# Surface Operation Automation Research — SOAR —

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**Virtual Airspace Modeling and Simulation (VAMS)**
**Air Transportation System Capacity-Increasing Research**
**Technical Interchange Meeting**
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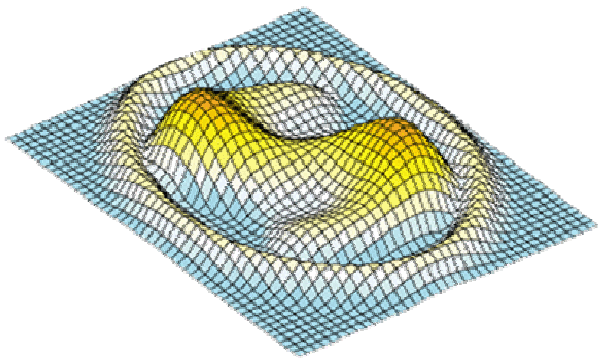
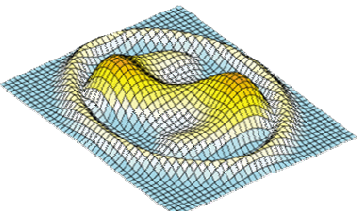


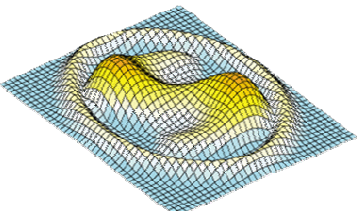
# Outline

- What is the question to be answered using ACES?
- Approach: How is ACES used to answer the question?
- Metrics
- Phase III evaluation results
- Lessons learned
- Issues/Challenges about assessment



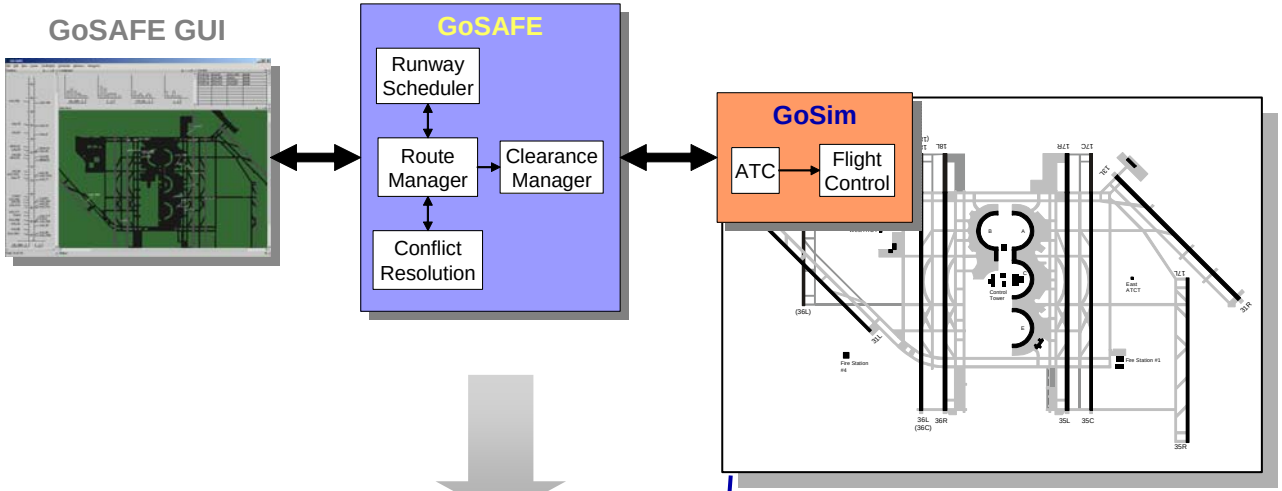
# What is the question to be answered using ACES?

- **Phase II self-evaluation explored enhancements**
  - **Enabled by SOAR concept over baseline operational practices**
  - **Using computer simulation of a single airport: DFW 7-runway south-flow configuration**
  - **With 3 demand data sets provided by VAMS: 98-airport, 250-airport, and future**
  - **Based on capacity-related metrics in two areas:**
    - **Airport periphery: runway throughputs**
    - **Airport surface: taxi delay and efficiency**
- **Phase III evaluation would use ACES to explore the system-wide benefits of the SOAR concept**
  - **Using system-wide delays as primary metrics**
  - **With airport delay models calibrated with Phase II results**
  - **To account for ripple effect of propagating delays through the NAS, to the extend possible with ACES**

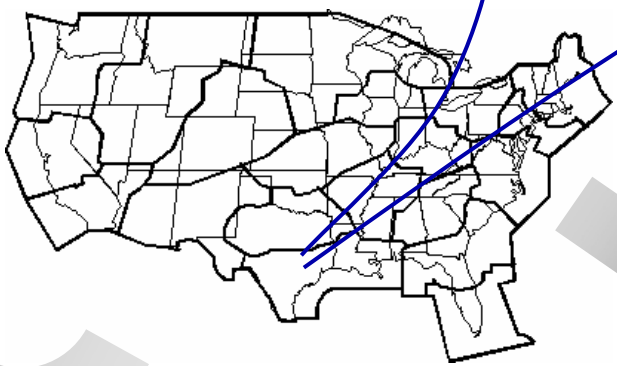


# Evaluation of SOAR and Blended Concept

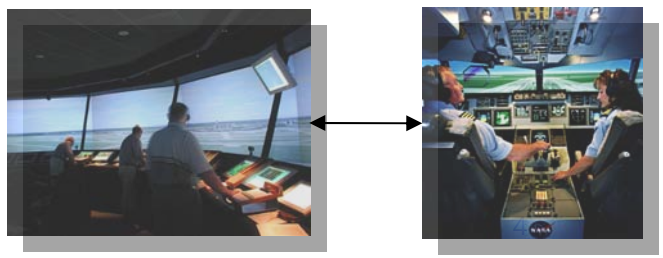
Phase II: Surface-Domain Computer-Simulation Evaluation of SOAR

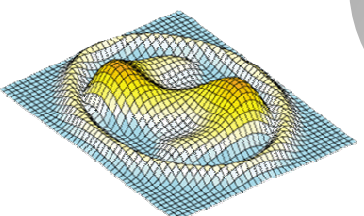



Phase III: ACES NAS-Wide Assessment of SOAR



Real-Time Human-in-the-Loop Evaluation





Phase IV: ACES NAS-Wide Assessment of Blended Concept

# Metrics for Single-Airport Evaluation in Phase II

- **Airport Periphery Capacity: Arrival/Departure Throughputs**
- **Surface Capacity: Taxi Delay/Efficiency**

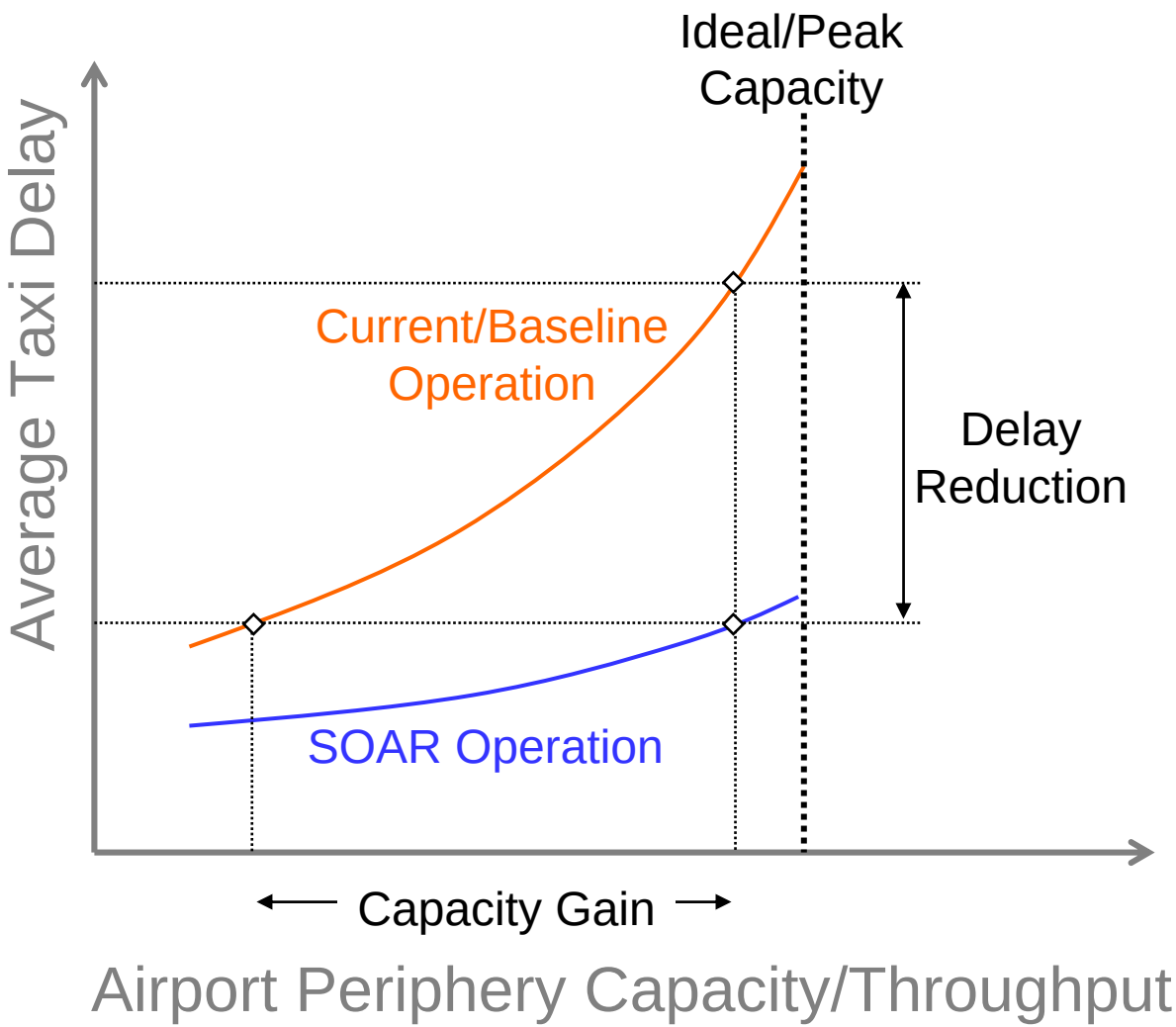
$$\text{Taxi Delay} = \text{Actual Taxi Time} - \text{Unimpeded Taxi Time} \geq 0$$

