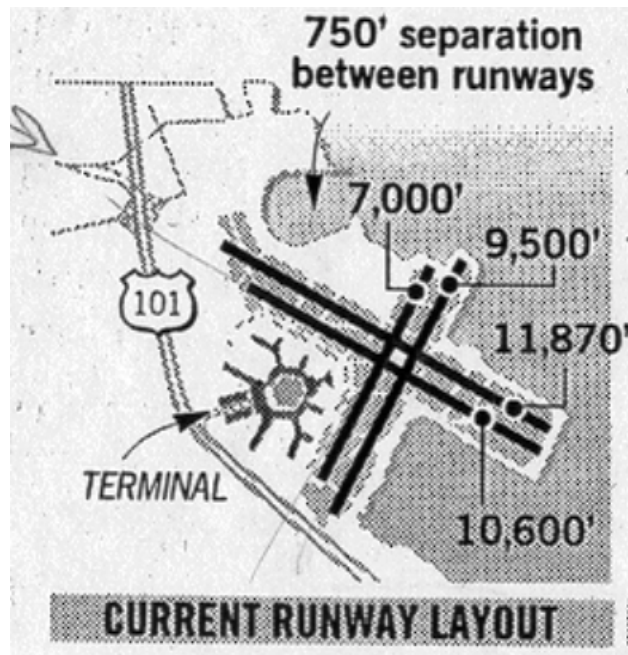


# A Case Study of RNP at SFO

Advanced Navigation  
Subgroup

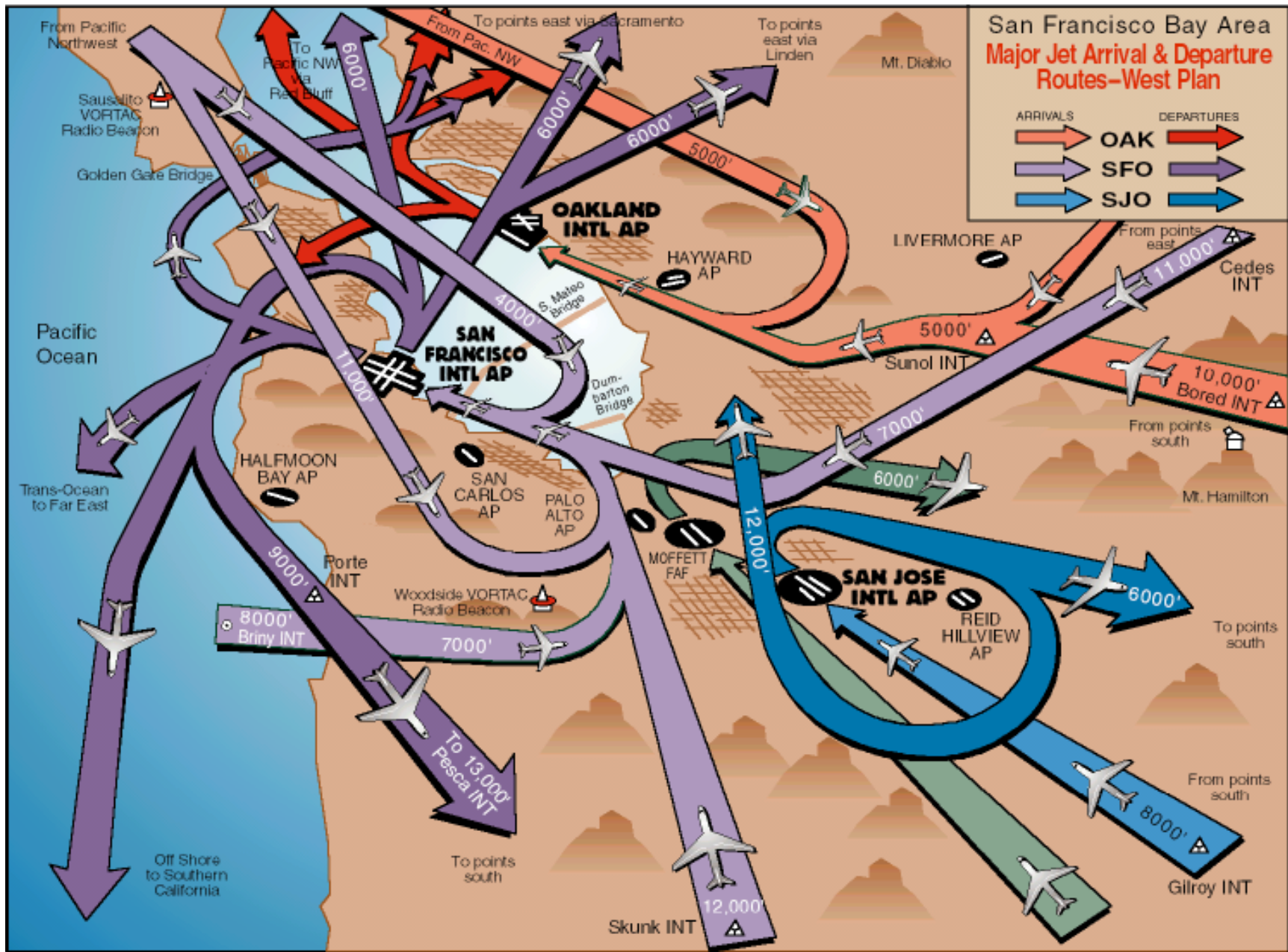
# Background - the SFO Airport Air Traffic situation

