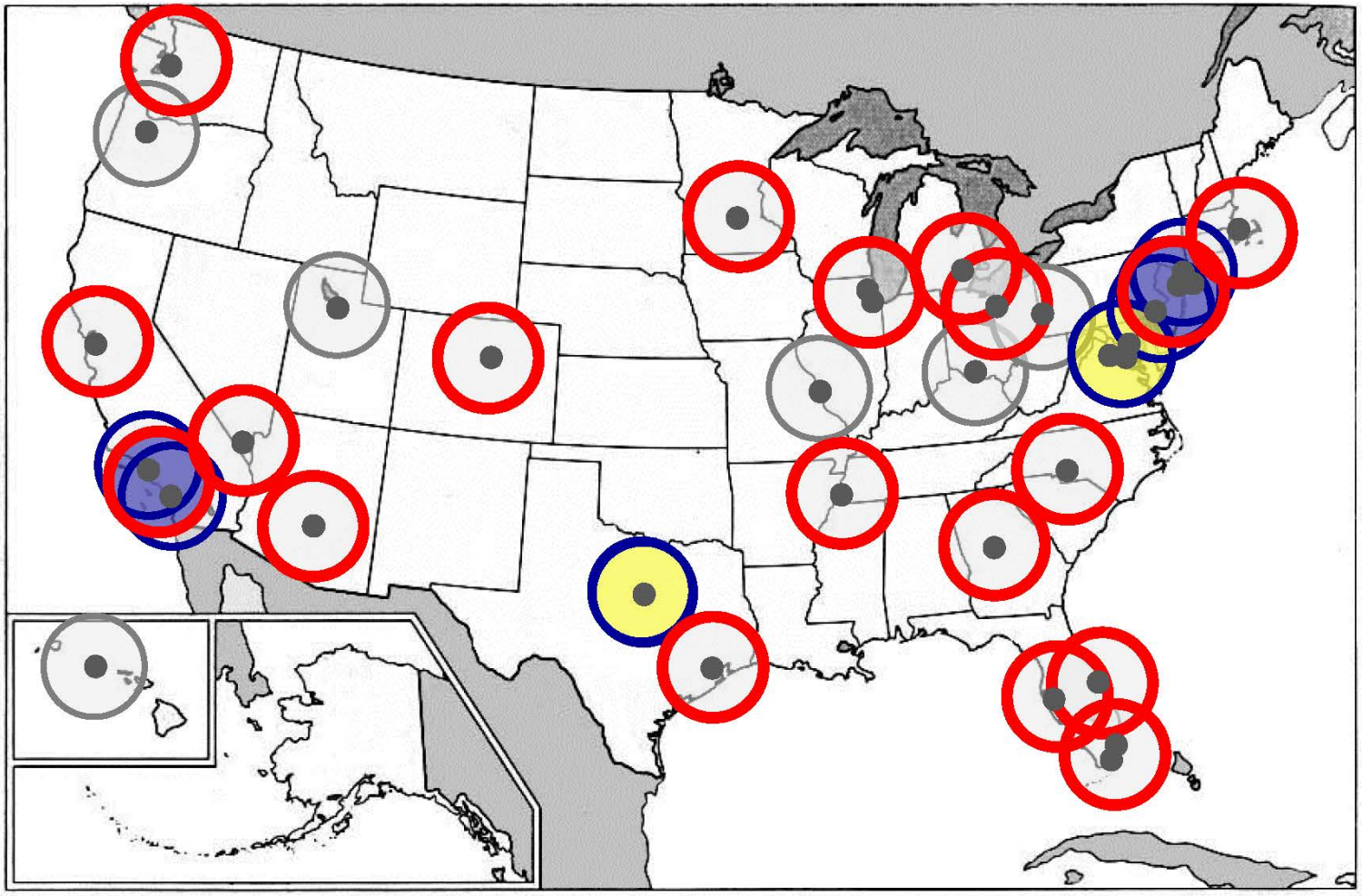
INTRODUCING METROPLEX

- Main purpose of Metroplex is to enhance efficiency in the SoCal Metroplex
- Reduce Complexity
- Provide Predictability
- Provide Flexibility

Southern California Metroplex

- Metroplex is an optimized approach to integrated airspace and procedures projects. Airspace and procedures solutions are limited to those that can be achieved without producing significant noise increases
- Noise impacts assessed and reported in an Environmental Assessment (EA)
- Draft EA will include a noise analysis and track/altitude information
- Years modeled: 2015 and 2020 forecast conditions
- Preliminary analysis shows no significant noise increases in the 65 DNL

Candidate Metroplexes



Start with 29 metroplexes around the OEP airports

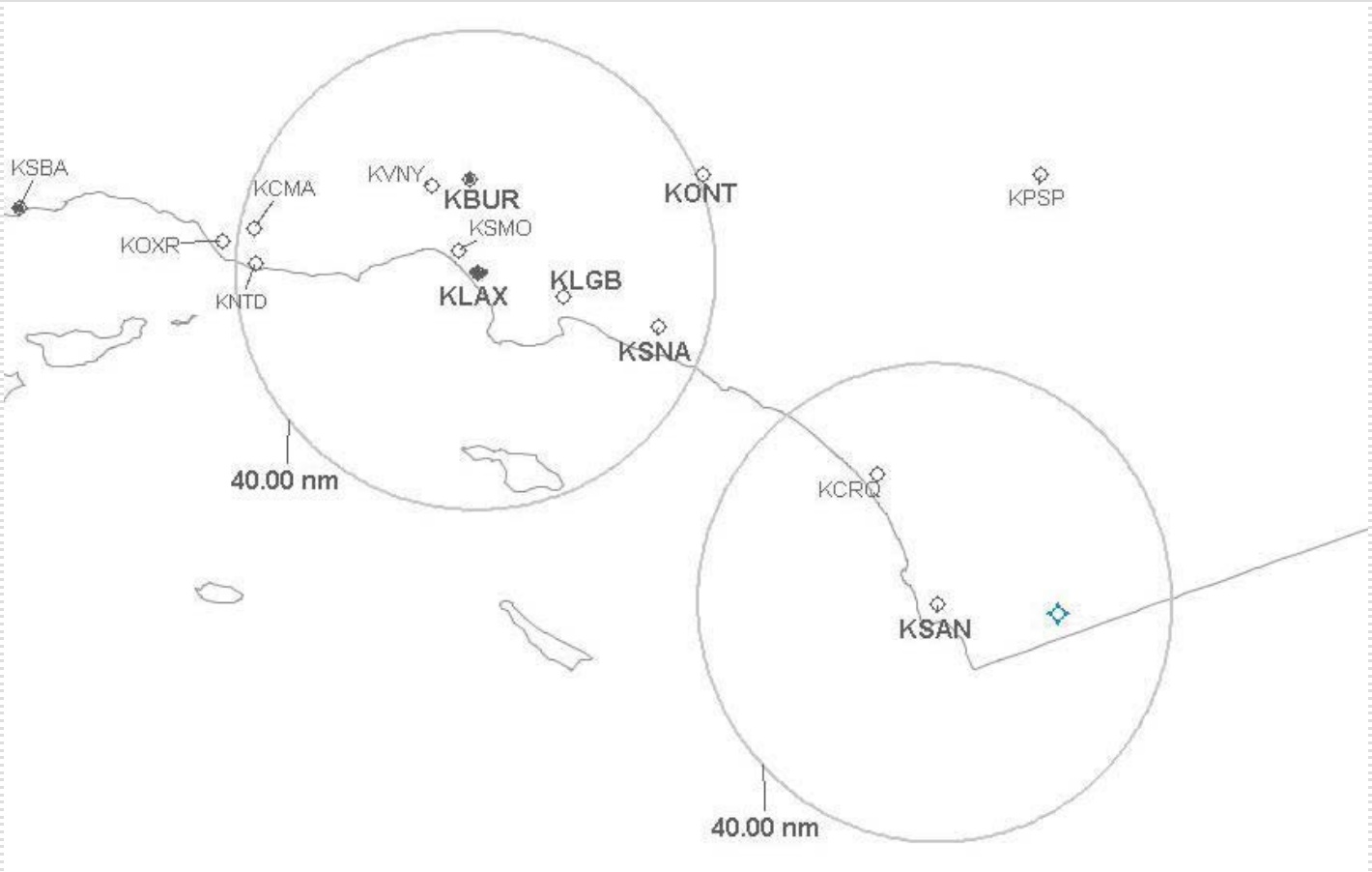
Reduce initial set to RTCA TF5 "where" sites