$$\text{Taxi Efficiency} = \frac{\text{Unimpeded Taxi Time}}{\text{Actual Taxi Time}}$$

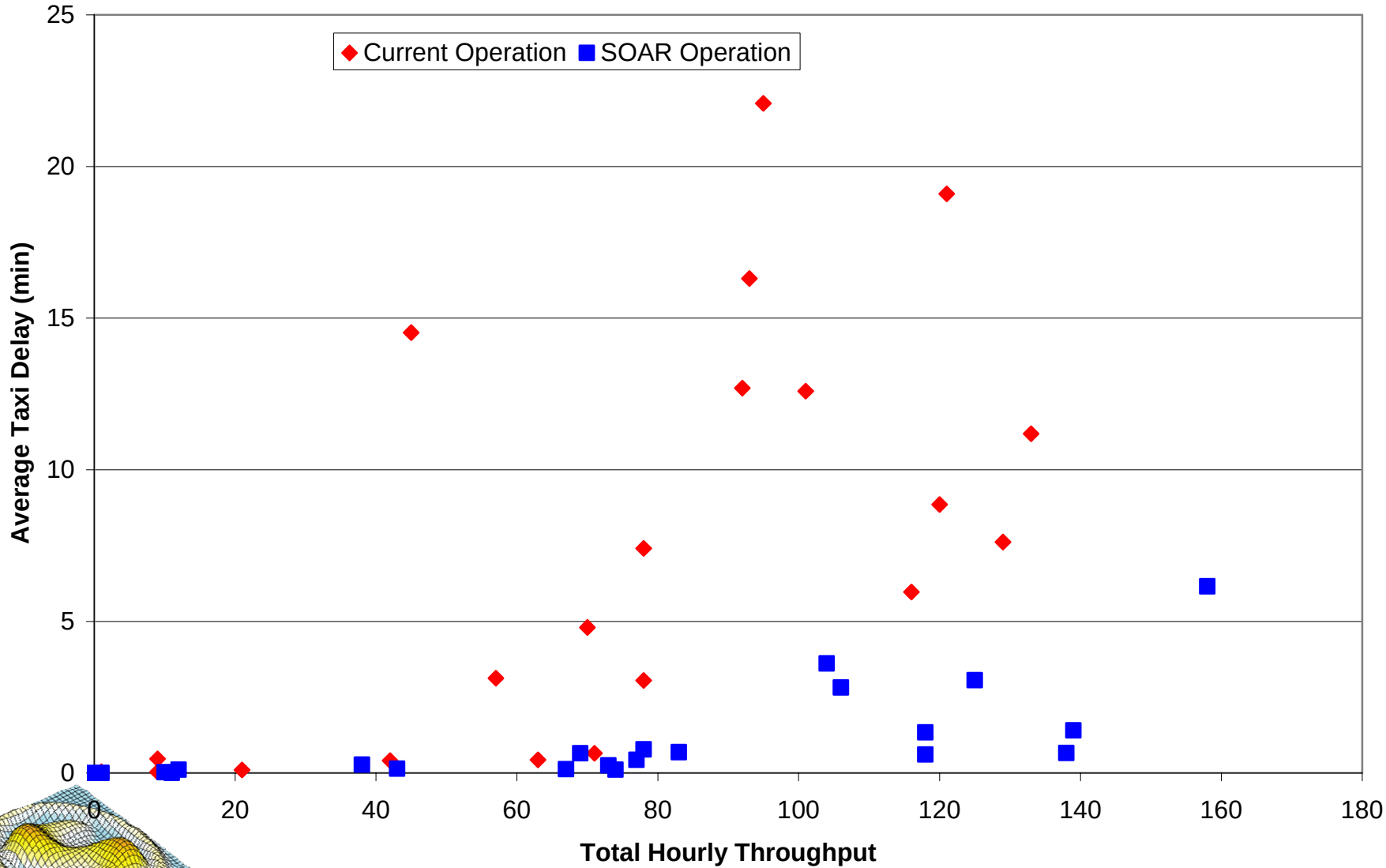
$$= \frac{\text{Actual Effective Speed}}{\text{Unimpeded Effective Speed}} \leq 1$$

$$\text{Surface Traffic Efficiency} = \frac{\sum \text{Unimpeded Taxi Time}}{\sum \text{Actual Taxi Time}}$$

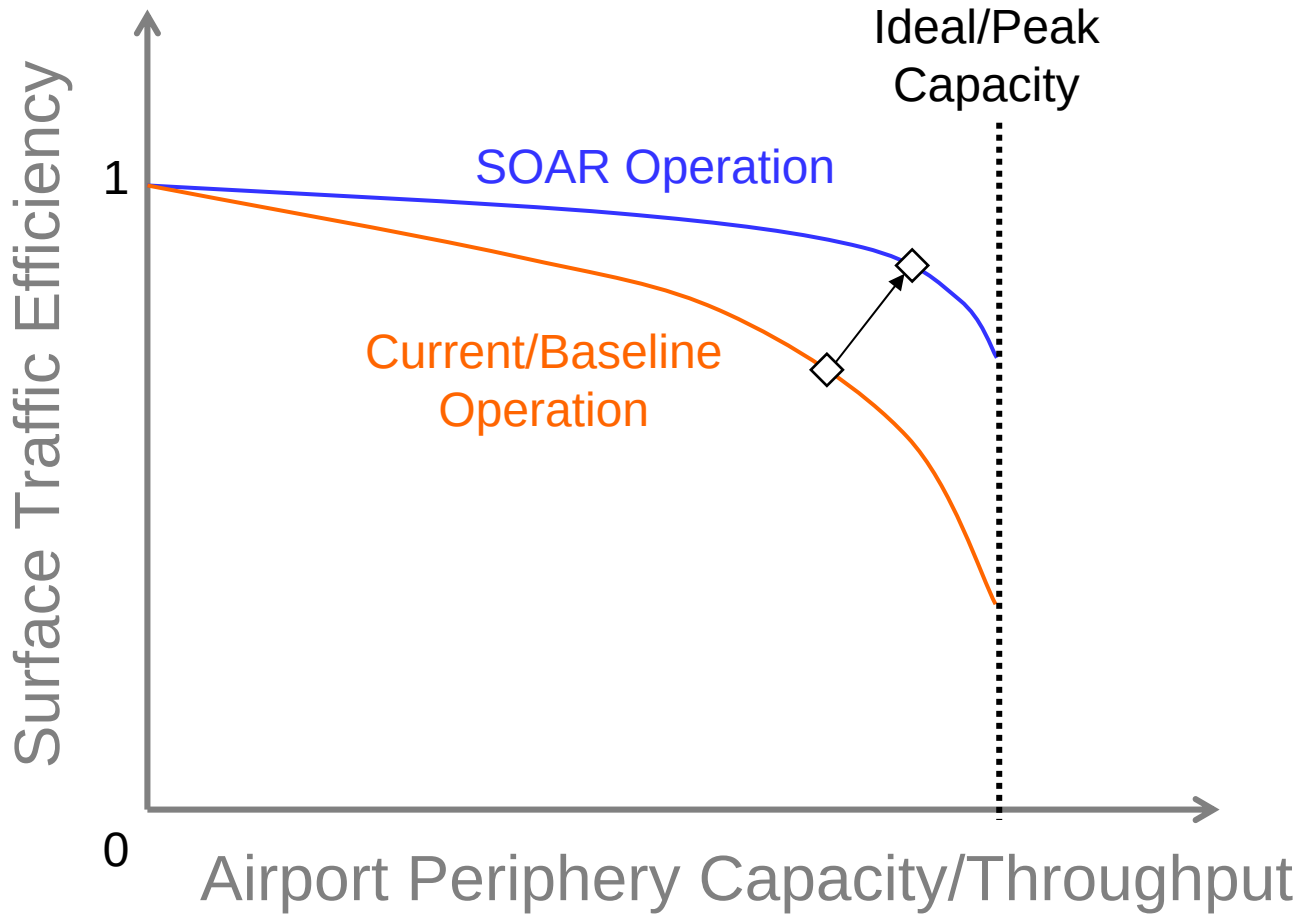
# Anticipated SOAR Benefits of Capacity Gain and Delay Reduction