- The geography - two sets of parallel intersecting runways, 750 feet spacing between parallel runways



# The traffic demands at SFO

- Daily operations - approx 1,300
- Two peak times 10:00- 1300; 18:00- 21:00
- Peak times - arrival rates of 45 - 55 per hour with like high number of departures
- Peak demand requires dual runway arrival streams



# SFO Today - the impact of Weather

- United and our competitors' schedules demand dual runway operations
- When weather is forecast to fall below 3,500 foot ceilings, SFO goes to single runway operation
- As the operating day proceeds, delays build both at SFO and at outlying stations

# The Question for this Analysis - Is there an RNP Approach with good economic payback?

- The RNP Approach must decrease delays by increasing arrival rates to the 28L/R runways while maintaining departure rates on 1L/1R in marginal VMC
- Questions
  - How large will be the delay reduction benefits?
  - What are the associated aircraft equipage costs?

# RNP - A Primer

- RNP stands for Required Navigation Performance - expressed in Nautical Miles
  - For this analysis we will be examining two levels of RNP -
    - RNP 0.3 - A requirement for 0.30 nm accuracy
    - RNP 0.15 - A requirement for 0.15 nm accuracy

## 2 Scenarios were examined

- An approach requiring RNP 0.3
- An approach requiring RNP 0.15
- Both are assumed to provide the same benefit
- The issue is what are the economic implications of RNP 0.3 Vs 0.15 for attaining these benefits.

# What is required to attain RNP 0.3?

- An aircraft with an FMS with RNP alerting and DME/DME
- Aircraft capable out of the factory
  - A310/320, A330/340,
  - B777, B747-400 FANS-1,
  - 737NG, latest 757/767

## What is required to attain RNP 0.15?

- An aircraft with dual advanced FMS with RNP alerting capability and GPS
- Aircraft capable out of the factory:
  - B777, 737NG, latest 757/767;
  - A319/320 and A330/340 in 2001/2002

## A key issue - Percent of aircraft RNP equipped for ATC to sanction the approach?

- For this analysis we assumed a base case of 75% equipage to initiate the procedure
- Today SFO operations fall short of 75% of RNP 0.15 and 0.3 capable aircraft
- To reach the critical 75% aircraft either must be retrofitted or replaced by new capable aircraft