Combine closely associated metroplexes

Remove prototype sites

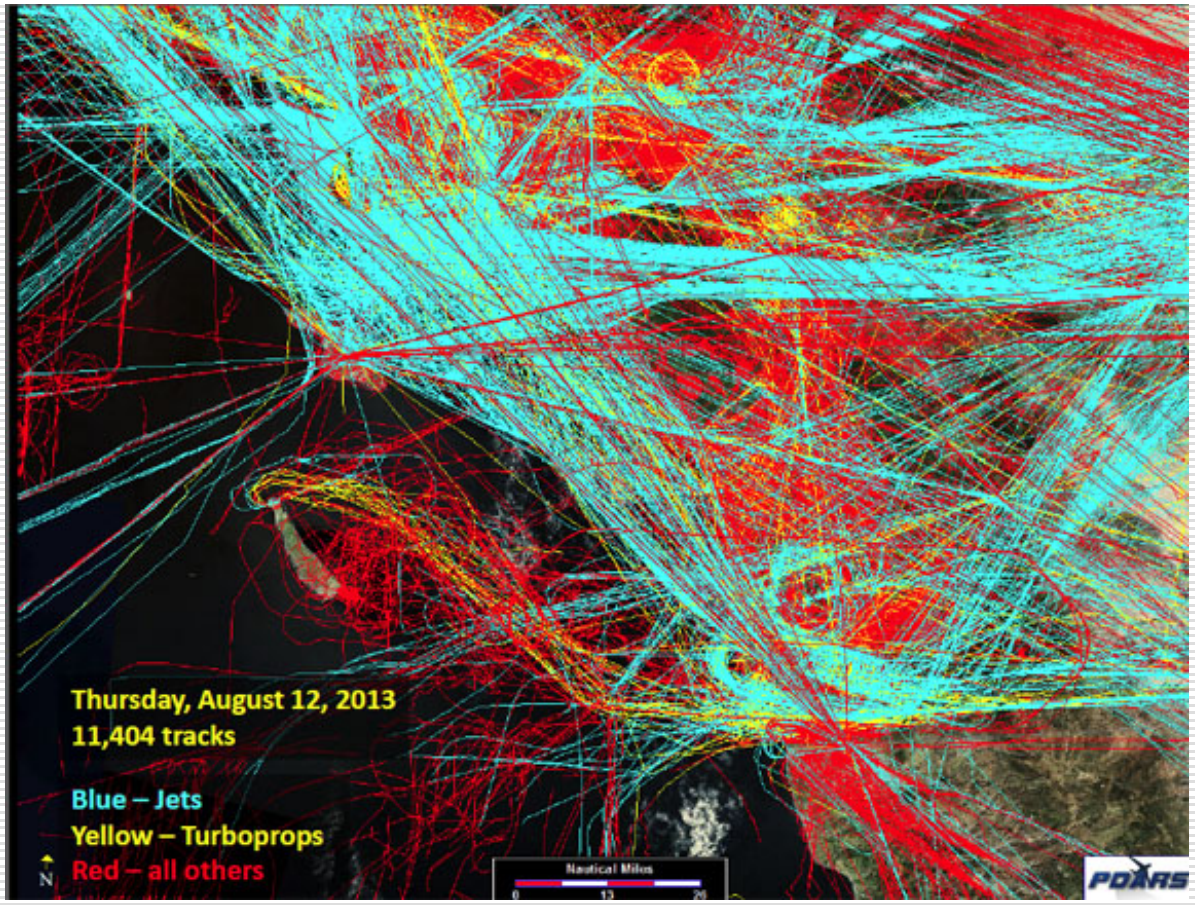
Final set: 19 candidate metroplexes

SoCal Metroplex Area of Interest



This figure shows the six primary airports including BUR, LAX, LGB, ONT, SAN and SNA along with CRQ, PSP, SMO and VNY

Crowded SoCal Airspace



SoCal Metroplex Airports

- **The Southern California Metroplex consists of airspace delegated to the SCT and ZLA**

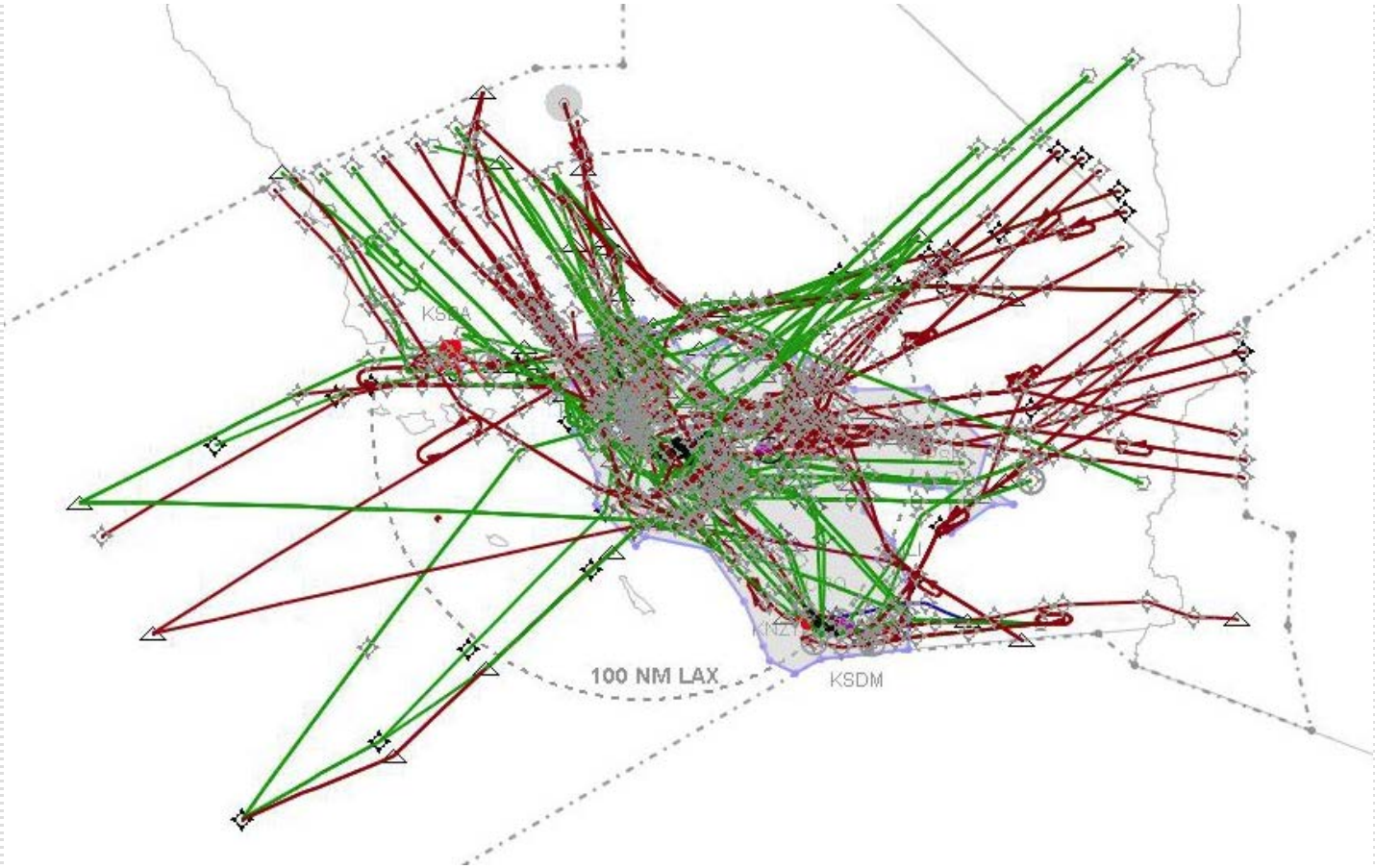
  Interactive operations at eight SCT airports were examined closely

