

# Space Weather Effects on Society

## Effects on Wide Area Augmentation System (WAAS)

Kenneth Ward  
Navigation Services Systems  
Engineering and Requirements  
Team

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Federal Aviation  
Administration





# WAAS Subsystems

- **Reference Receiver and Ground Segment**
  - WAAS program developing next generation reference receiver (G-III)
  - G-III receiver will add significant new capability and support WAAS dual frequency upgrades in 2014 – 2019 timeframe
  - Communications Upgrades
  - Initiation of Iono Robustness upgrade
- **Space Segment**
  - WAAS operating with 3 GEO satellites since April 2011
  - Initial acquisition phase for follow-on GEOs underway

# Uses Of WAAS

- **Aviation**
  - Enroute navigation
  - Terminal navigation
  - Approach/Landing
  - Surveillance Automatic Dependant Surveillance
- **Maritime**
- **General Navigation**
  - Cars, Trucks, Trains
- **Geographic Information**



# Aviation Uses

- **Enroute**
  - High
  - Low
- **Terminal**
  - Arrivals and Departures
  - Approach/Landing
- **Integrity & Vertical Navigation**



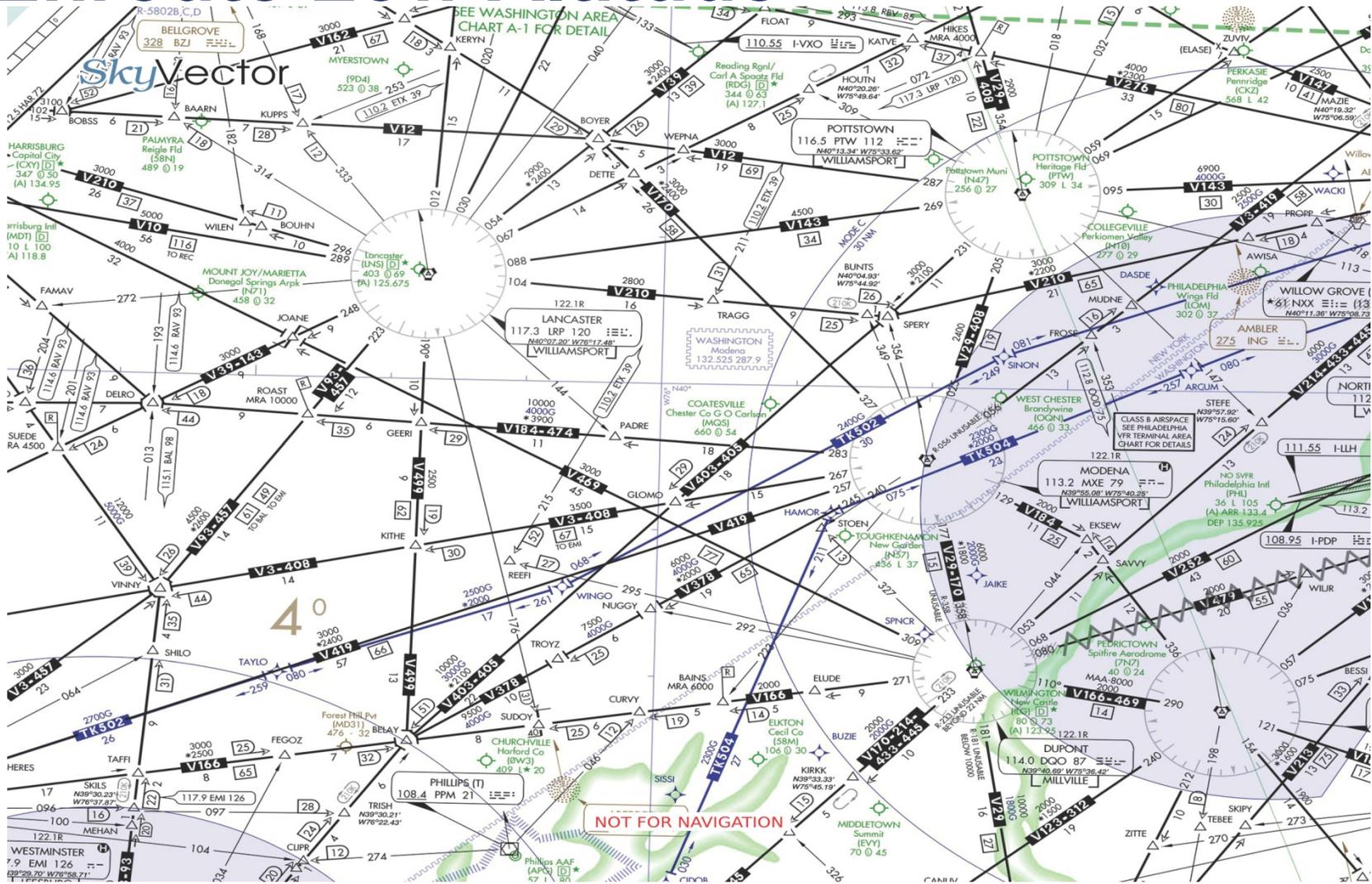
# Capacity Benefits (part 1)

Capacity Benefit	Flight Mode	System	Without GNSS	With GNSS	Example
→ Guided Departures	Departure	GBAS WAAS	SID that takes Aircraft to certain Navaids which is restrictive	Procedural separation allows for less restrictive departures	<ul style="list-style-type: none"> <li>• <a href="#">Houston GBAS Guided Departures</a></li> <li>• Aspen Simultaneous Departures and Arrivals</li> </ul>
→ Flexible Routes	Cruise	GPS WAAS	Confined to pre-existing route structure which may be inefficient in terms of fuel and time	More direct routings, hence saving time and fuel – better use of airspace	<ul style="list-style-type: none"> <li>• <a href="#">GNSS Route as Compared to Standard route</a></li> </ul>
→ Vector Free Arrivals	Final Approach	GPS WAAS	Radar vectoring is an ATC burden and fuel inefficient. Less aircraft can move in and out of the airport on an hourly basis, hence passenger delays	Vector free arrivals give ATC more time for other responsibilities and provide more direct routing and efficiency of the airport	<ul style="list-style-type: none"> <li>• New York / New Jersey MetroPlex</li> </ul>
→ Wake Turbulence Management	Landing	WAAS	Must follow existing separation standards	ATC can manage wake turbulence due to varying glide slopes	<ul style="list-style-type: none"> <li>• <a href="#">Boston Cape Air Varying Glide Slopes</a></li> <li>• <a href="#">Closely Spaced Parallels</a></li> </ul>
→ Enhanced Operations in Poor Weather	Landing	WAAS GBAS	Ground delays occur during poor weather conditions due to traffic holds	Less holding because of the lower minima	<ul style="list-style-type: none"> <li>• <a href="#">Good bad, and Better animation with EWR</a></li> <li>• <a href="#">Aspen Airport WAAS Arrival</a></li> </ul>