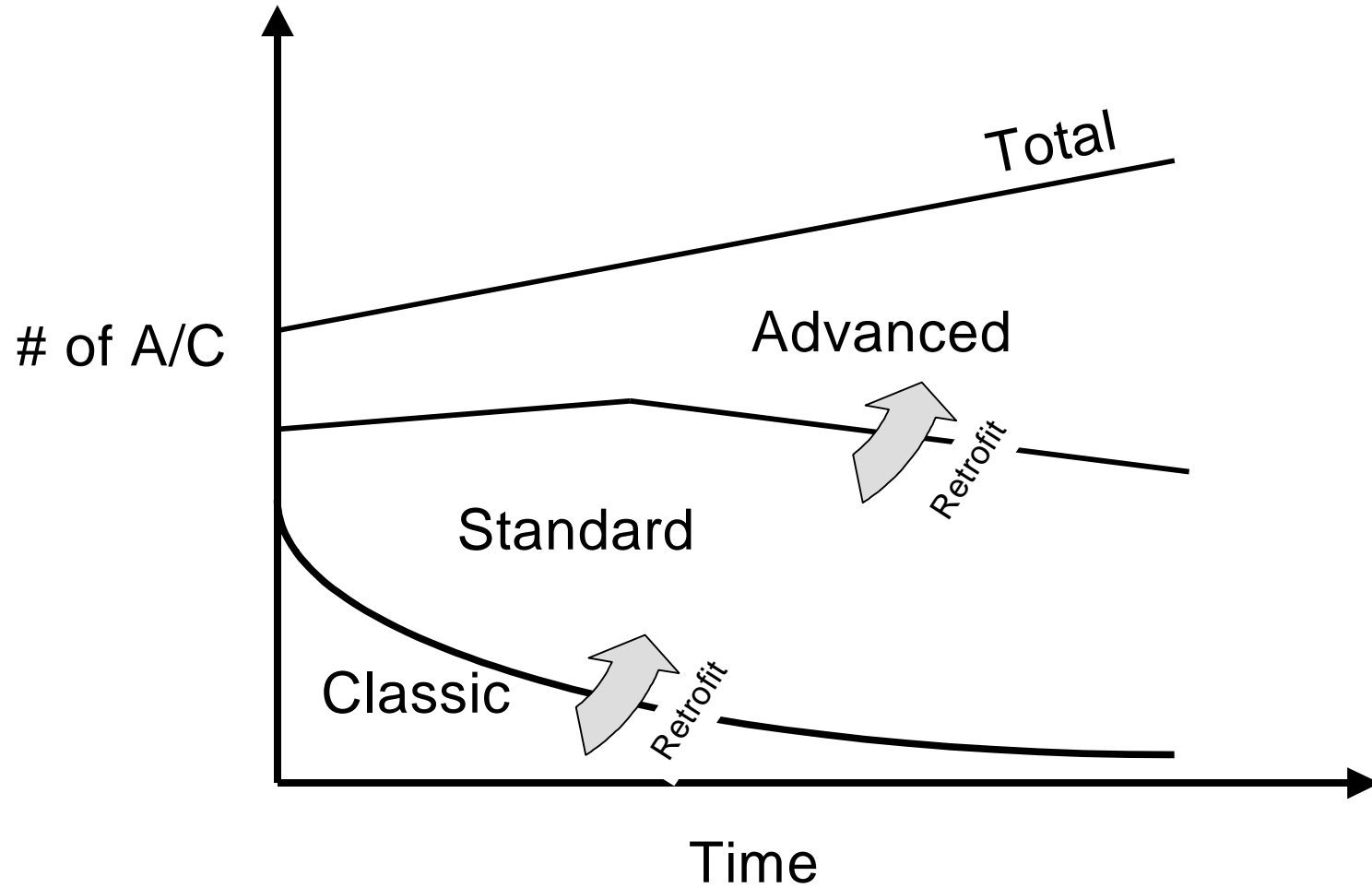
# Approach to the Analysis

- Developed timelines and costs of attaining 75% equipped RNP capable aircraft, through
  - retrofit;
  - replacement of retired aircraft;
  - purchase of new for growth (assumed new aircraft RNP capability provided in aircraft base price).
- Compared costs to the benefit of RNP, with the value of reduced delays \$25 per delay minute (and alternatively \$50 per delay minute)

## Year 2000 SFO Airplane Types

|          | Avg Arrivals/day | % of total avg/day |
|----------|------------------|--------------------|
| Classic  | 224              | 29                 |
| Standard | 512              | 67                 |
| Advanced | 27               | 4                  |
| TOTAL    | 763              | 100                |