  - Los Angeles International Airport (LAX)
  - San Diego International Airport (SAN)
  - Bob Hope Airport (BUR)
  - Ontario International Airport (ONT)
  - John Wayne Airport – Orange County (SNA)
  - Long Beach/Daugherty Field (LGB)
  - Santa Monica Municipal Airport (SMO)
  - Van Nuys Airport (VNY)

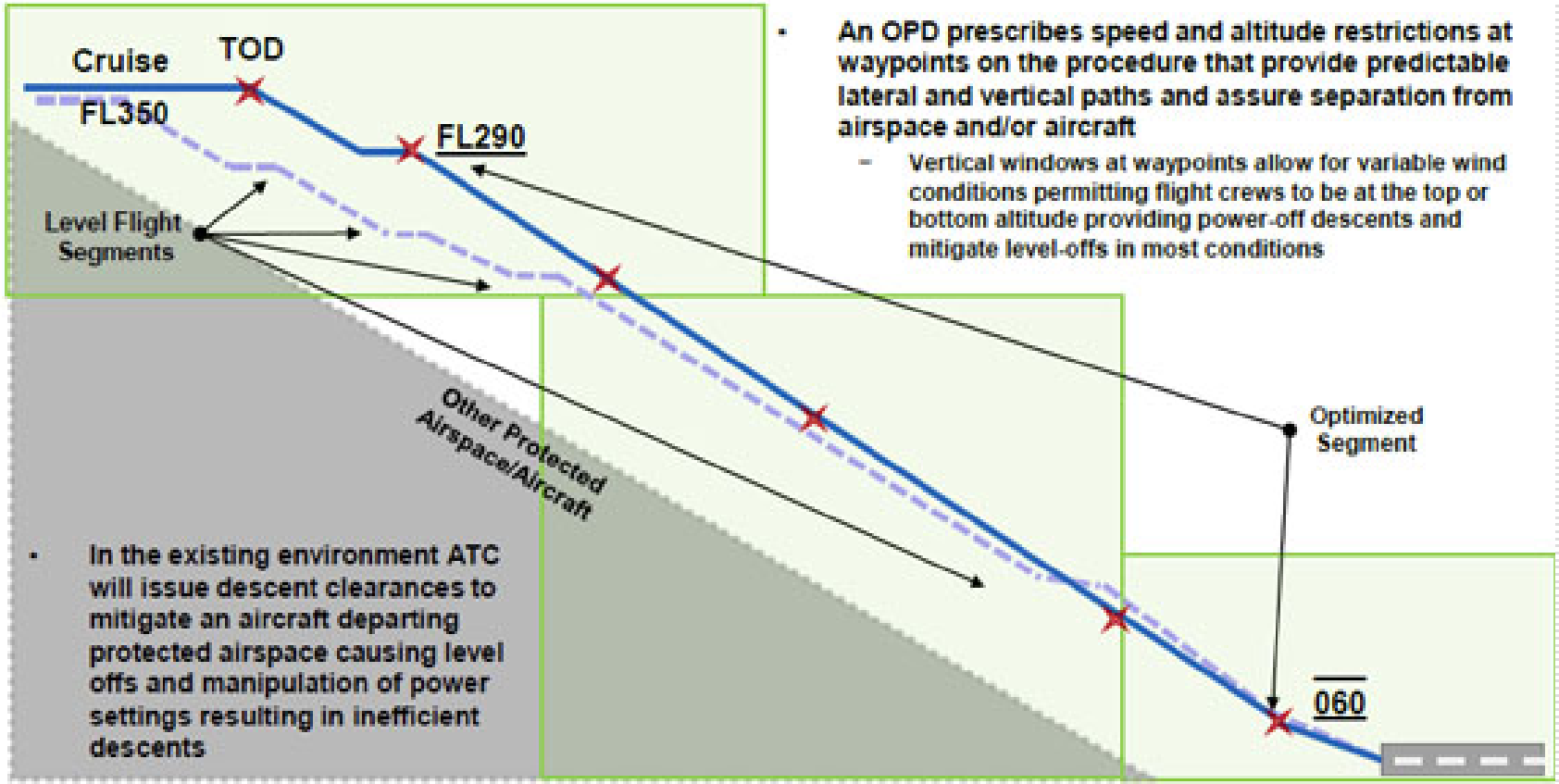
Example Arrival and Departure proceedures under consideration

- **SID**: Standard Instrument Departure
- **STAR**: Standard Terminal Arrival Route