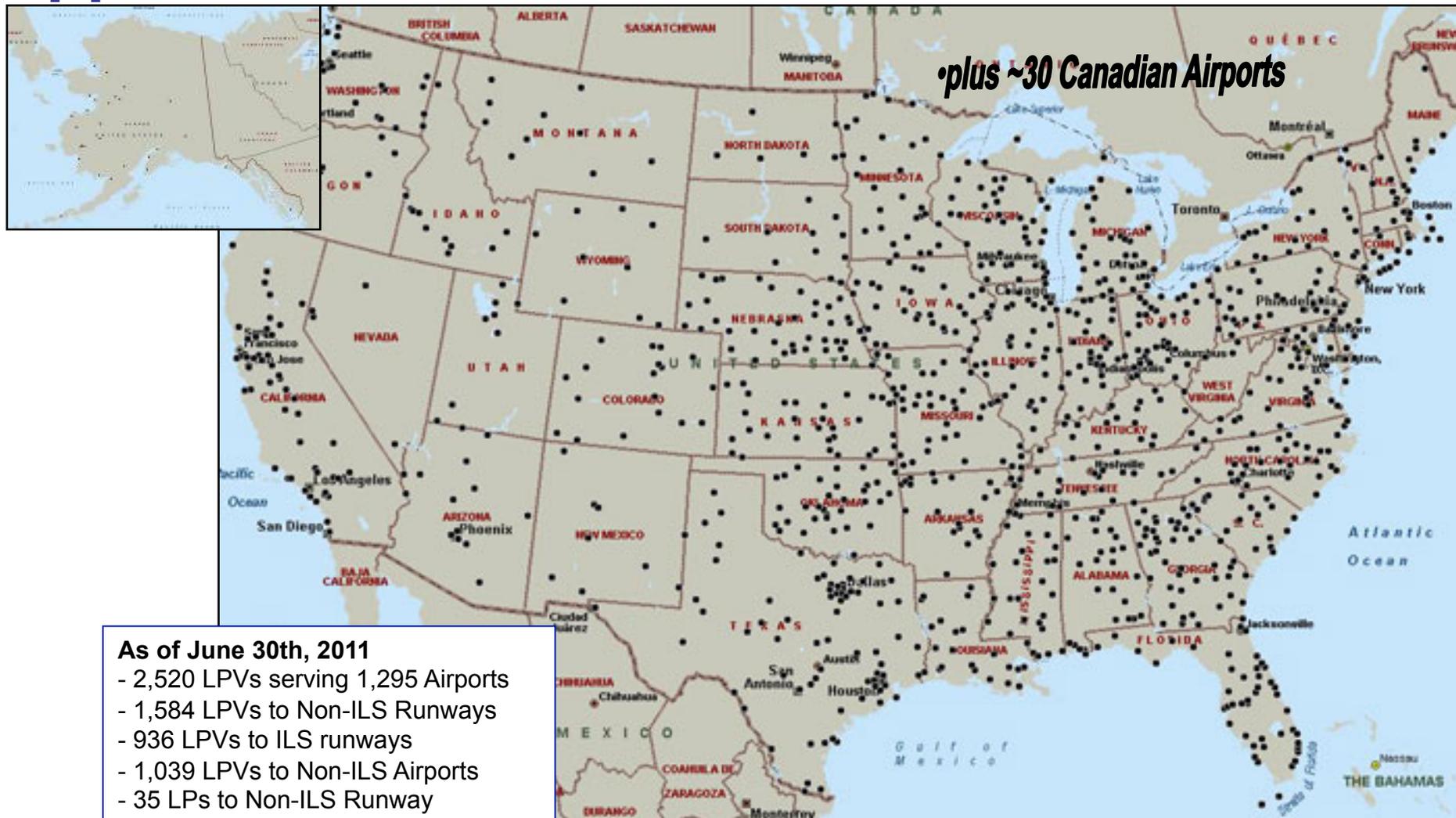
Many of the system benefits described above being proven in demonstration projects, with criteria under development