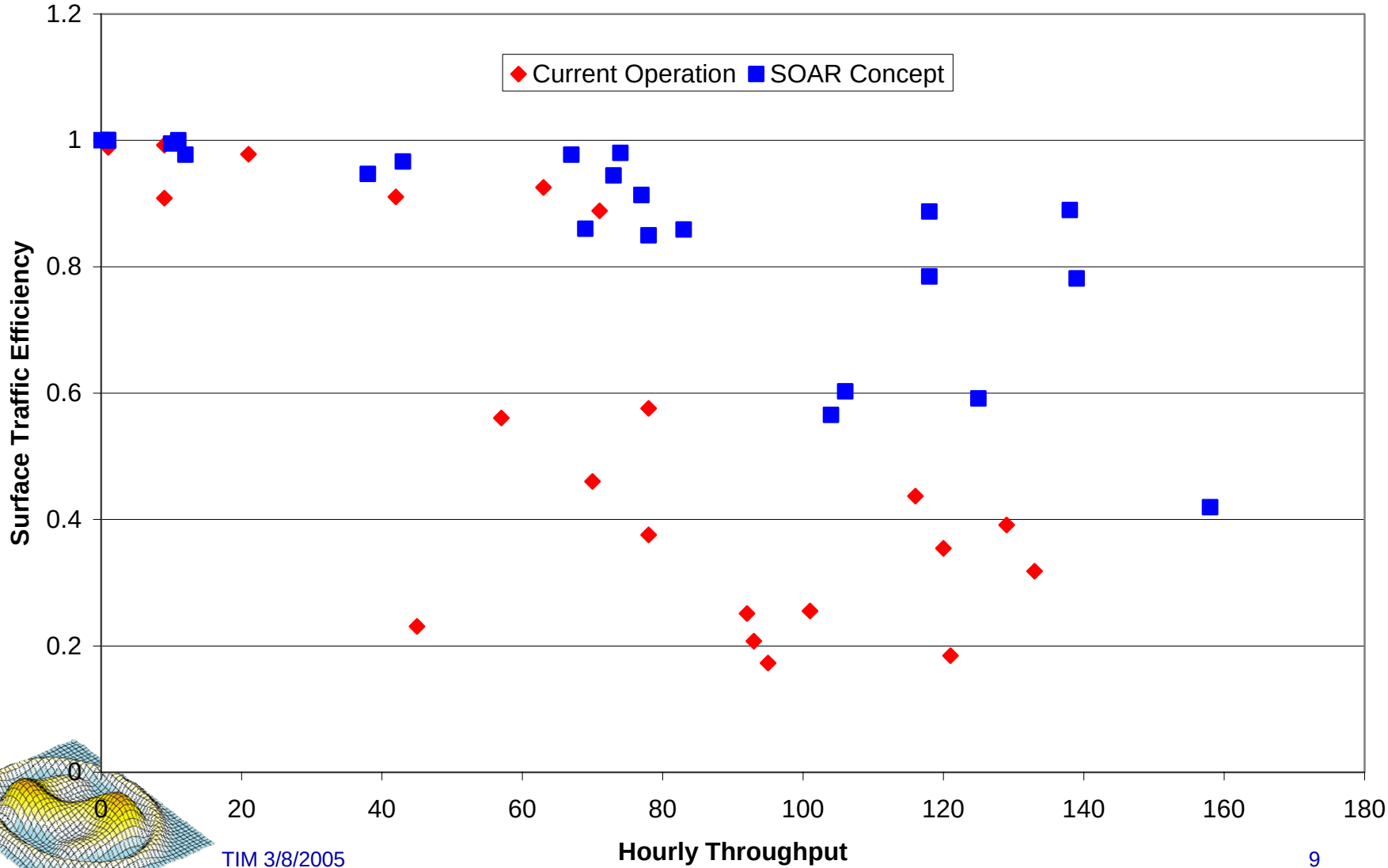
# Relationship between Taxi Delay and Throughput for 250-Airport Demand Set: Current Ops vs SOAR



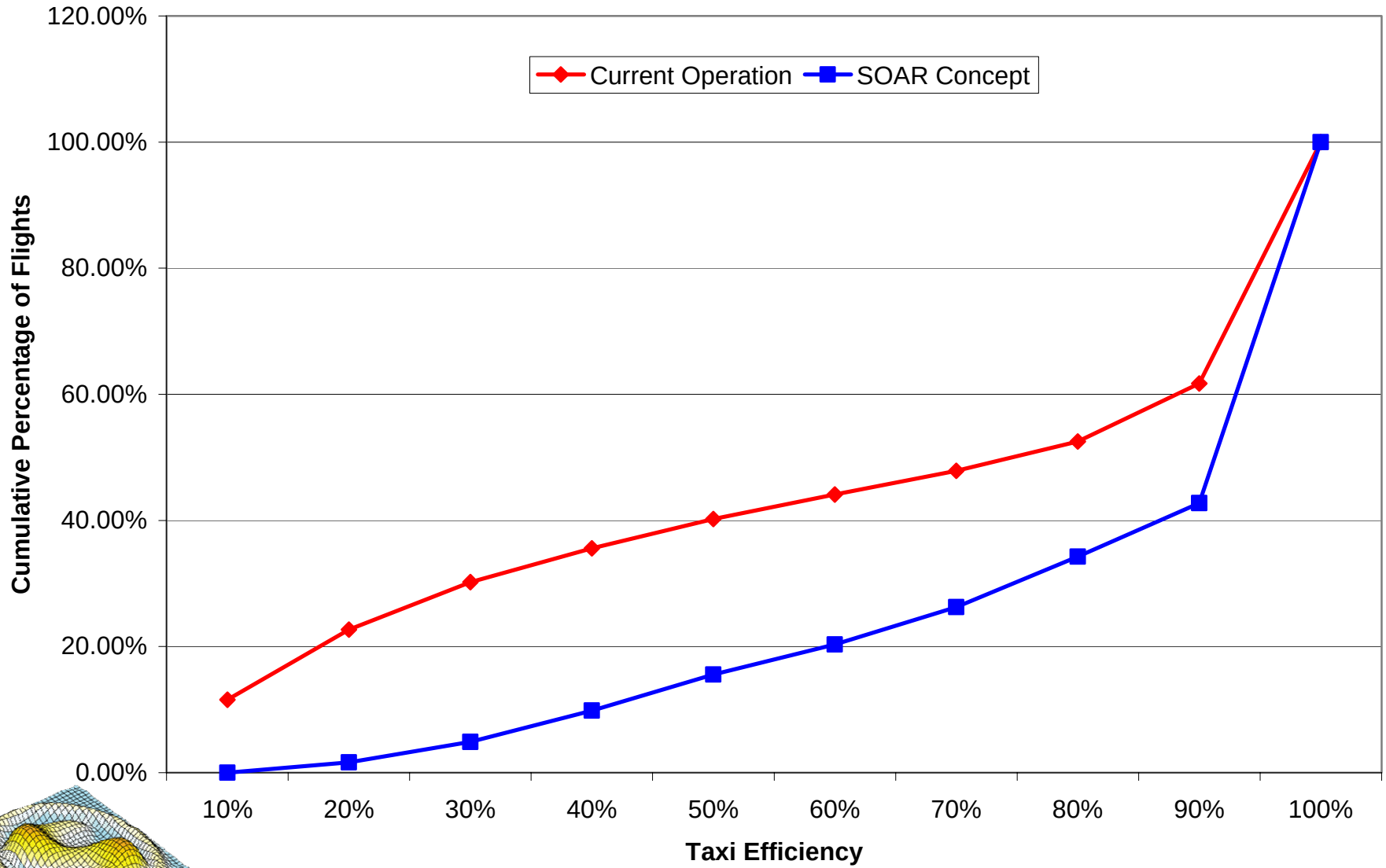
# Anticipated Improvement in Efficiency/Capacity Tradeoff