SoCal Metroplex SIDs and STARs



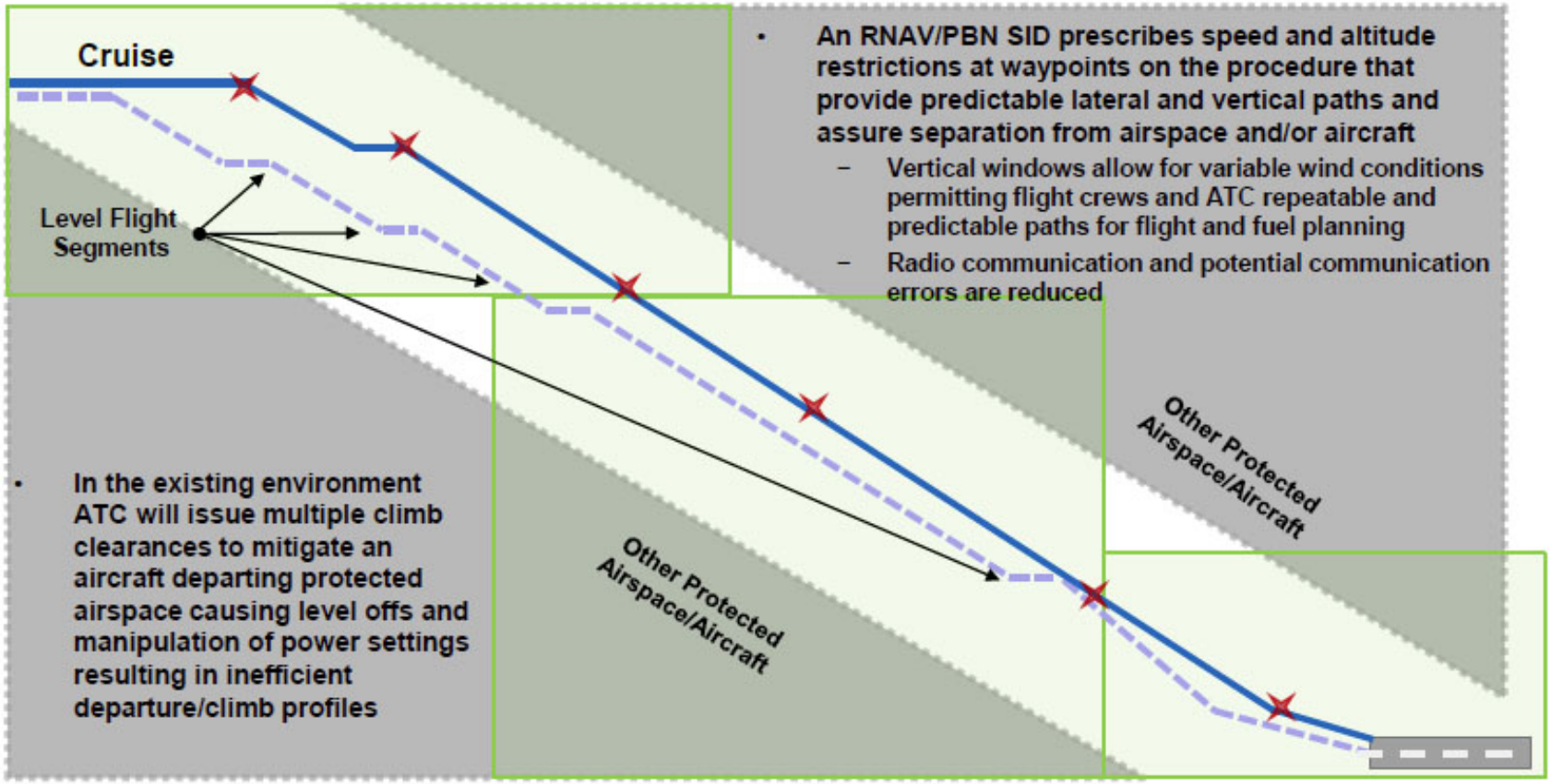
Optimized Profile Descent Example
(Arrival)



- An OPD prescribes speed and altitude restrictions at waypoints on the procedure that provide predictable lateral and vertical paths and assure separation from airspace and/or aircraft
  - Vertical windows at waypoints allow for variable wind conditions permitting flight crews to be at the top or bottom altitude providing power-off descents and mitigate level-offs in most conditions

- In the existing environment ATC will issue descent clearances to mitigate an aircraft departing protected airspace causing level offs and manipulation of power settings resulting in inefficient descents

Optimized Climb Profile Example
(Departure)

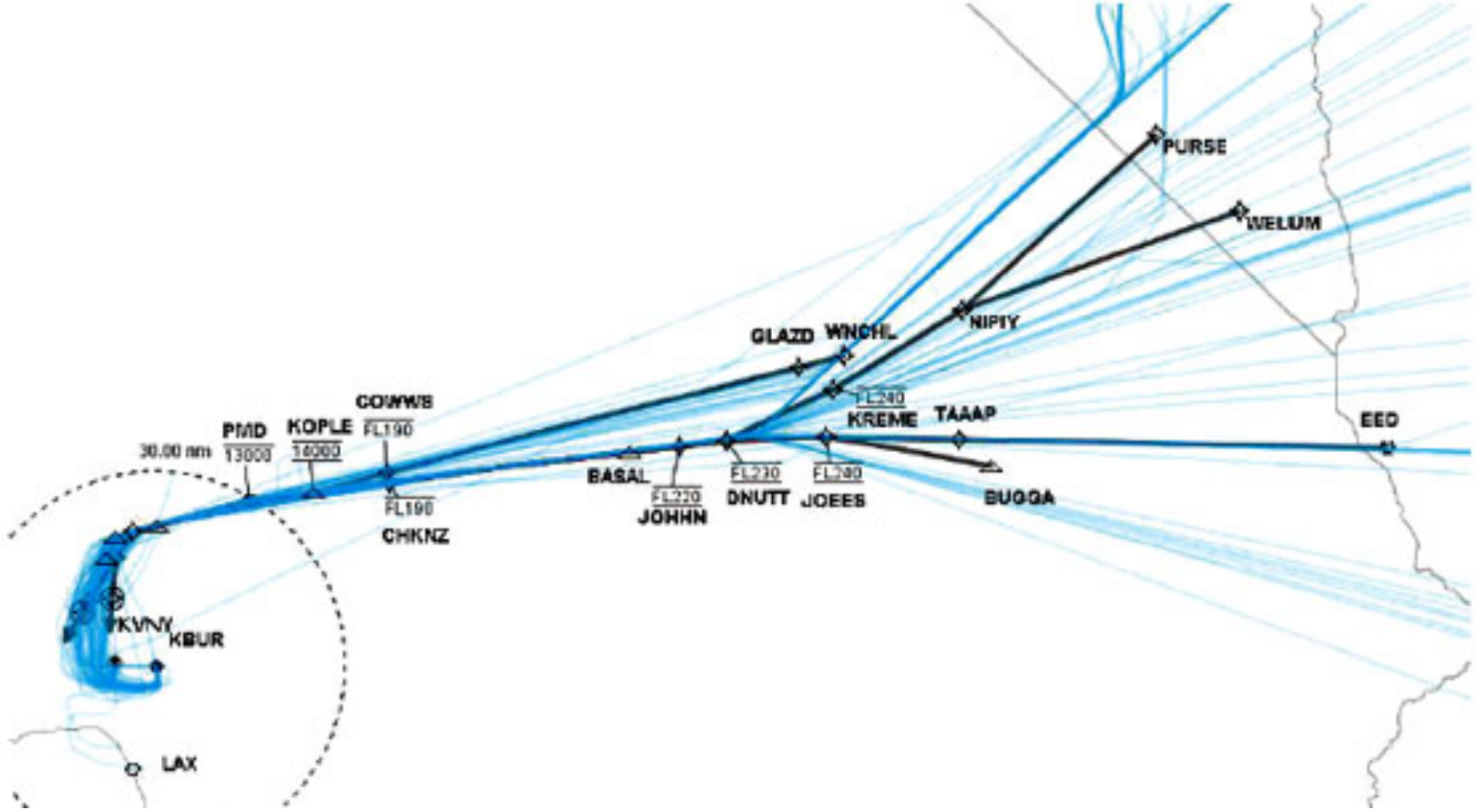


- An RNAV/PBN SID prescribes speed and altitude restrictions at waypoints on the procedure that provide predictable lateral and vertical paths and assure separation from airspace and/or aircraft
  - Vertical windows allow for variable wind conditions permitting flight crews and ATC repeatable and predictable paths for flight and fuel planning
  - Radio communication and potential communication errors are reduced

- In the existing environment ATC will issue multiple climb clearances to mitigate an aircraft departing protected airspace causing level offs and manipulation of power settings resulting in inefficient departure/climb profiles