# Enroute Low Altitude

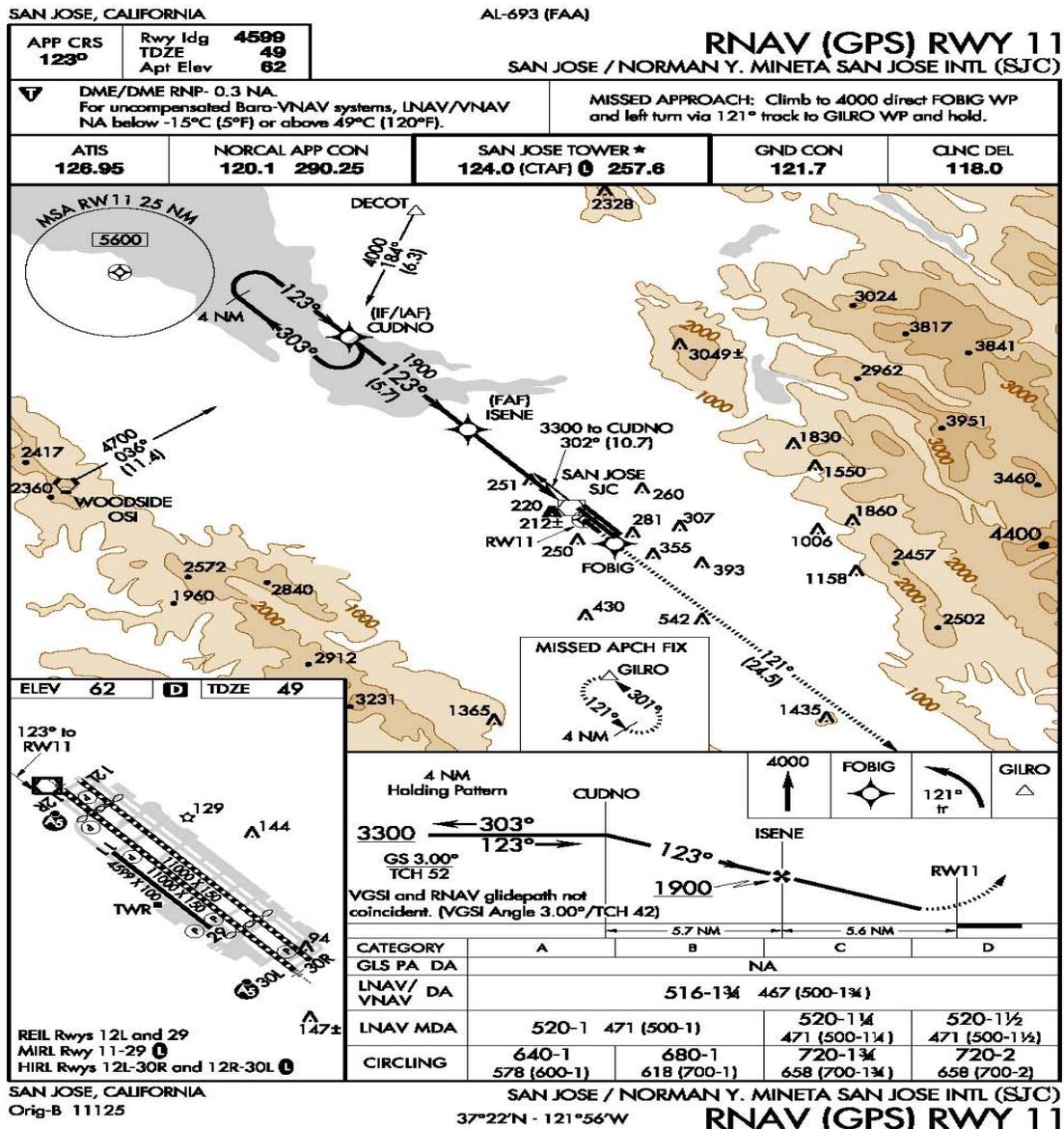


# Airports with WAAS LPV/LP Instrument Approaches

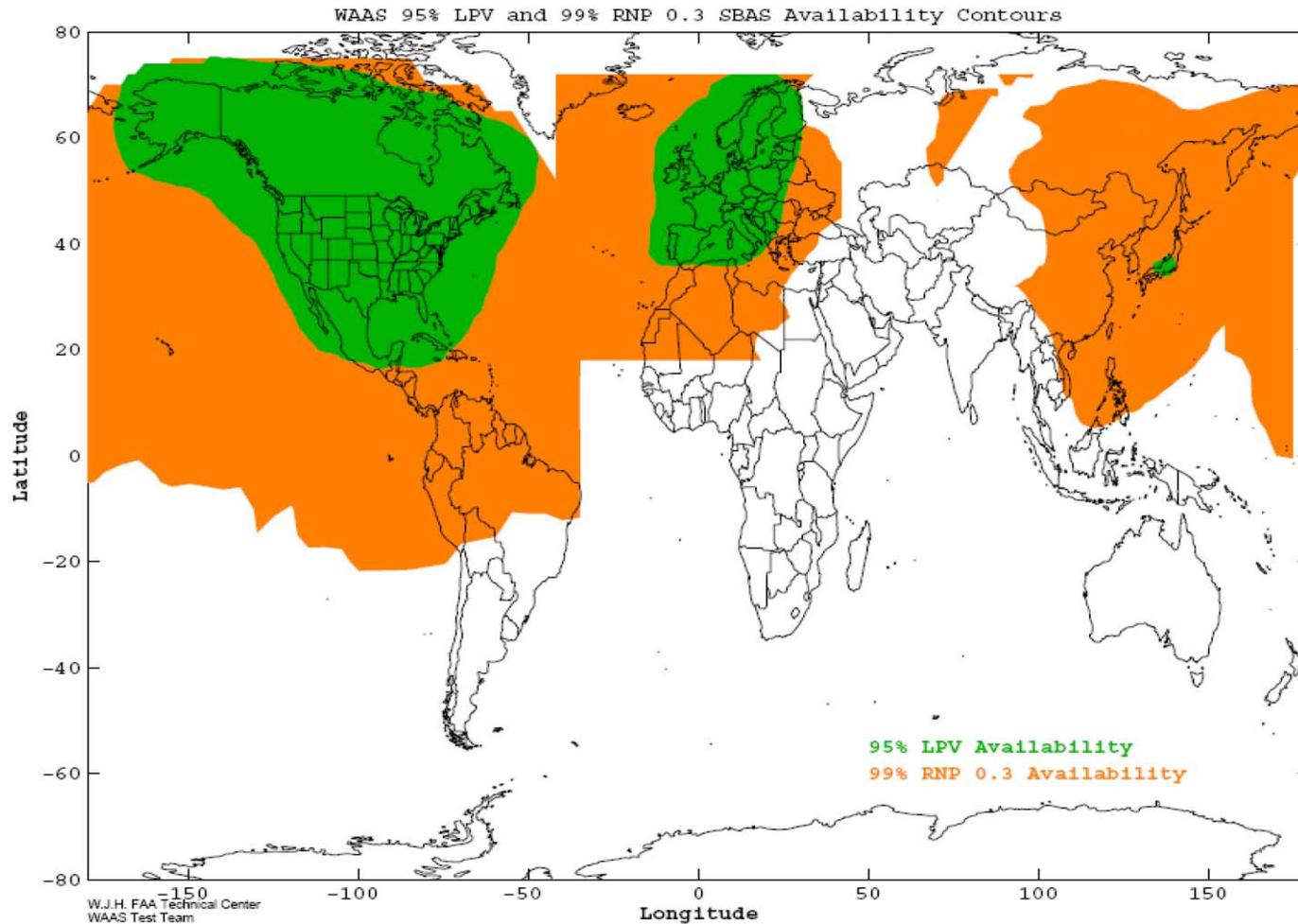


# Approaches

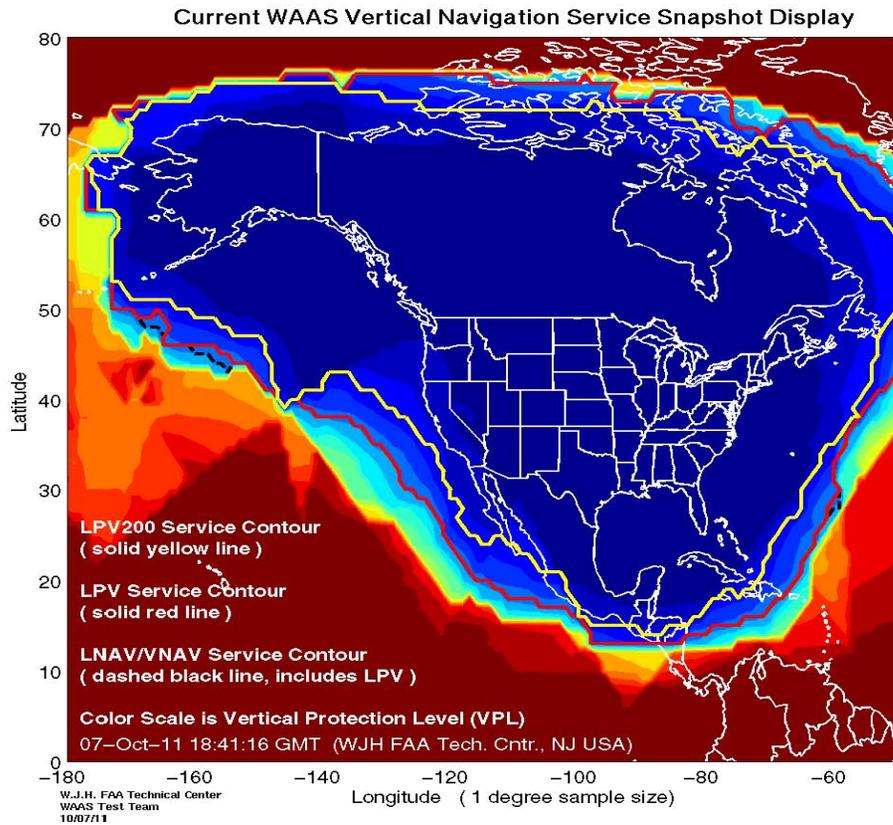
## Example of RNAV (area navigation) approach at SJC