# Fleet Migration



# RNP 0.3 Fleet Equipage

- Standard Aircraft - Many Require FMC Upgrade
  - % requiring Retrofit % - 50%/65%/80%
  - FMC Retrofit Cost - \$80k/\$125k/\$200k
  - Out-of-service costs - 0/0/\$50k
  - Time frame to complete retrofit in years -1/2/2
- No Classic Retrofit;

# RNP 0.15 Fleet Equipage

- Standard Aircraft - All Require FMC Upgrade and GPS installation
  - FMC Retrofit and GPS installation Cost - \$300k/\$500k/\$800k
  - Out-of-service costs - 0/75k/\$125k
  - Time frame to complete retrofit in years -10 years/5 years/4 years
- No Classic Retrofit;

## Benefits - Reduced Delays in Marginal VMC

- Summer Stratus marginal VMC ceilings - 750 feet to 2000 feet
- SFO weather analysis - About 13% of flights are at MVMC
- RNP Approach will allow operations at ceilings of 1,200 feet initially, lowering to 1,000 and 750 feet

# **% of MVMC flights Benefiting from RNP**

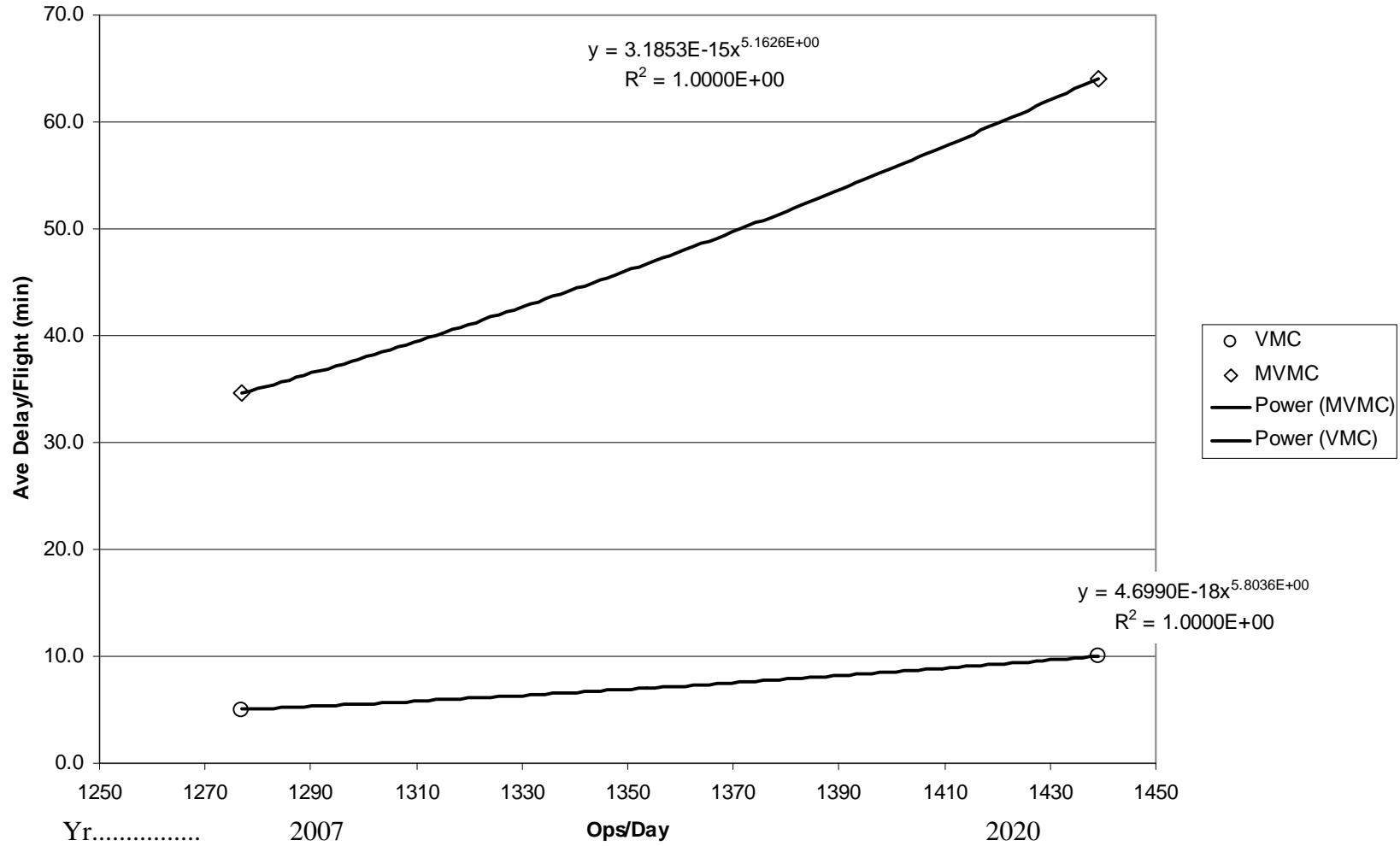
## **•% of MVMC Flights benefiting**

| Ceilings            | Low (10th percentile) | Base (50 <sup>th</sup> percentile) | High (90 <sup>th</sup> percentile) |
|---------------------|-----------------------|------------------------------------|------------------------------------|
| Stage 1 (> 1200 ft) | 50%                   | 60%                                | 70%                                |
| Stage 2 (> 1000 ft) | 70%                   | 75%                                | 85%                                |
| Stage 3 (> 800 ft)  | 75%                   | 85%                                | 90%                                |