# Relationship between Taxi Efficiency and Throughput for 250-Airport Demand: Current Ops vs SOAR Concept



# Cumulative Distributions of Taxi Efficiencies for 250-Airport Demand Set

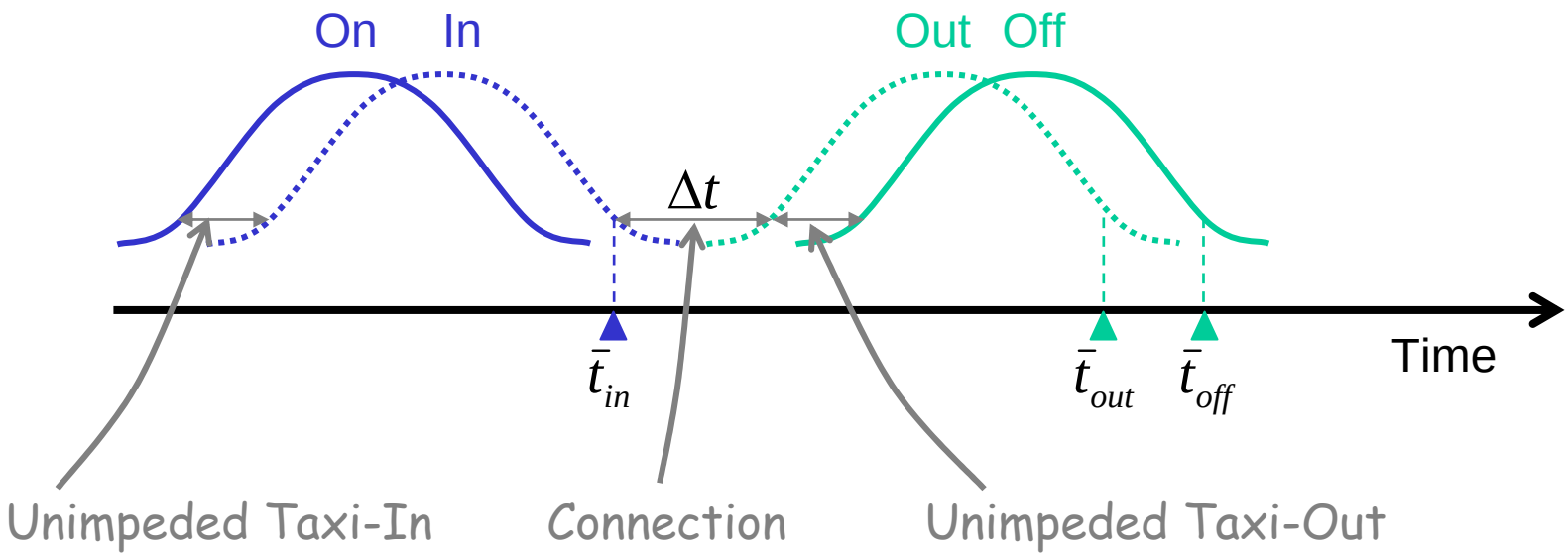


# Approach: How is ACES used to answer the question?

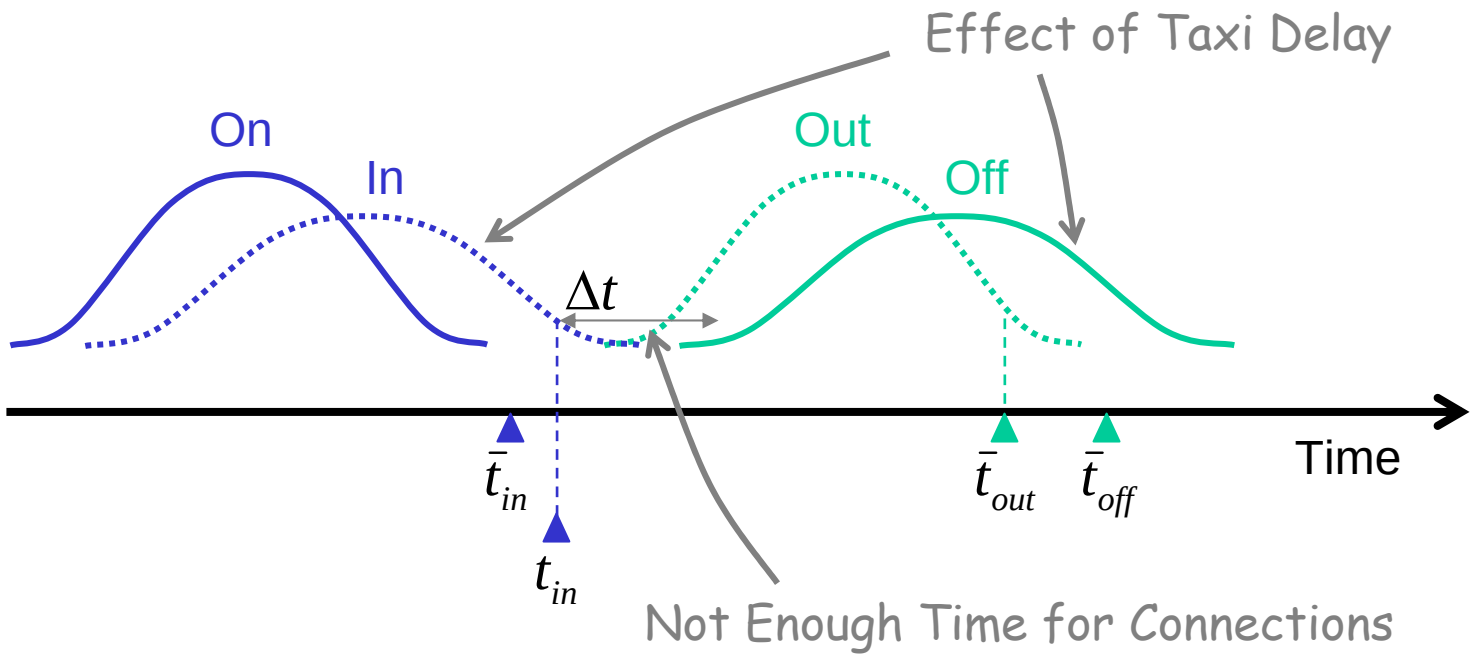
**Intended use of ACES:**

- **Single-airport surface delay and throughput enhancements enabled by SOAR are identified for inclusion in airport models in ACES. (Primary effects)**
- **AOC model in ACES will effectively introduce pushback delays and cancellations. (Secondary effects)**
- **Simulation with ACES with full-day data will produce delays rippling through the NAS. (Tertiary effects)**