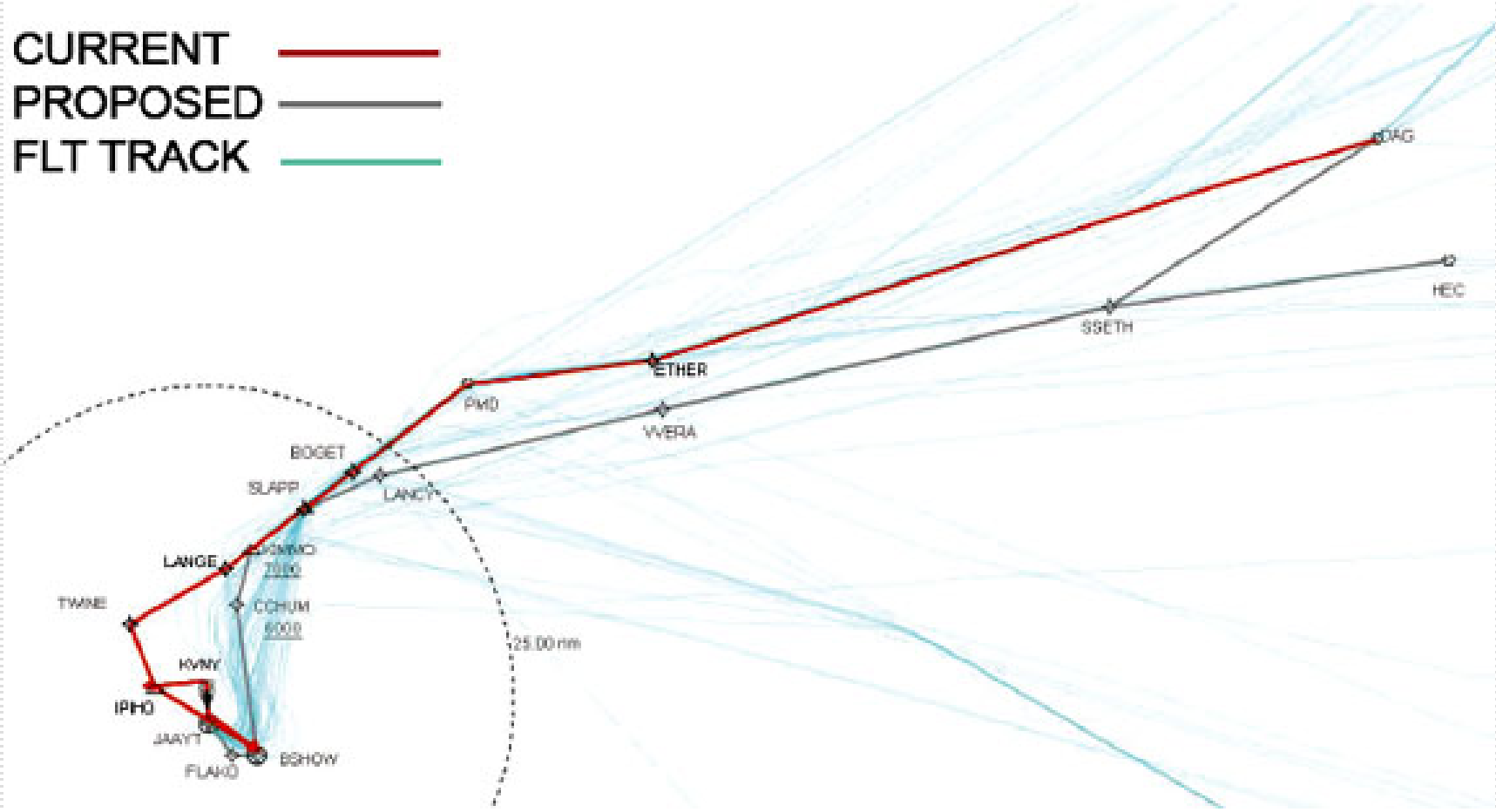
BUR VNY JANNY3 STAR (Modified)

Wide View



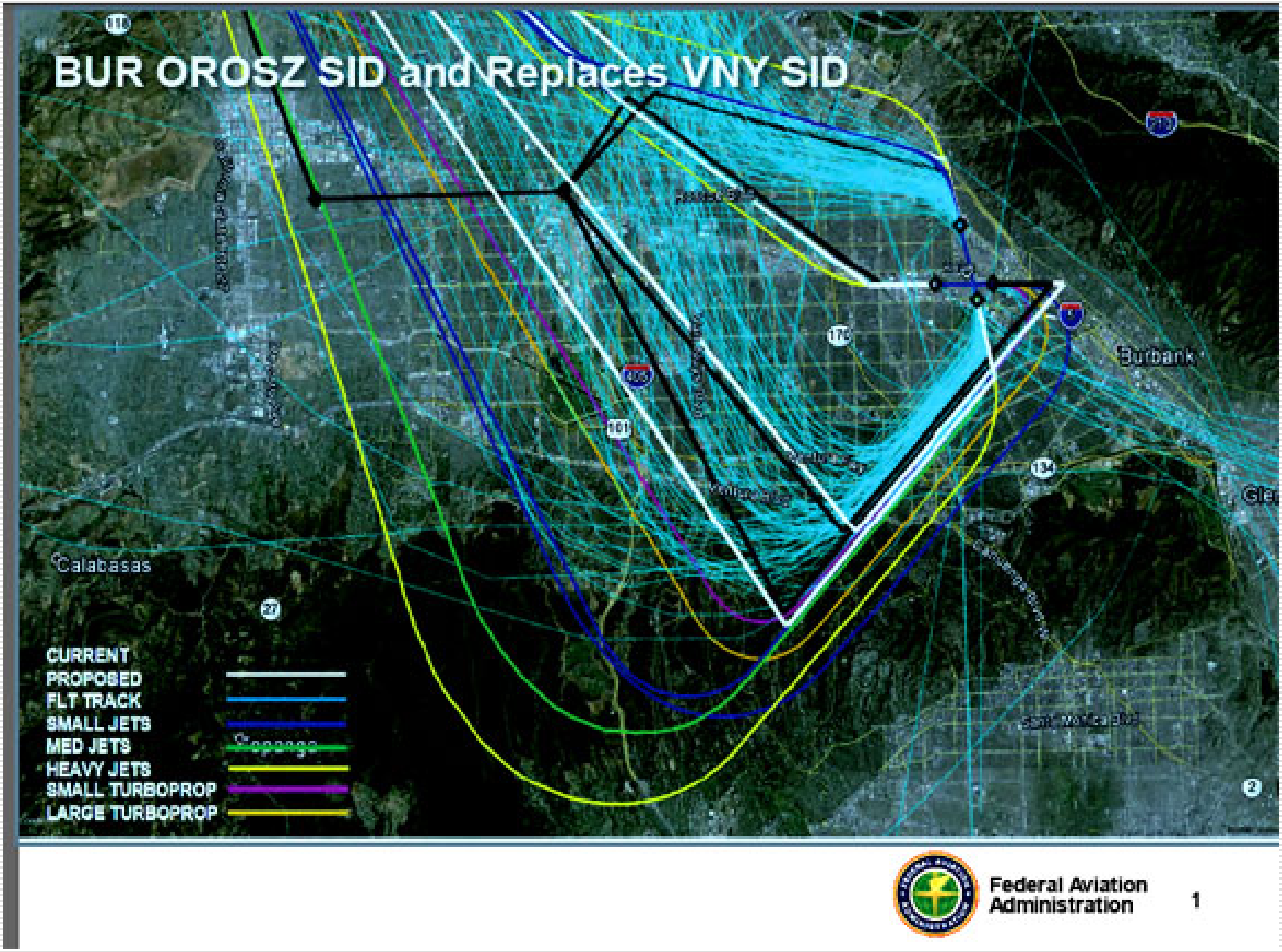
VNY NEWHALL SID (Old)
VNY ROSCOE SID (New)