# Global SBAS Coverage

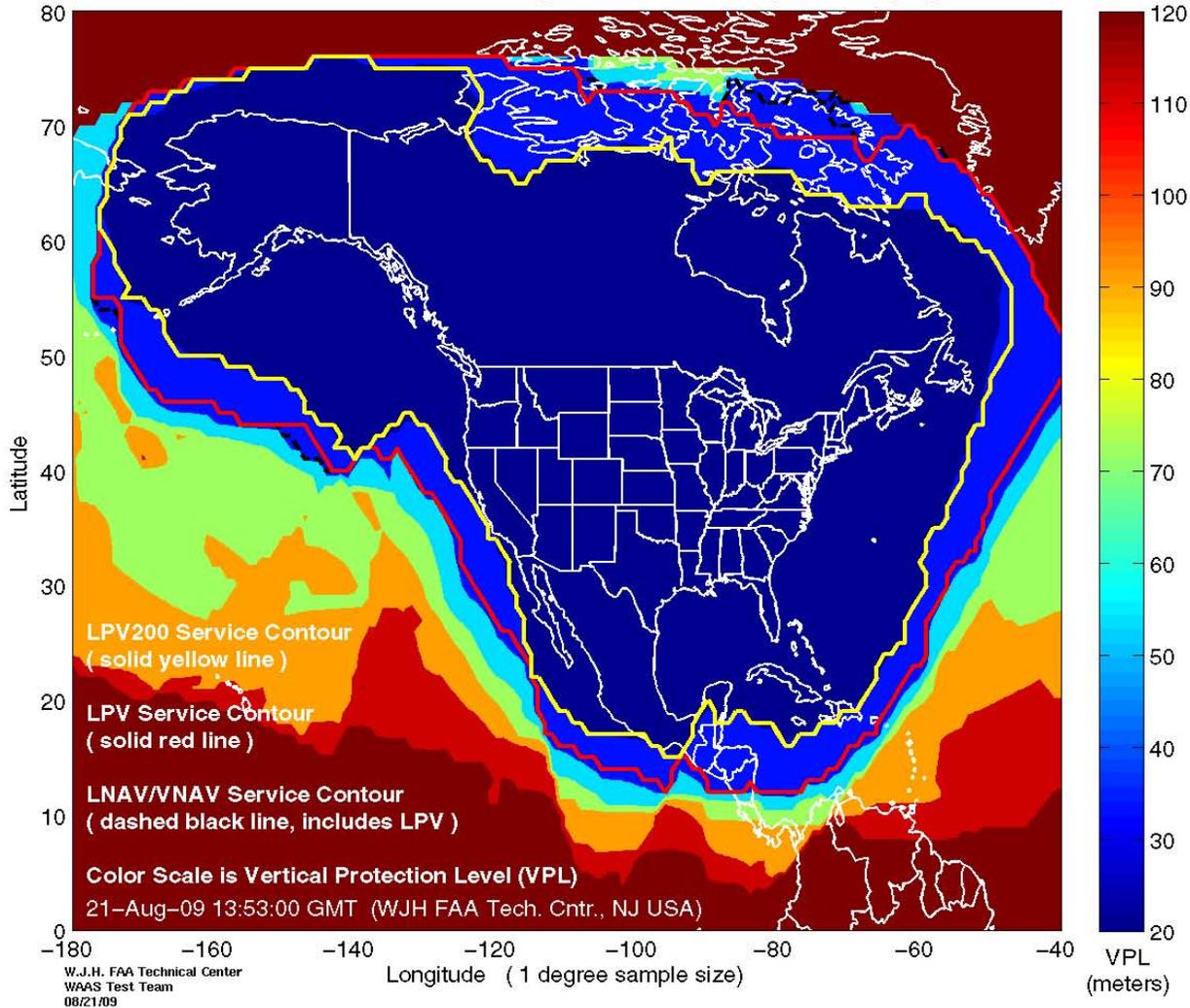


# Localizer Performance Vertical (LPV)



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Current WAAS Vertical Navigation Service Snapshot Display



# Space Weather Effects on WAAS

- **Ionosphere Disturbance**
- **Scintillation**



# Space Weather Relative to Other GPS/WAAS Failure Mechanisms

- **Compared to**
  - Unintentional Jamming
  - Intentional Jamming
  - Equipment/System Failures
  - Troposphere effects