# Advanced Nav

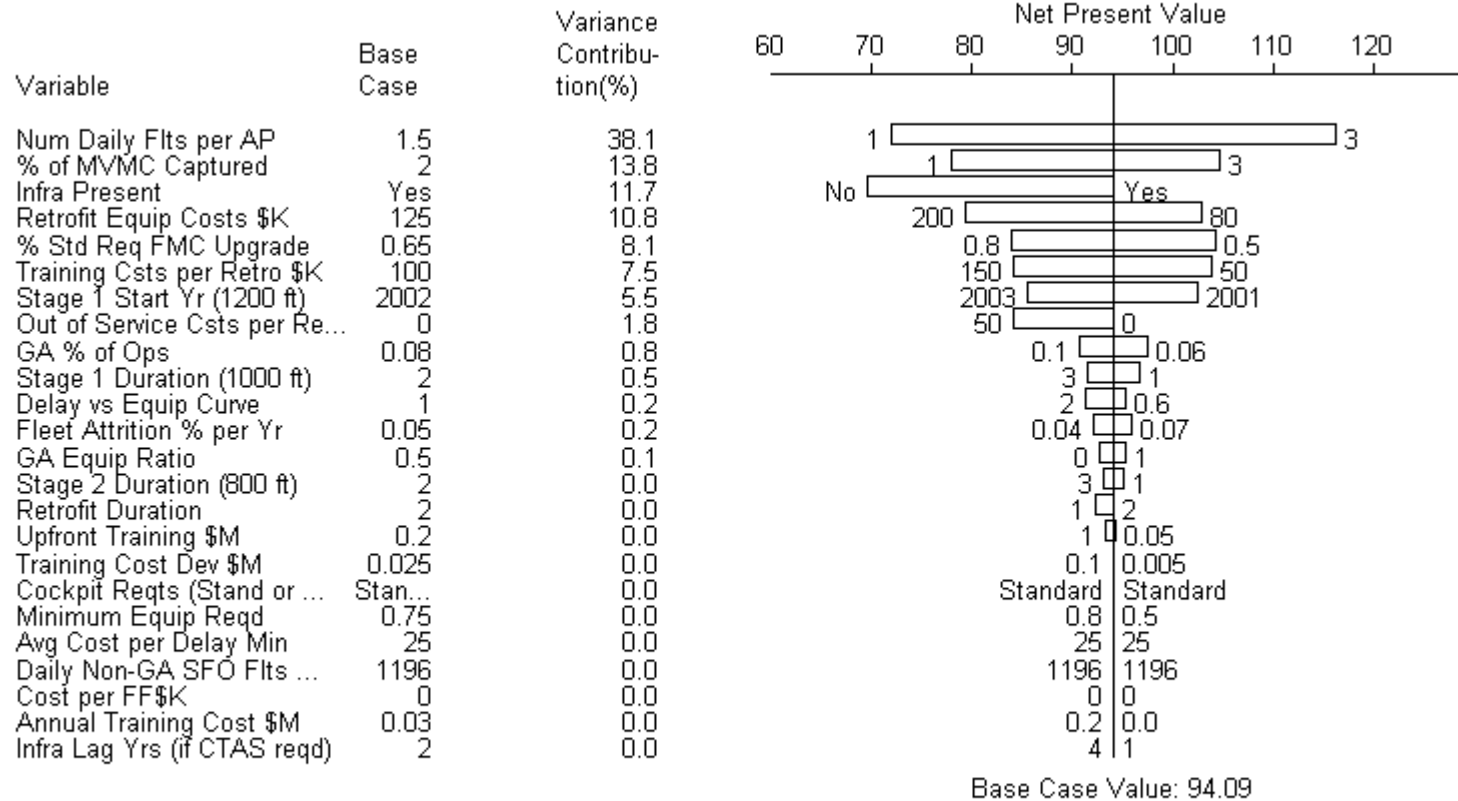
## Delay Reduction Model

### SFO Delay Curves (CAFT)



# Advanced Nav--RNP.3 DME/DME WITH RETROFIT

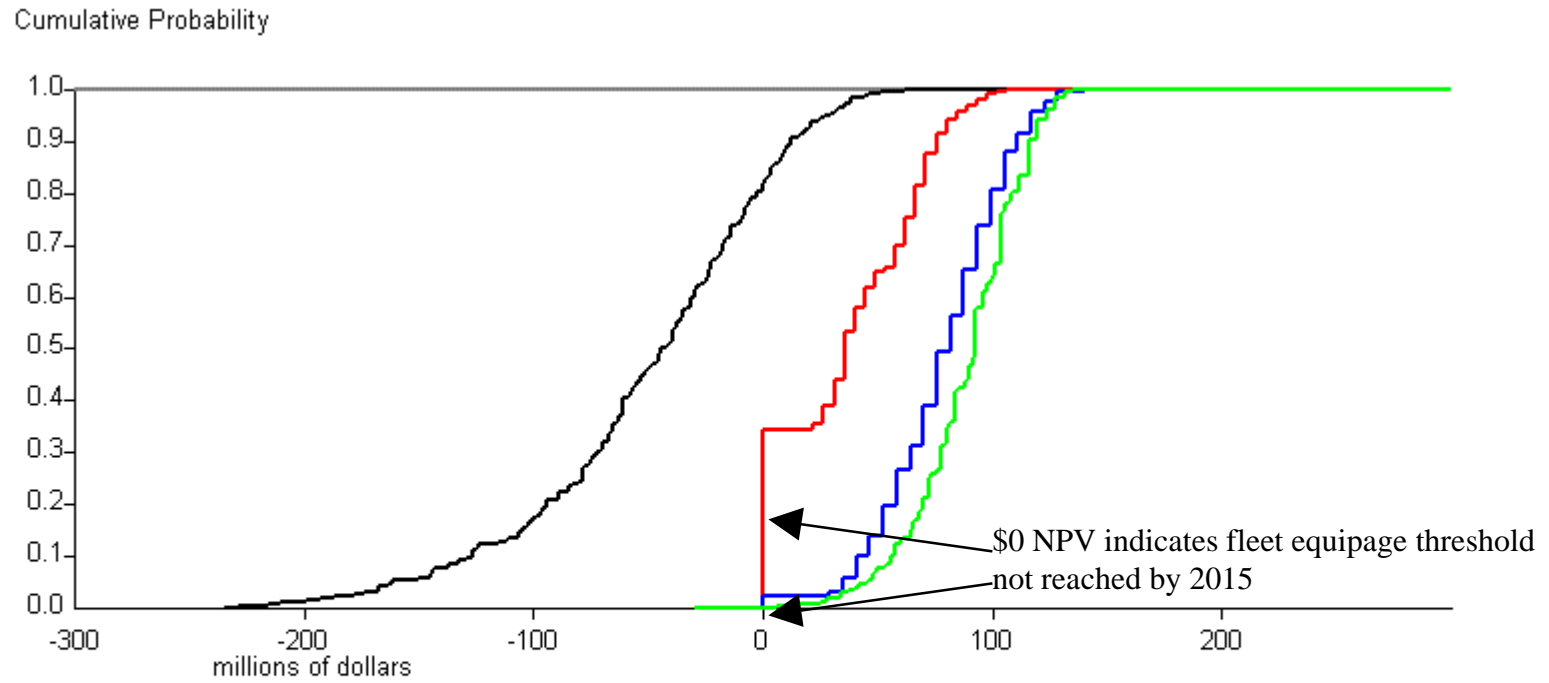
## Tornado Diagram



1) % of MVMC Captured--Annotation--See page 9

# Advanced Nav

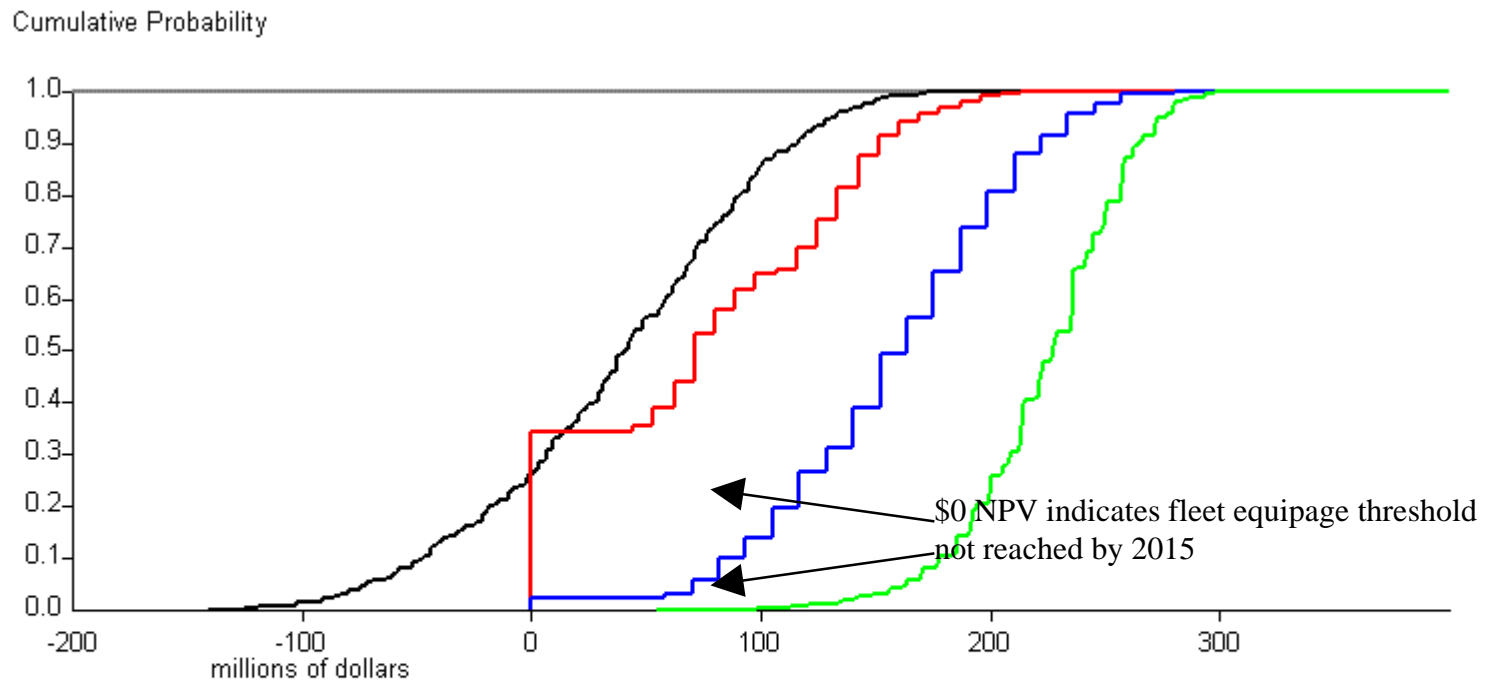
## Cumulative Probability Distribution



|                                 | Mean:  | SD:   | Benefit-Cost Ratio | Min Equipage Yr..... |
|---------------------------------|--------|-------|--------------------|----------------------|
| ● RNP 0.15 GLS/GLS w/ Retrofit  | -50.31 | 55.22 | 0.7                | 2008                 |
| ● RNP 0.15 GLS/GLS--No Retrofit | 36.15  | 30.93 | 174.8              | 2014                 |
| ● RNP 0.3 DME/DME--No Retrofit  | 78.31  | 26.56 | 377.6              | 2009                 |
| ● RNP 0.3 DME/DME with Retrofit | 88.70  | 23.97 | 2.9                | 2002                 |