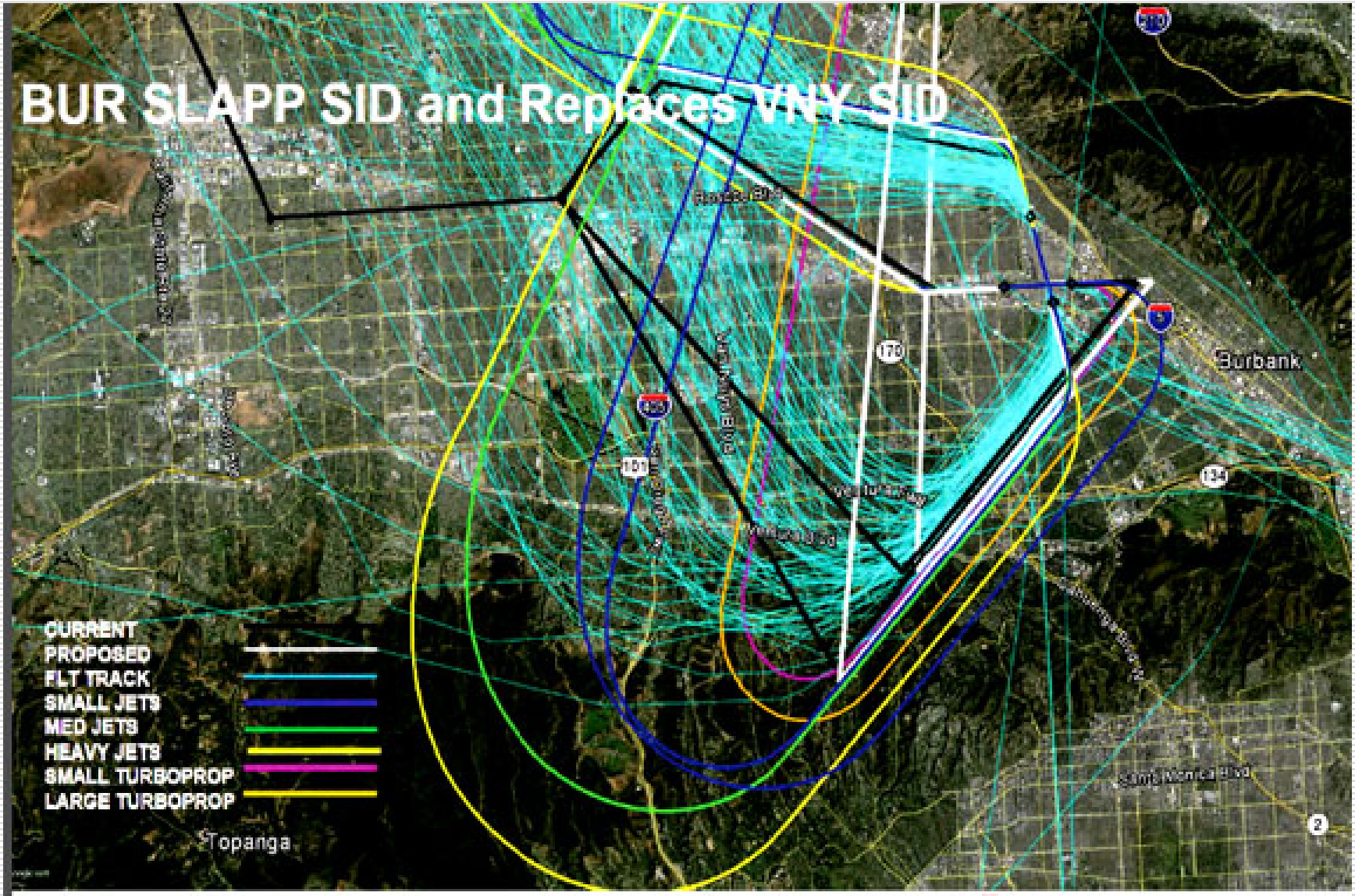
Wide view



Interpreting the graphics

- **LIGHT BLUE LINES** are actual flight track, how the aircraft are flying under current procedures.
- **DARK BLUE LINES** (small jet) are the TARGETS fly ability line. Meaning this is how we expect the aircraft (small jets) to fly the procedure.
- **LIGHT GREEN LINES** (medium jets) are the TARGETS fly ability line. Meaning this is how we expect the aircraft (medium jets) to fly the procedure.
- **PURPLE LINES** (small turboprops) are the TARGETS fly ability line. Meaning this is how we expect the aircraft (small turboprops) to fly the procedure.
- **ORANGE LINES** (large turboprops) are the TARGETS fly ability line. Meaning this is how we expect the aircraft (large turboprops) to fly the procedure.
- **WHITE LINES** are the TARGETS proposed design lines. They are a reference for design only.
- **BLACK LINES** are the current TARGETS design lines. Again utilized for reference only