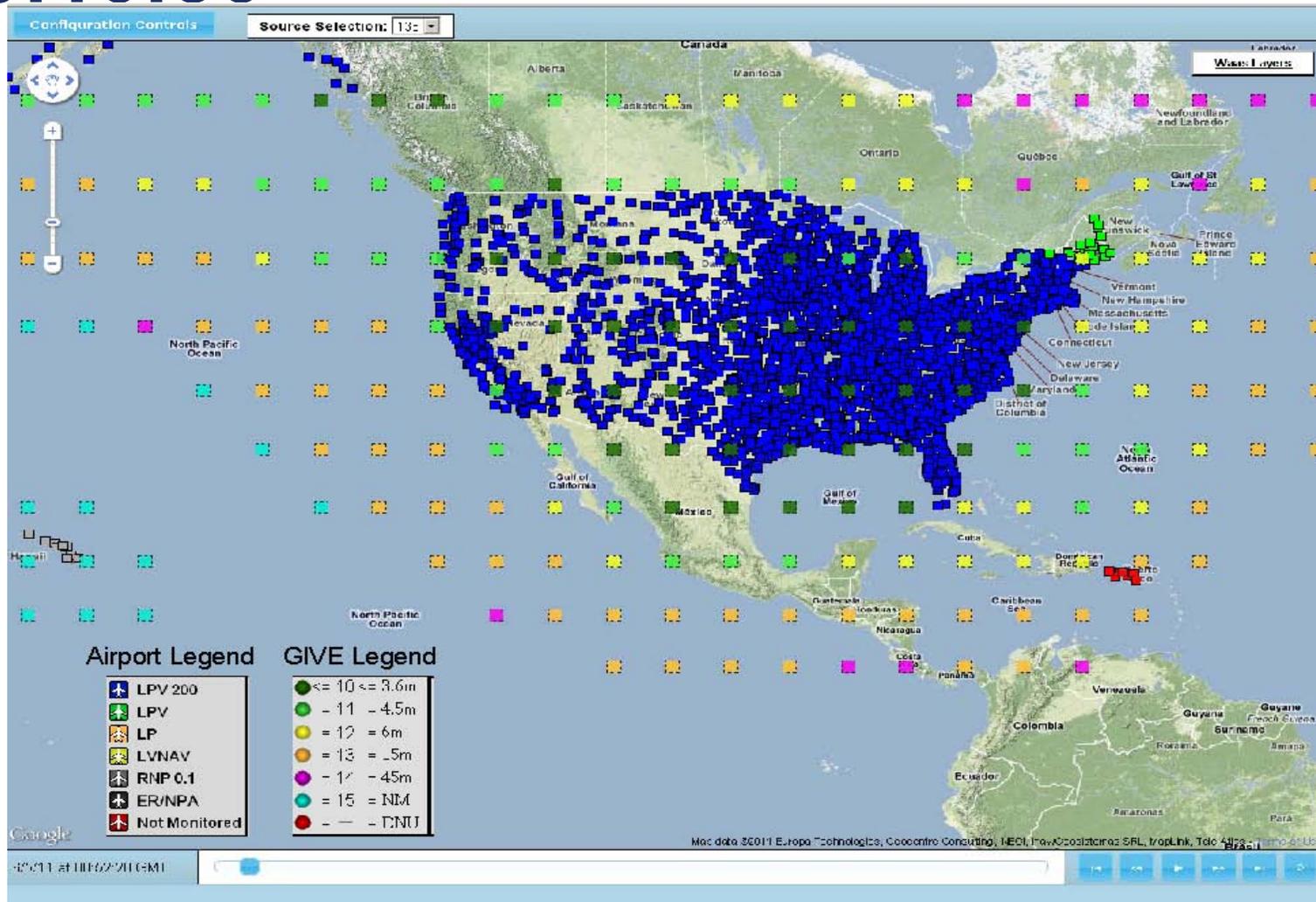
# Example of “Normal” Ionosphere Disturbance Event

- **June 5, 2011 (0100 to 0430 GMT)**
  - Evening of June 4 local time in CONUS
  - WAAS degradation begins in north central/western CONUS, Canada, and southern Florida/Caribbean. Canada

# Ionosphere Activity Event Effects

- **Following slides show airports in CONUS effected by ionosphere activity**
  - Plots include IGP GIVEs at the time of the plots
  - Each small square is an airport that has at least a GPS published procedure
  - Each larger square is an IGP
  - Airport Legend notes
    - LPV 200 =  $VPL < 35m$  &  $HPL < 40m$
    - LPV =  $35m < VPL < 50m$  &  $HPL < 40m$
    - LP =  $VPL > 50m$  &  $HPL < 40M$
    - LVNAV =  $VPL < 50m$  &  $40m < HPL < 556m$