# Advanced Nav--\$50 per Delay Minute

## Cumulative Probability Distribution



|                             | Mean   | SD    | Benefit-Cost Ratio | Min Equipage Yr..... |
|-----------------------------|--------|-------|--------------------|----------------------|
| ● Adv Cockpit with Retrofit | 37.46  | 60.96 | 1.2                | 2008                 |
| ● Adv Cockpit--No Retrofit  | 72.50  | 61.87 | 349.7              | 2014                 |
| ● Std Cockpit--No Retrofit  | 156.83 | 53.11 | 755.2              | 2009                 |
| ● Std Cockpit with Retrofit | 223.98 | 34.76 | 5.9                | 2002                 |

## RNP 0.15 GPS--Sensitivity to Retrofit Costs

### Base Case

Retrofit Costs = \$675K

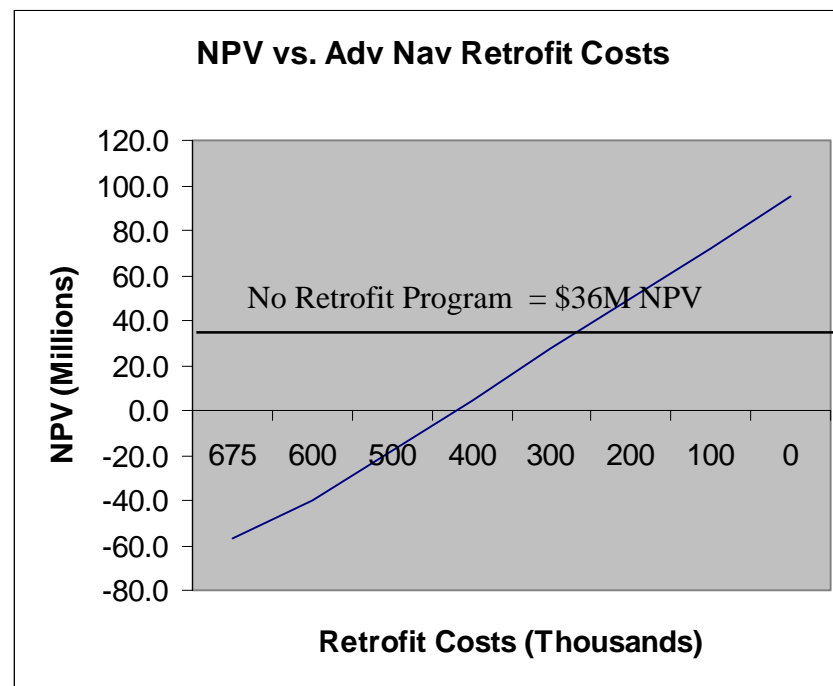
\$500K equipment

\$100K crew training

\$75K out-of service

Retrofit Cost where NPV equals No Retrofit Program,  
\$36M = \$260K

A 3:1 Benefit/Cost Ratio  
would require a retrofit cost  
= \$140K.



# SFO RNP Conclusions

- This approach has positive economics if it can be performed with RNP 0.3 DME/DME equipped aircraft
  - The base case - a \$94 m Net Present Value for benefit of \$25/delay minute
  - Retrofit reaches 75% threshold in 2002
  - A benefit-cost ratio of 3.0

# SFO RNP Conclusions

- IF RNP 0.15 GPS/GPS is required the approach benefits do not have positive economics to justify retrofit
  - Requirement to accomplish retrofit on D checks pushes attainment of 75% equipage to 2008
  - Net Present Value is (\$50 m), with a 0.7 benefit/cost ratio
  - Retrofit costs would have to be less than \$260K to “breakeven” in the RNP 1.5 case
- If delay costs are increased to \$50/minute, the RNP 0.15 has positive NPV and 1.2 benefit/cost ratio