BUR OROSZ SID and Replaces VNY SID
Burbank
Calabasas
CURRENT
PROPOSED
FLT TRACK
SMALL JETS
MED JETS
HEAVY JETS
SMALL TURBOPROP
LARGE TURBOPROP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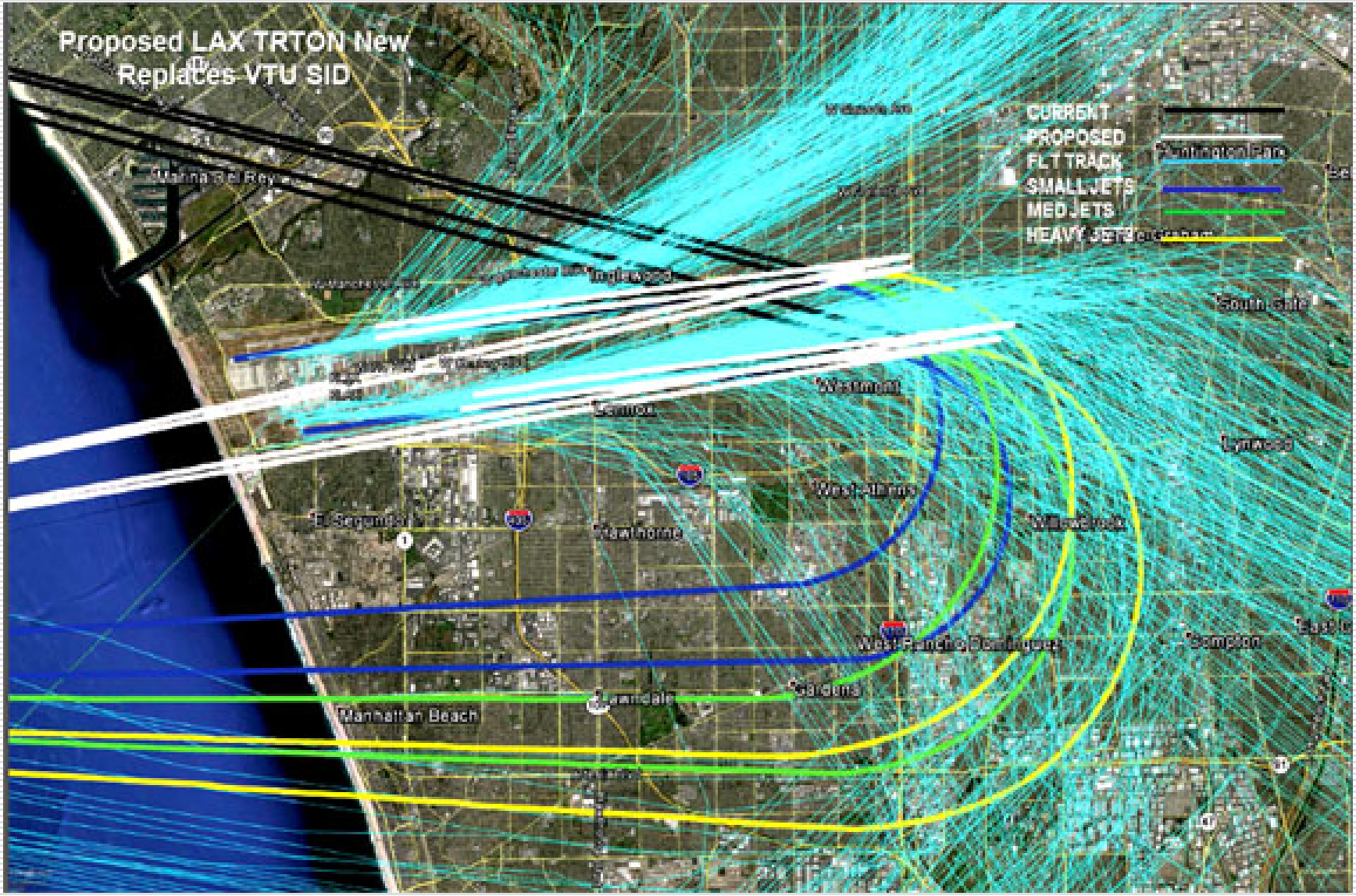
Proposed LAX TRTON New
Replaces VTU SID
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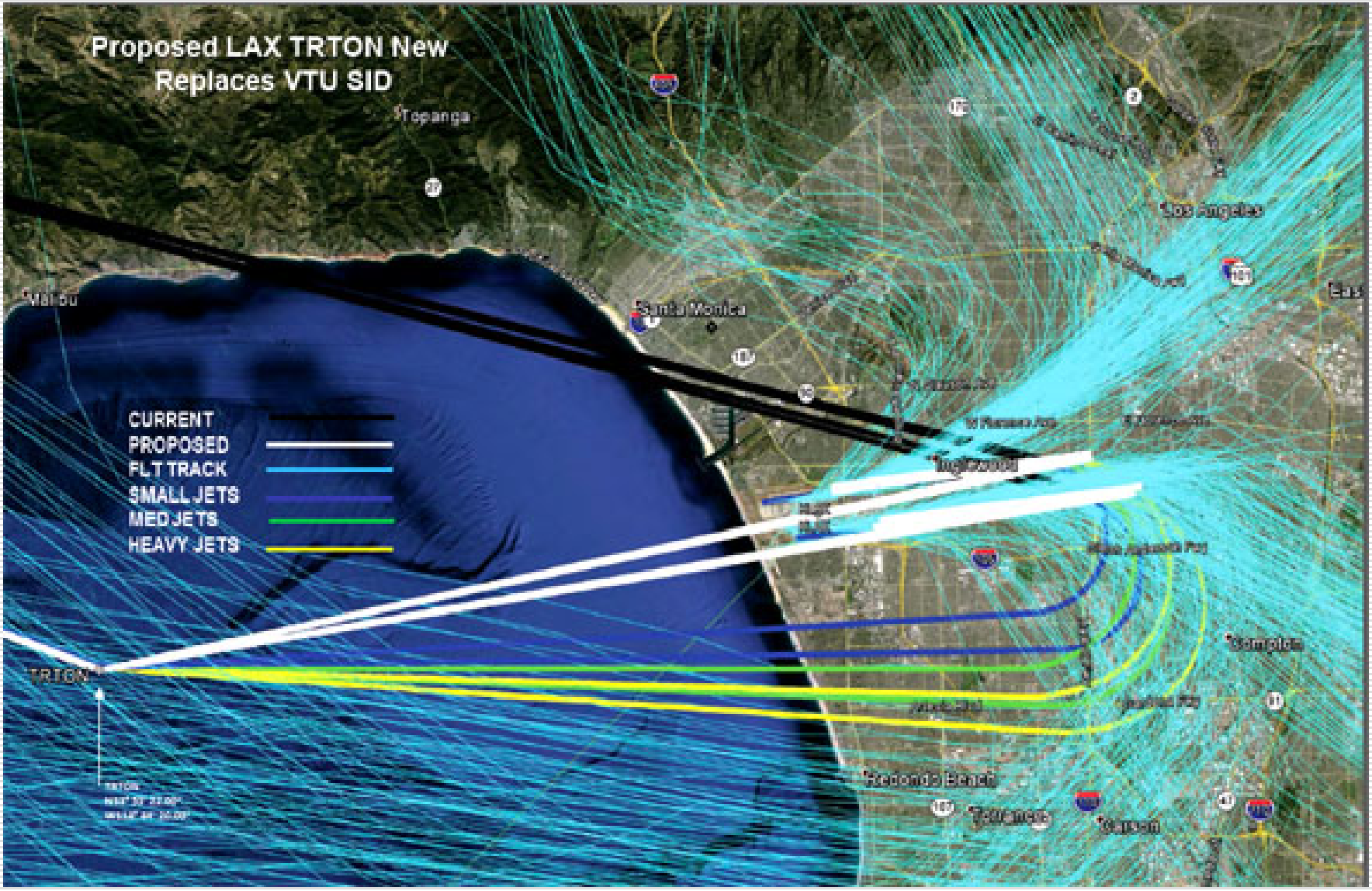
Hawthorne
Lawndale
Westmont
Inglewood
Marina Del Rey
South Gate
Lynwood


Proposed LAX TRTON New
Replaces VTU SID
Topanga
Malibu
Santa Monica
Los Angeles
CURRENT
PROPOSED
FLT TRACK
SMALL JETS
MED JETS
HEAVY JETS
TRTON
Redondo Beach

Summary of Potential Benefits

Qualitative Benefits

- Reduced ATC task complexity
- Reduced communications (flight deck and controller)
  - Reduced phraseology
  - Reduced frequency congestion
- Reduced pilot workload
- Repeatable, predictable flight paths
- Accurate fuel planning
- Laterally or vertically segregated flows where practical

Quantitative Benefits

	Low	High
Estimated Annual Fuel Savings: SIDs and STARs (Dollars)	$9.94M	$22.68M
Estimated Annual Fuel Savings: SIDs and STARs (Gallons)	3.36M	7.72M
Estimated Annual Carbon Savings: SIDs and STARs (Metric Tons)	34K	77K
Estimated Annual ADOC Savings: LAX Dual Independent Finals	$3.99M	
Estimated Annual Fuel Savings: SMO / LAX Interactions	$200K	$260K
Estimated Annual Savings: TOTAL	*$14.13M*	*$26.93M*

Metroplex brings new noise issues

- A “Metroplex” is a geographic area covering several airports serving major metropolitan areas, such as the Los Angeles Basin.
- The project involves changing aircraft flight paths and/or altitudes in certain areas.
- The new flight procedures, using satellite-based navigation technology, are more precise and create a narrower flight path, resulting in a concentration of flights over certain areas.
- Residents in areas under the concentrated flight path may experience more noise, while those outside the flight path may experience less noise.