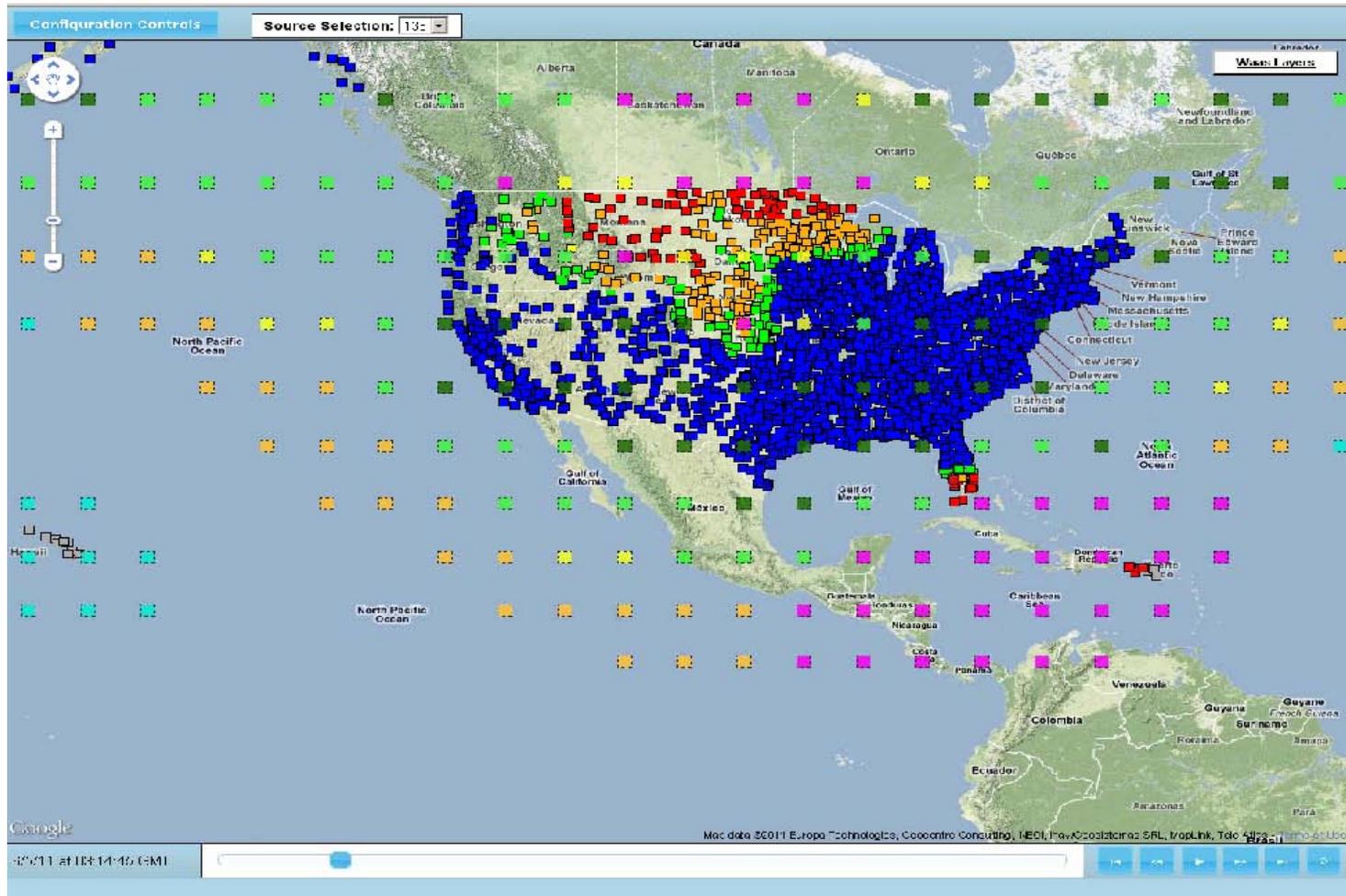
00:10:36



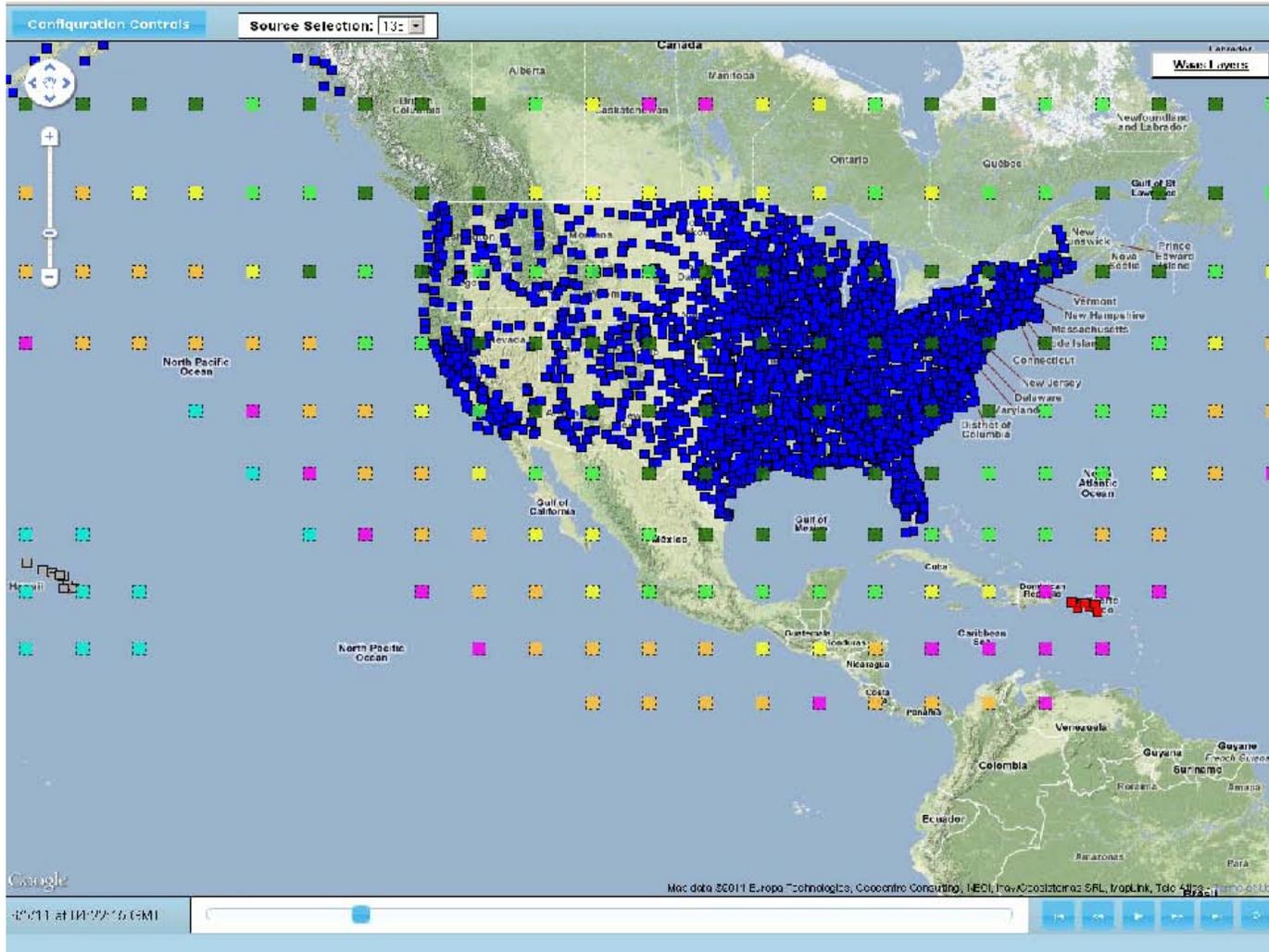




03:14:44



# 04:22:15



# Effects of “Normal” Event

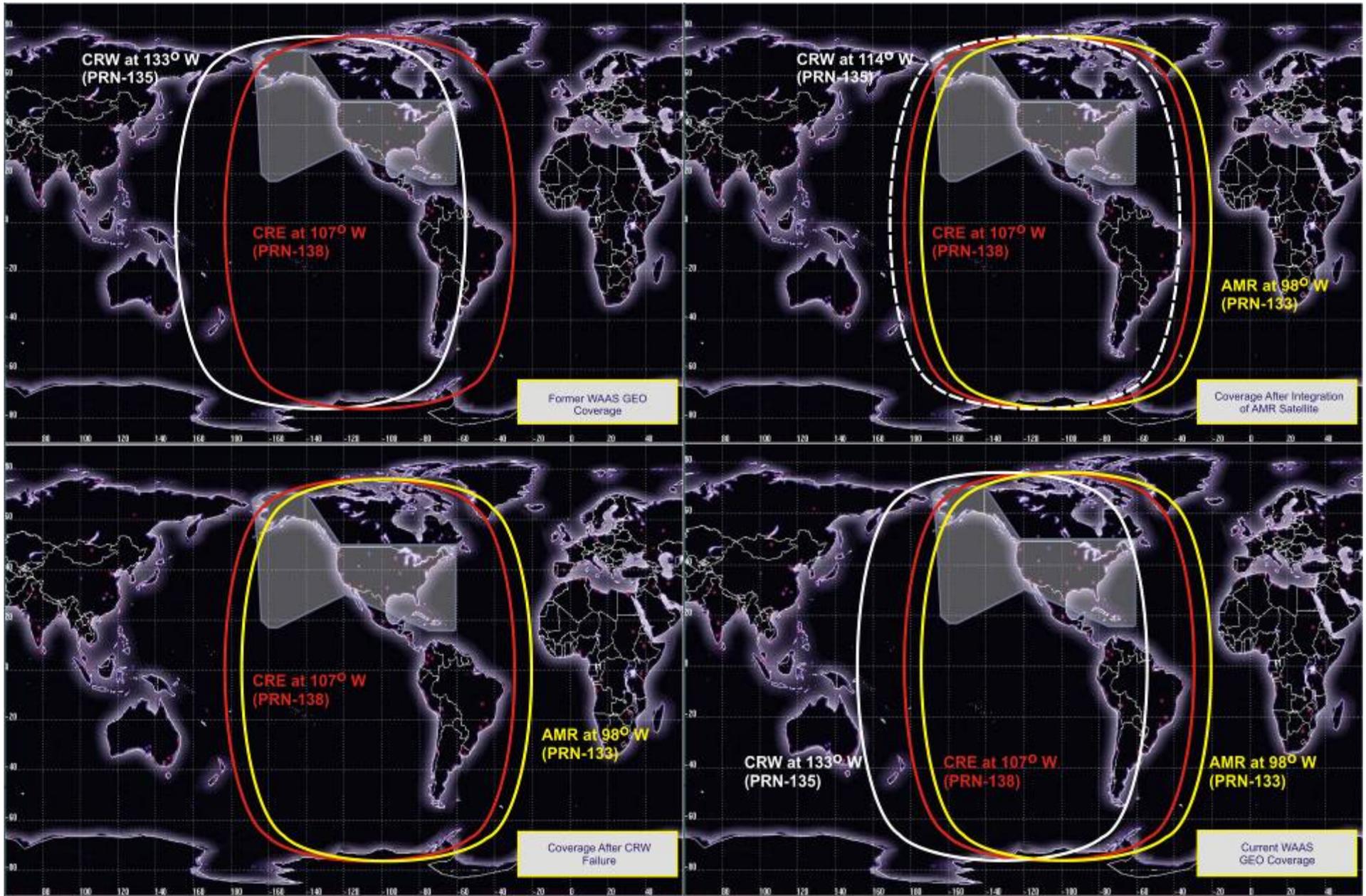
- **Note the areas that loose LPV 200 and LPV approach service... Puerto Rico, N. Maine, then Minneapolis, Milwaukee, Chicago... then Miami, Ft. Lauderdale, and Orlando. Entire cycle is approximately 3.5 hours**
- **If GPS and WAAS had been the only means of navigation and approach services the impacts to air navigation would be significant disruption causing diversions to other airports through airspace with service. This might be inferred to be comparable to the effects experienced during winter weather events where areas and airports are unusable due to weather.**
- **GPS and WAAS are not the only means of navigation and approach services so impact is reduced and mainly economic.**
- **Aviation schedule and economic impact not inconsiderable but manageable.**