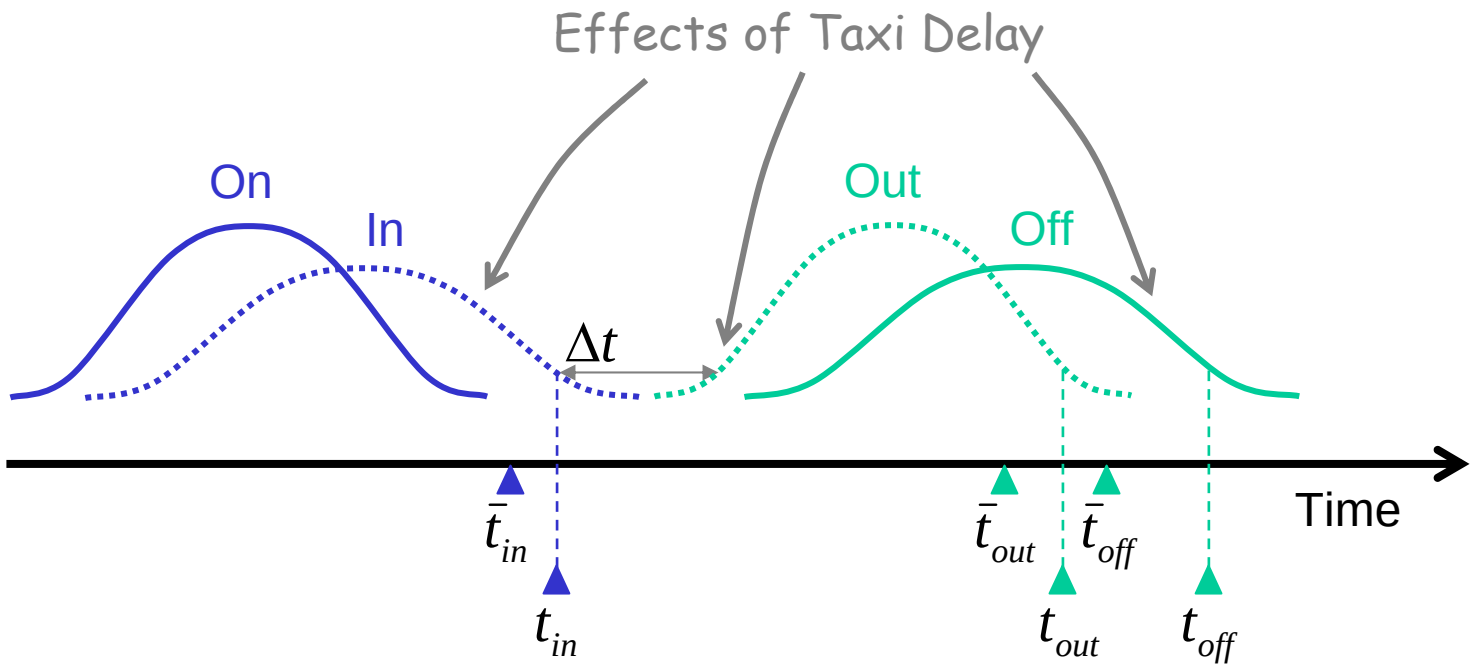
# Ripple Effect: Ideal Hub Connections



# Ripple Effect: Effect of Taxi Delay

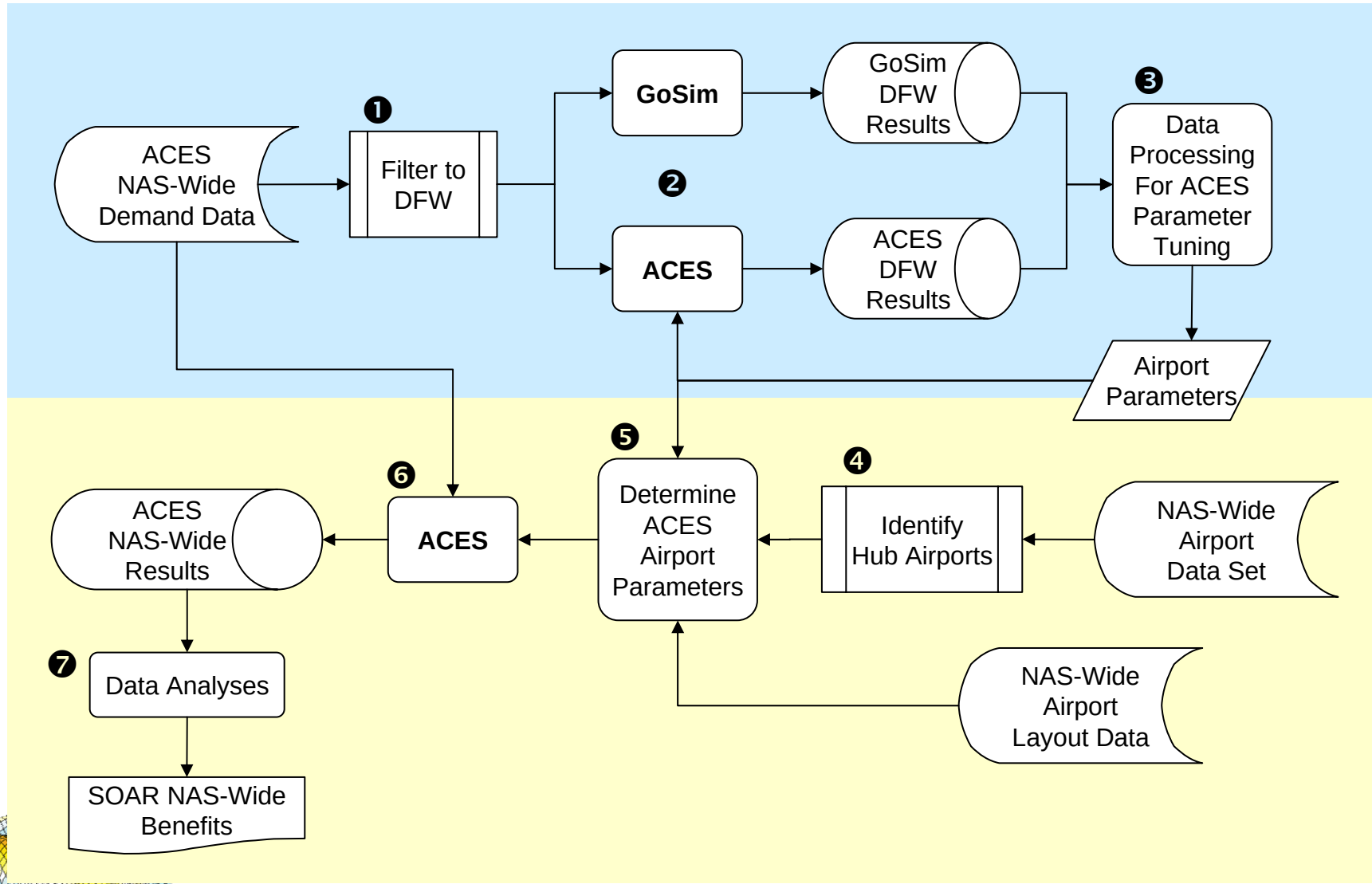


# Ripple Effect: Delayed Pushback




Ripple Effect: Delayed departure will lead to arrival delays at subsequent airports . . .

# Plan for Evaluating System-Wide Benefits of SOAR



# Procedure for System-Wide Evaluation of SOAR

1) Extract DFW-specific traffic data from system-wide demand data sets
2) Run both ACES and GoSAFE/GoSim simulations with DFW traffic data as input
3) Compare simulation outputs, and adjust airport parameters in ACES as necessary to repeat Step 2 until the simulation results are compatible
4) Identify major hub airports in NAS
5) Extend DFW airport model parameters to the identified hub airports
6) Run ACES with full-NASA demand data sets
7) Perform post-simulation analyses

# Metrics

**Delay metrics supported by ACES**

- **Gate Departure Delay — relative to originally scheduled gate departure time**
- **Surface Departure Delay — same as the Taxi-Out Delay**
- **Airborne Delay — from takeoff to landing, relative to originally scheduled flight time**
- **Surface Arrival Delay — same as the Taxi-In Delay**
- **Block Delay — based on gate-to-gate travel time, relative to originally scheduled gate-to-gate travel time**
- **Total Delay — difference between actual gate arrival time and originally scheduled gate arrival time**

**Ultimate system-wide metric is based on total delay.**

# Phase III Evaluation Scenarios

- **Traffic demand:**
  - **May 17, 2002 CONUS Top 250 Airports: similar to Phase II data, but with a more complete set of flights**
  - **TAF 2015 CONUS Top 250 Airports**
  - **TAF 2020 Top 250 Airports**
  - **2× May 17, 2002 CONUS Top 250 Airports**
- **Tried to reconcile ACES taxi delays with GoSim results**
- **Focused on two ACES models**
  - **Surface operations and taxi delay model according to ACES Surface Traffic Limitations (STL) function**
  - **Airline Operational Control (AOC) model**