Culver City noise issues

- **Culver City to Sue Over Flight Path Changes**
- At its October 24, 2016 Council meeting, the City Council of the City of Culver City directed the City Attorney to file a lawsuit against the Federal Aviation Administration (FAA) related to aircraft overflights. The FAA recently issued an Environmental Assessment of its So Cal Metroplex changing flight path procedures.
- Over the past several years, hundreds of Culver City residents have come to City Council meetings, and over a thousand complaints were submitted to the FAA and LAX, regarding serious concerns about current noise and pollution impacts of the aircraft overflights. Recently, 300 residents signed a petition submitted to the City Council, requesting that the Council take legal action against the FAA to protect them against further impacts from the So Cal Metroplex project.
- Culver City in the News - 10/26/2016

Orange County noise issues

- **Orange County criticizes flight changes**

- Orange County has filed a petition in federal court to join Newport Beach in suing the Federal Aviation Administration with both trying to block revised air traffic plans for planes coming in and out of John Wayne Airport. The legal motion, filed Nov. 10, argued that the changes could lead to a significant increase in airplane noise for areas surrounding the county-owned-and-operated airport.

- The county's Board of Supervisors filed the petition in the U.S. 9th Circuit Court of Appeals after a vote to join with the coastal city "in protecting all of our communities," said Supervisor Todd Spitzer. "We have an absolute duty to speak up for citizens who will be affected by airport noise, and Newport Beach has been so aggressive in doing that. We as a county need to be right alongside it," said Spitzer, who represents Tustin and other areas of Orange County heavily affected by the arrival of jets.The legal action targets an environmental impact review conducted by the FAA to determine the effects of the Southern California Metroplex project, which would replace outdated, ground-based air-traffic control procedures with a GPS-based system at 21 regional airports, including John Wayne.

Los Angeles Times 11/24/2016

Phoenix noise issues

- PHOENIX -- Phoenix residents disrupted for months by noise from new flight paths at Phoenix Sky Harbor International Airport will have their complaints voiced in court because the city on Monday filed a lawsuit against the Federal Aviation Administration. City legal staff filed the petition in the U.S. Court of Appeals D.C. Circuit, said Dan Brown, acting city attorney. The City Council never voted on filing the suit but provided legal direction in executive sessions over the past several months, he said.
- *The Arizona Republic June 2, 2015*

San Francisco noise issues
Boxer-Feinstein letter April 12, 2016

April 12, 2016

The Honorable Michael Huerta
Administrator
Federal Aviation Administration
800 Independence Avenue S.W., Room 1022
Washington, DC 20591

Dear Administrator Huerta:

We write to ask that you take all practicable steps to address the noise impacts of the NextGen initiative on California communities. While we appreciate that this airspace modernization program is intended to benefit airlines and their customers, these benefits may not outweigh the serious noise concerns reported by many other Californians.

Since your agency began implementing the NextGen flight paths in the San Francisco Bay Area, hundreds of residents have contacted our offices to describe how the sounds of more frequent and lower-altitude flyovers are disrupting their lives. In Southern California, where NextGen changes are still forthcoming, we are already hearing from constituents who believe that the new patterns were developed without adequate regard for noise impacts.

We recognize that optimizing airspace requires careful consideration of safety, efficiency, and environmental impacts, and noise is only one element in this complex balance. However, given that the new California flight patterns were not designed to address specific safety issues and will actually result in a slight increase in greenhouse gas emissions per flight operation (according to the environmental reviews performed for both the Northern and Southern

Acronym Definitions

ATC: Air Traffic Control
EA: Environmental Assessment
NextGen: Next Generation Air Transportation System
OAPM: Optimization of Airspace and Procedures in the Metroplex
OPD: Optimized profile descent
PBN: Performance based navigation
RTCA: Radio Technical Commission for Aeronautics
RNAV: Area Navigation
RNP :Required Navigation Performance
SCT: Southern California Terminal Radar Approach Control
SID: Standard Instrument Departure
SoCal: Southern California
STAR: Standard Terminal Arrival Route
ZLA: Los Angeles Air Traffic Control Center

Points of Contact

- **Rob Henry, Manager SoCal Metroplex**
  - Robert.Henry@faa.gov
- **Jose Gonzalez, SoCal NATCA Article 48**
  - Jose.J.Gonzalez@faa.gov
- **Shawn Kozica, SoCal District Management POC**
  - Shawn.M.Kozica@faa.gov
- **Mike Taylor, SCT NATCA POC**
  - Michael.J.Taylor@faa.gov
- **Ken Brissenden, ZLA Management POC**
  - Ken.Brissenden@faa.gov
- **Walter Alexis, ZLA NATCA POC**
  - Walter.F.Alexis@faa.gov

Resources

- **Optimization of Airspace and Procedures in the Metroplex (OAPM)**
- https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0ahUKEwiE6vTV86vQAhWBOiYKHf1NBMYQFggjMAE&url=https%3A%2F%2Fwww.lawa.org%2FuploadedFiles%2Flax%2Fnoise%2Fpresentation%2FnoiseRT_130109_FAA%2520Presentation%2520on%2520OAPM%2520Process.pdf&usg=AFQjCNF_6NAFKbVhE9YEWYA5uaVVqup6Ww&cad=rja

- **FAA Southern California Metroplex Fact Sheet**
- https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwjF-Mui7avQAhVmw1QKHW7OC0EQFggbMAA&url=http%3A%2F%2Fwww.lawa.org%2Fwelcome_lax.aspx%3Fid%3D12168&usg=AFQjCNE7Z9AdXv_ewBVGsDCIAglXOk6ITQ&bvm=bv.138493631,d.cGw

- **NextGen Project Implementation Plan 2016**
- https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwim0NP17avQAhWhrlQKHYMkAlwQFggeMAA&url=https%3A%2F%2Fwww.faa.gov%2Fnextgen%2Fmedia%2FNextGen_Implementation_Plan-2016.pdf&usg=AFQjCNHiX5IwyCzAU3bYc8aHTq0qDQNImA&bvm=bv.138493631,d.cGc

Resources (Continued)

- **LAX Noise Management - FAA's Southern California**
- http://www.lawa.org/welcome_lax.aspx?id=12168

- **Northern California Metroplex Overview EA**
- http://www.metroplexenvironmental.com/norcal_metroplex/norcal_introduction.html

- **Navigation PowerPoint**
- https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjugZKP9qvQAhUKQCYKHTDdDNoQFggeMAA&url=http%3A%2F%2Fwww-gpsg.mit.edu%2F~tah%2F12.215%2F12.215.Lec07.ppt&usg=AFQjCNEXmcpTKygKjW-tpi_PFfNfdKyOWg&bvm=bv.138493631,d.eWE&cad=rja

- **Neighbors Committee Meeting PowerPoint July 14, 2015**
- https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwi8mo_O9avQAhXJNSYKHb-lAkcQFggeMAA&url=http%3A%2F%2Fwww.maacommunityrelations.com%2Fcontent%2Fneighborscommittee%2Fminutes.php&usg=AFQjCNEcXnE_deFZR1wyXh-6i0EKE-6yYA&bvm=bv.138493631,d.eWE

Resources (Continued)

VOR Navigation PowerPoint
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwiDxb7U9qvQAhXC7CYKHUnuDAcQFggbMAA&url=http%3A%2F%2Fwww3.nd.edu%2F~ndpi%2Fcurrent%2Flessons%2FNavigationII.ppt&usg=AFQjCNG7VfLyqUAfpM36nvg66aUacXSs0Q&bvm=bv.138493631,d.eWE&cad=rja

SCAUWG PowerPoint
www.scauwg.or

SoCal Metroplex EA
http://www.metroplexenvironmental.com/socal_metroplex/socal_introduction.html

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