# Effects of “Exceptional” Events

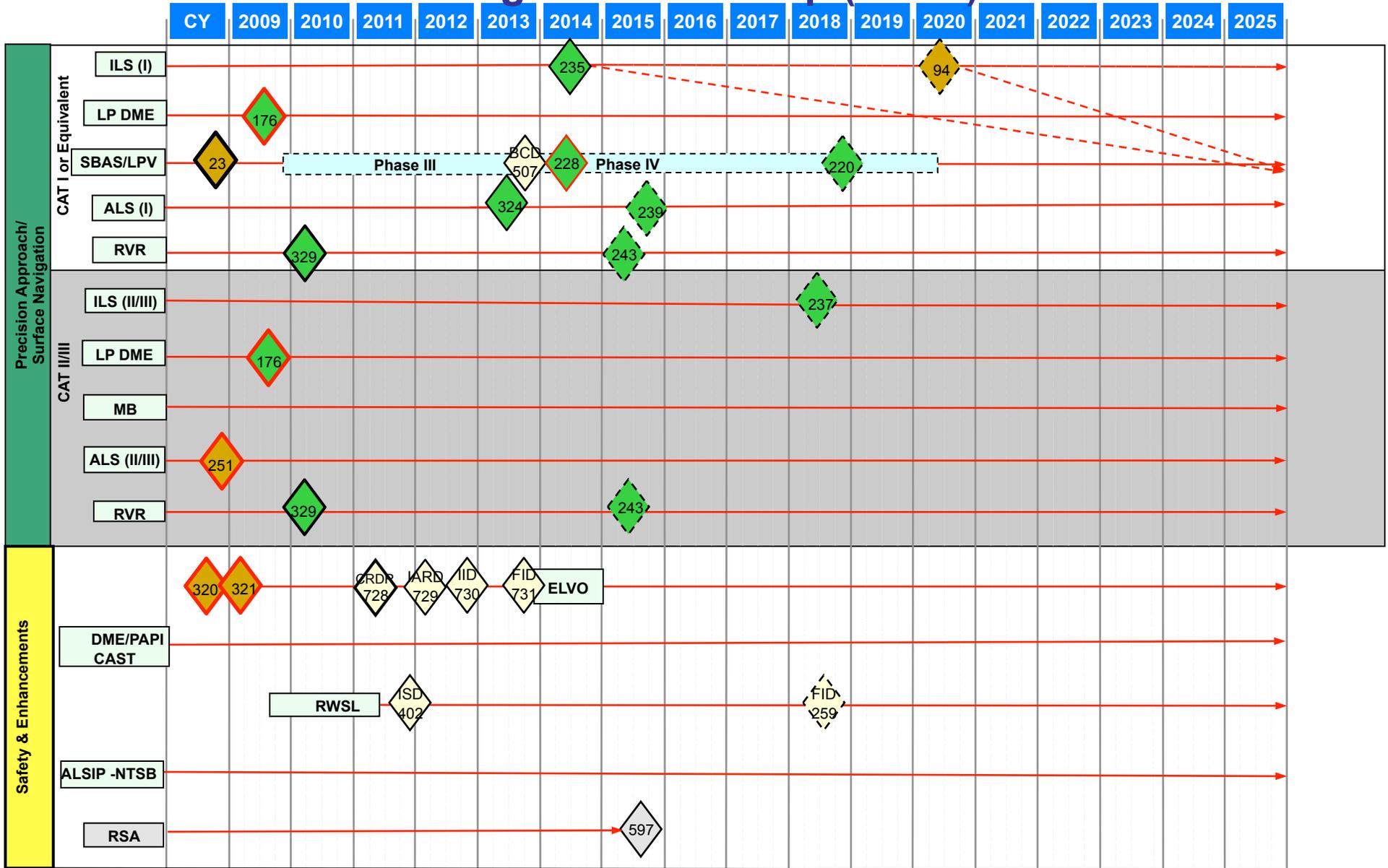


# Questions ?



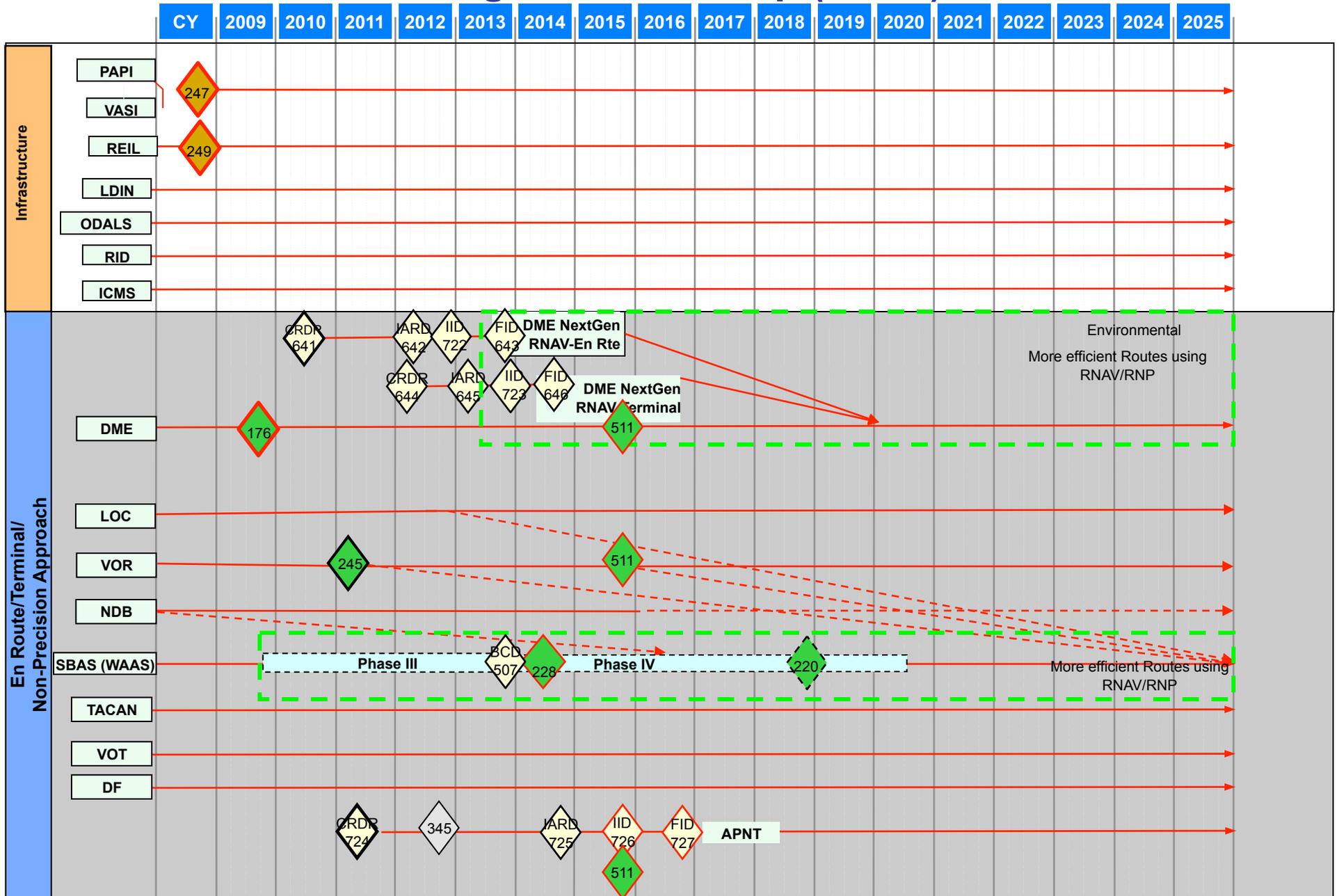


# Navigation Roadmap (1 of 3)



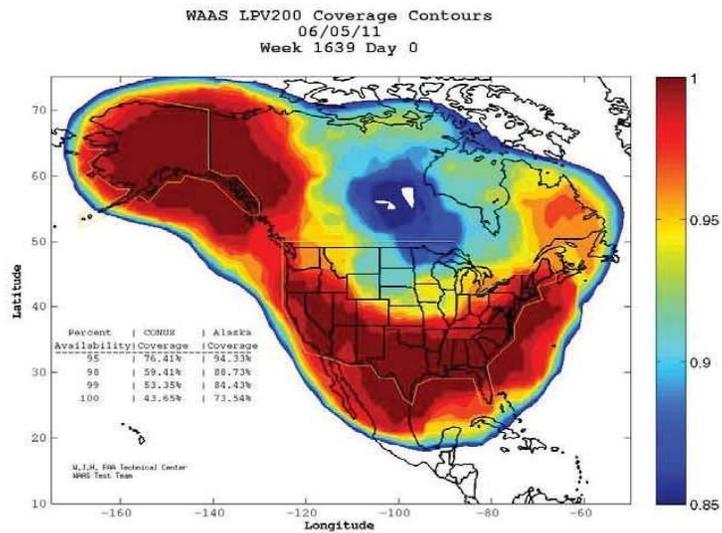
Working Draft

# Navigation Roadmap (2 of 3)

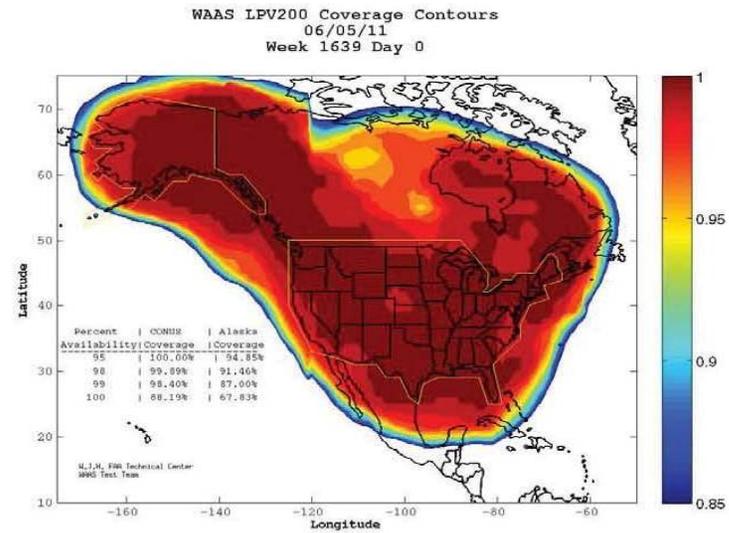


Working Draft

# LPV 200 24 Hour Plot



Operational WAAS



Release 3A