# Taxi-Delay Models

- **ASPM taxi times ($\tau$) as function of queue sizes (Q):**

$$\tau_D = a_{DA} Q_A + a_{DD} Q_D + b_D$$

$$\tau_A = a_{AA} Q_A + a_{AD} Q_D + b_A$$

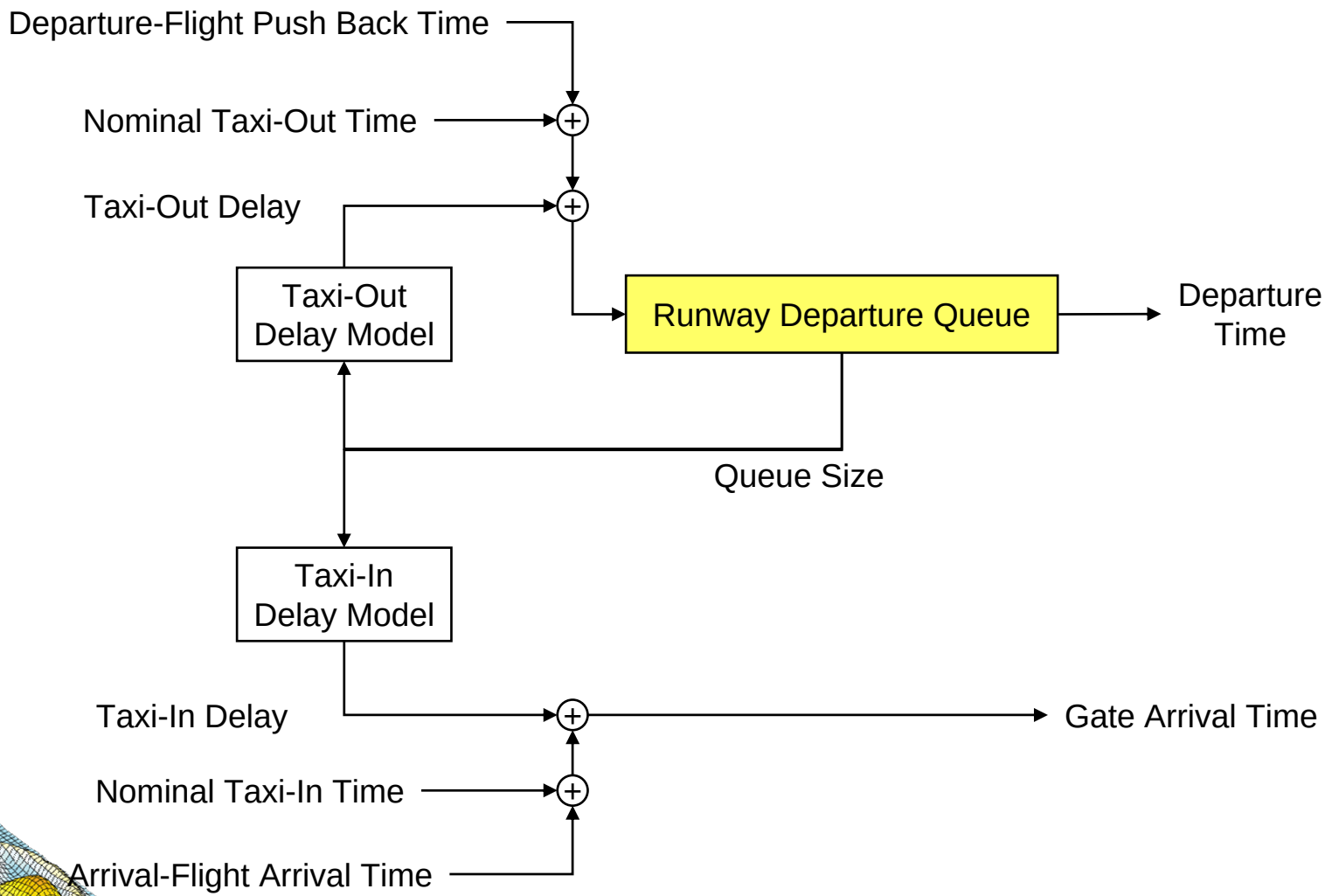
- **ACES taxi-delay model**

taxi delay

unimpeded taxi time

  - **Depends only on runway-departure-queue size in 15-min time windows**
  - **Allows specification of minimum queue size for taxi delay to become effective, default 10**
  - **Default incremental delay of 30 s per additional flight in queue**
  - **Allows specification of maximum taxi delay, default 30 min**
  - **Results in highly nonlinear effects**
- **ACES taxi-in delay model not working**

# ACES Taxi-Delay Models



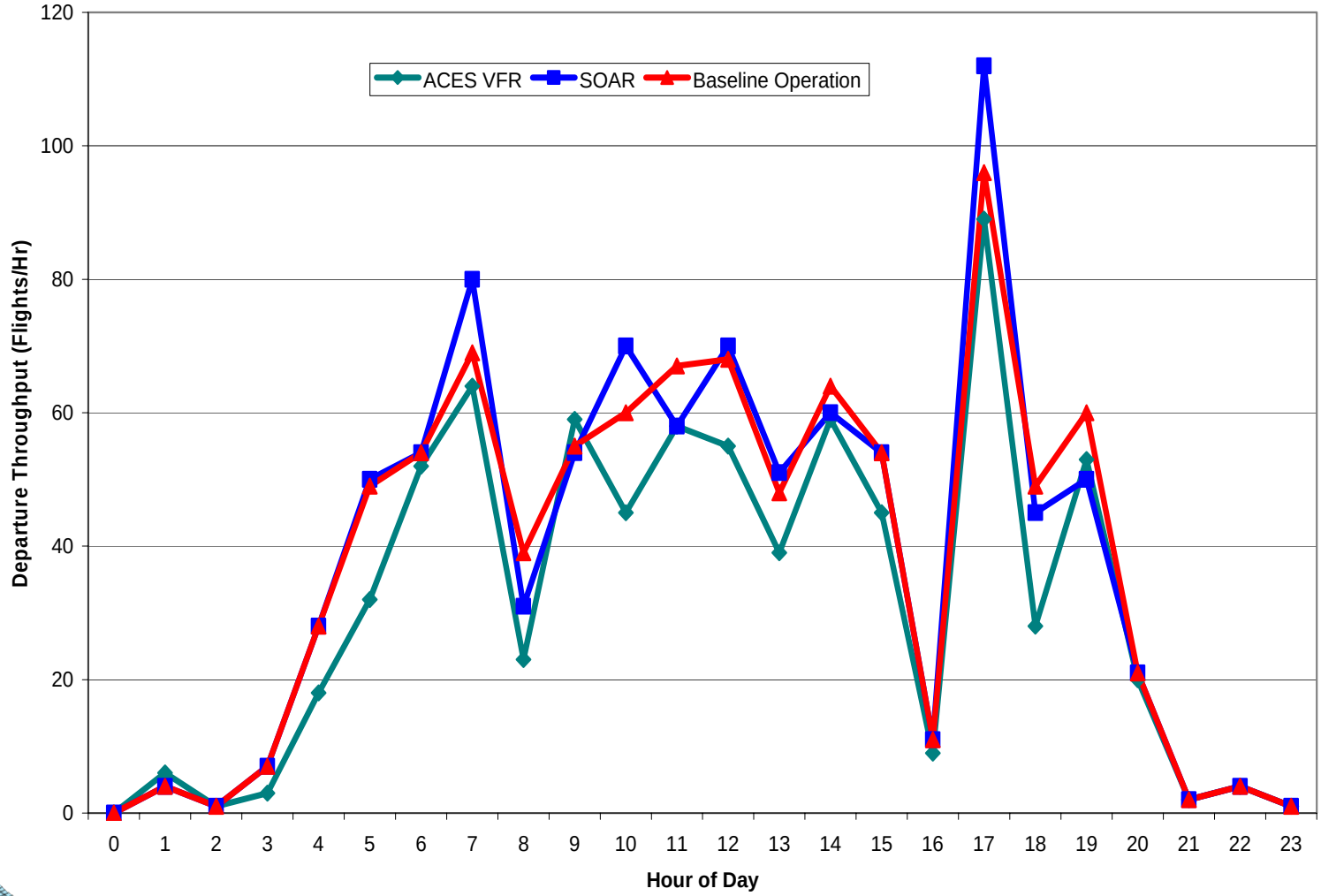
# ACES AOC Model

- AOC can delay or cancel specific flights in response to predefined strategies.
- Delay strategies
  - Based on AOC's percentage of total arrival flight operations
  - Delay of departure flight based on
    - Average delays of the arrival flights of that AOC
    - Geographical distribution of the arrival flights.
- Cancellation strategies based on
  - Threshold delay time (default 2 hr)
  - Departure times of the previous and next AOC's flights to a particular destination
- AOC model was originally developed in ACES 1.1, but has not been tested or activated.
- Current evaluation was done without AOC model due to errors in activating it.

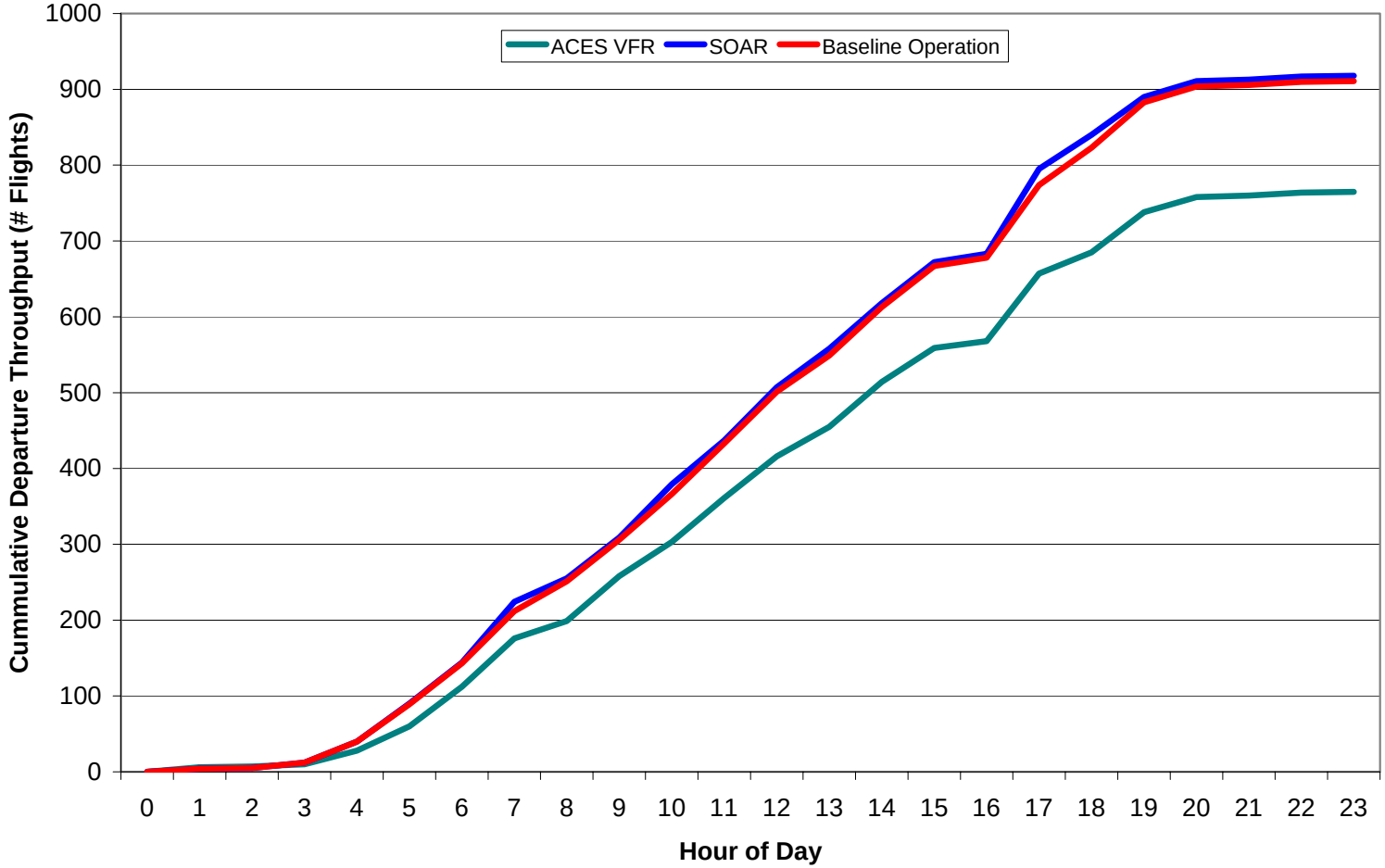
# Tuning of Airport Surface Model Parameters

- **Simulations were based on "May 17, 2002 CONUS Top 250 Airports" data set.**
- **ACES did not output taxi-in delays properly, but pertinent data could be extracted from a message file.**
- **To compare delays, we need to ensure that traffic densities/throughputs are comparable among the simulations:**
  - **GoSim with baseline concept**
  - **GoSim with SOAR concept**
  - **ACES under VFR**
- **Initial tests showed that the ACES-VFR case produced lower throughputs through the day.**

# Initial Comparison of Throughputs between SOAR, Baseline Operations, and ACES VFR Capacity



# Comparison of Cumulative Throughputs



# Resolution of Traffic Discrepancy

- **ACES was rejecting flights from the demand data set.**

| Data sets | | 5/17/2002 | 2015 | 2020 | 5/17 × 2 |
|---|---|---|---|---|---|
| Flights accepted | From DFW | 765 | 1126 | 1272 | 2116 |
| | To DFW | 819 | 1201 | 1362 | 2286 |
| | Total | 1584 | 2327 | 2634 | 4402 |
| Flights rejected | | 265 | 370 | 411 | 622 |

- **For calibration of ACES, GoSim runs have to be repeated with the same set of accepted flights.**

# Tuning of ACES Taxi Delay Parameters

- **Runway Departure Queue size threshold was reduced from the default value of 10 to zero.**
- **Maximum taxi delay per flight was increased from the default value of 30 min to 60 min.**
- **Original idea to fit delay data from GoSim results was an overkill.**
  - **GoSim used specific airport layout model.**
  - **Neither ASPM nor ACES has this level of modeling.**
- **GoSim taxi times have to be scaled to account for ramp operations.**
- **Taxi-Delay Parametric Analysis for SOAR Concept:**

| | | Total Arrival Taxi Delay (min) | Total Departure Taxi Delay (min) |
|---|---|---|---|
| | | | |
| **SOAR GoSim Reference** | | 778 | 1438 |
| | | | |
| **ACES Results** | | | |
| Arrival Coef (sec) | Departure Coef (sec) | | |
| 30 | 30 | 356 | 1279 |
| 52 | 42 | 766 | 1394 |

# Tuning of ACES Taxi Delay Parameters for Baseline

- **ACES model nonlinearity prevented achievement of taxi delays for baseline case via parameter adjustment.**

| | | Total Arrival Taxi Delay (min) | Total Departure Taxi Delay (min) |
|---|---|---|---|
| | | | |
| **Baseline GO-Sim Reference** | | 626 | 4456 |
| | | | |
| **ACES Results** | | | |
| Arrival Coef (sec) | Departure Coef (sec) | | |
| 30 | 30 | 356 | 1279 |
| 50 | 600 | 413 | 2976 |
| 90 | 550 | 786 | 2942 |
| 60 | 520 | 536 | 2993 |
| 90 | 500 | 866 | 3805 |
| 60 | 500 | 577 | 3806 |
| 65 | 500 | 625 | 3806 |
| 70 | 480 | 584 | 2856 |
| 90 | 450 | 756 | 2748 |
| 60 | 450 | 504 | 2748 |
| 60 | 400 | 530 | 2580 |

# Comparison of Taxi Delays between ACES Runs and ASPM

| | Average Arrival Taxi Delay (min) | Average Departure Taxi Delay (min) |
|---|---|---|
| **ASPM: 5/17/2002** | 6.06 | 13.92 |
| **ASPM: Seasonal Average** | 10.7 | 17 |
| **ACES: Baseline Operations** | 0.78 | 4.95 |
| **ACES: SOAR Concept** | 0.98 | 1.81 |

- **For ASPM, 5/17/2002 delays are lower than the seasonal average.**
- **ACES results simulating baseline operations have substantially lower delays.**
  - **ASPM delays include gate-capacity effects.**
- **Issues and potential causes:**
  - **Traffic included in demand data set too low to represent the real situation**
  - **Inaccurate ACES modeling (worse with default parameters)**
  - **Inaccurate GoSim modeling, especially for arrival operations**

# Benchmark Airports and Hubs Used by Big Six

- **Lack of modeling capability and SOAR data to tune parameters for all airports**
- **Decision to try the same parameter set for all airports**

| Airport | Code | Airline Hub |
|---|---|---|
| Hartsfield Atlanta Intl, GA | ATL | DAL |
| Logan, Boston, MA | BOS | AA, DAL, UAL |
| Baltimore-Washington, MD | BWI | |
| Cleveland-Hopkins Intl, OH | CLE | CO |
| Charlotte Douglas Intl, NC | CLT | US |
| Cincinnati-Northern Kentucky | CVG | DAL |
| Ronald Reagan, Washington, DC | DCA | |
| Denver International, CO | DEN | UAL, US |
| Dallas-Forth Worth International, TX | DFW | AA |
| Detroit Metro Wayne County, MI | DTW | NW |
| Newark International, NJ | EWR | DAL, CO |
| Fort Lauderdale-Hollywood Intl | FLL | |
| Honolulu International, HI | HNL | |
| Dulles, Washington, DC | IAD | UAL, US |
| George Bush Intl, Houston, TX | IAH | CO |
| John F Kennedy International, NewYork, NY | JFK | AA |
| McCarran, LasVegas, NV | LAS | |
| Los Angeles International, CA | LAX | UAL, US |
| LaGuardia, NewYork, NY | LGA | AA |
| Orlando International, FL | MCO | DAL |
| Midway, Chicago, IL | MDW | |
| Memphis International, TN | MEM | NW |
| Miami International, FL | MIA | AA, US |
| Minneapolis-St Paul International, MN | MSP | NW |
| Chicago O'Hare International, IL | ORD | AA, UAL, US |
| Portland International, OR | PDX | |
| Philadelphia International, PA | PHL | US |
| Phoenix Sky Harbor International, AZ | PHX | |
| Greater Pittsburgh International, PA | PIT | US |
| San Diego International Lindbergh, CA | SAN | |
| Seattle-Tacoma International, WA | SEA | |
| San Francisco International, CA | SFO | UAL, US |
| Salt Lake City International, UT | SLC | DAL |
| Lambert St. Louis International, MO | STL | AA |
| Tampa International, FL | TPA | |

# Order-of-Magnitude Comparison of Baseline Delays with ASPM Data

| Airport | Average Arrival Taxi Delay (min) | | | | Average Departure Taxi Delay (min) | | | |
|---|---|---|---|---|---|---|---|---|
| | ASPM 5/17/2004 | ASPM Seasonal Average | ACES Baseline | ACES SOAR | ASPM 5/17/2004 | ASPM Seasonal Average | ACES Baseline | ACES SOAR |
| ATL | 0.91 | 8.9 | 3.67 | 1.22 | 7.17 | 19.6 | 21.60 | 2.51 |
| BOS | 0.93 | 7.1 | 0.36 | 0.19 | 3.81 | 17.5 | 4.05 | 1.04 |
| BWI | 0.39 | 5 | 0.21 | 0.14 | 1.43 | 13 | 2.41 | 0.71 |
| CLE | -1.24 | 5.4 | 0.43 | 0.43 | 6.04 | 16.6 | 4.89 | 2.33 |
| CLT | 1.36 | 5.3 | 0.41 | 0.39 | 4.07 | 17.3 | 4.85 | 1.82 |
| CVG | 0.19 | 6.2 | 0.82 | 0.62 | 4.43 | 17.5 | 8.03 | 2.75 |
| DCA | 0.9 | 4.5 | 0.14 | 0.06 | 3.11 | 14.8 | 2.56 | 1.21 |
| DEN | 0.23 | 7.2 | 0.05 | 0.04 | 1.67 | 14.9 | 1.31 | 0.88 |
| DFW | 6.06 | 10.7 | 0.78 | 0.98 | 13.92 | 17 | 4.95 | 1.81 |
| DTW | 2.25 | 9 | 1.14 | 1.16 | 3.7 | 18 | 11.35 | 2.99 |
| EWR | 1.09 | 8.6 | 0.71 | 0.53 | 7.08 | 24.6 | 8.84 | 1.92 |
| FLL | -0.01 | 4.8 | 0.00 | 0.00 | 1.27 | 16.3 | 0.38 | 0.38 |
| IAD | 0.81 | 5.8 | 1.08 | 0.41 | 3.28 | 17 | 11.08 | 2.76 |
| IAH | 2.32 | 7.4 | 2.50 | 2.20 | 27.46 | 19.4 | 15.27 | 4.96 |
| JFK | 1.08 | 8.4 | 0.06 | 0.04 | 7.14 | 22.8 | 1.38 | 0.70 |
| LAS | 0.23 | 5.2 | 2.09 | 0.66 | 3.89 | 14.6 | 19.13 | 2.57 |
| LAX | 1.85 | 7.1 | 0.25 | 0.14 | 3.62 | 13.7 | 2.72 | 1.17 |
| LGA | 0.92 | 7.8 | 2.74 | 1.33 | 9.15 | 24.3 | 25.54 | 5.10 |
| MCO | -0.11 | 5.2 | 0.37 | 0.23 | 0.85 | 13.3 | 2.83 | 0.68 |
| MDW | -0.19 | 5.9 | 0.05 | 0.04 | 1.92 | 14.4 | 0.92 | 0.41 |
| MEM | 1.32 | 6.7 | 0.33 | 0.16 | 5.16 | 16.3 | 7.91 | 1.20 |
| MIA | 0.91 | 8.6 | 0.07 | 0.05 | 1.57 | 19.6 | 1.82 | 0.59 |
| MSP | 0.74 | 6.3 | 1.05 | 0.96 | 4.89 | 17.9 | 9.18 | 2.56 |
| ORD | 2.4 | 8.2 | 3.45 | 1.42 | 6.34 | 19.2 | 20.68 | 2.67 |
| PDX | -0.25 | 3.7 | 0.33 | 0.20 | 2.23 | 10.3 | 3.75 | 1.05 |
| PHL | 0.6 | 7.2 | 1.29 | 1.05 | 7.09 | 21.4 | 18.24 | 4.60 |
| PHX | 1.27 | 6.3 | 2.28 | 1.71 | 4.02 | 14.9 | 19.77 | 4.12 |
| PIT | 0.17 | 6.8 | 0.29 | 0.21 | 2.33 | 16.6 | 2.73 | 1.29 |
| SAN | 0.61 | 3.5 | 0.39 | 0.23 | 3.04 | 12.8 | 5.83 | 1.67 |
| SEA | 0.54 | 6 | 0.14 | 0.08 | 2.34 | 13.3 | 2.39 | 1.01 |
| SFO | 0.71 | 5.5 | 0.41 | 0.24 | 7.58 | 15.8 | 4.88 | 1.37 |
| SLC | 0.25 | 5.2 | 0.15 | 0.14 | 3.13 | 14.6 | 1.59 | 0.80 |
| STL | 1.56 | 6 | 2.62 | 2.11 | 6.53 | 17.2 | 18.83 | 4.74 |
| TPA | -0.05 | 4.6 | 0.34 | 0.26 | 1.36 | 12.9 | 4.44 | 0.87 |

# Evaluation Input Data

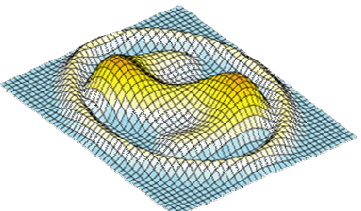
- **Number of flights in four demand data sets**

| Data Set | No. of Flights | No. of Flights Generated by Fratar | No. of Flights Rejected by ACES | No. of Flights in ACES Simulations |
|---|---|---|---|---|
| 2002 | 29423 | 0 | 3944 | 25479 |
| TAF 2015 | 37257 | 7834 | 4749 | 32508 |
| TAF 2020 | 40540 | 11117 | 5065 | 35475 |
| 2×2002 | 59353 | 29930 | 7110 | 52243 |

- **Capacity data sets**
  - **ACES VFR**
  - **OEP**

# Summary of Capacity Data Sets

| Benchmark Airports | ACES | | | | | | ASPM | | | | | | OEP | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VFR | | | IFR | | | Optimal | | | Reduced | | | | | |
| | A | D | T | A | D | T | A | D | T | A | D | T | A | D | T |
| ATL | 104 | 103 | 200 | 91 | 90 | 174 | 100 | 100 | 200 | 90 | 84 | 174 | 139 | 139 | 269 |
| BOS | 69 | 65 | 126 | 48 | 46 | 88 | 50 | 68 | 118 | 44 | 44 | 88 | 71 | 67 | 131 |
| BWI | 44 | 44 | 80 | 43 | 44 | 75 | 60 | 60 | 120 | 36 | 36 | 72 | 44 | 44 | 80 |
| CLE | 44 | 44 | 80 | 33 | 33 | 59 | 40 | 52 | 92 | 24 | 24 | 48 | 44 | 44 | 80 |
| CLT | 80 | 73 | 140 | 66 | 60 | 116 | 65 | 75 | 140 | 54 | 54 | 108 | 102 | 93 | 179 |
| CVG | 76 | 63 | 125 | 76 | 63 | 125 | 65 | 60 | 125 | 65 | 60 | 125 | 97 | 80 | 160 |
| DCA | 44 | 44 | 80 | 36 | 36 | 66 | 40 | 40 | 80 | 31 | 31 | 62 | 44 | 44 | 80 |
| DEN | 123 | 122 | 218 | 111 | 109 | 196 | 96 | 108 | 204 | 64 | 96 | 160 | 151 | 149 | 268 |
| DFW | 132 | 141 | 270 | 91 | 97 | 185 | 120 | 150 | 270 | 90 | 95 | 185 | 137 | 146 | 281 |
| DTW | 80 | 77 | 146 | 76 | 73 | 138 | 66 | 80 | 146 | 66 | 70 | 136 | 104 | 100 | 191 |
| EWR | 63 | 59 | 108 | 45 | 43 | 78 | 54 | 54 | 108 | 37 | 37 | 74 | 68 | 63 | 117 |
| FLL | 71 | 71 | 126 | 34 | 34 | 60 | 33 | 31 | 54 | 22 | 21 | 40 | 71 | 71 | 126 |
| IAD | 76 | 77 | 121 | 73 | 74 | 117 | 55 | 65 | 120 | 55 | 50 | 105 | 113 | 114 | 180 |
| IAH | 65 | 68 | 123 | 60 | 63 | 113 | 56 | 64 | 120 | 56 | 56 | 112 | 91 | 95 | 173 |
| JFK | 60 | 67 | 98 | 43 | 48 | 71 | 44 | 44 | 88 | 33 | 38 | 71 | 60 | 67 | 98 |
| LAS | 47 | 47 | 85 | 32 | 32 | 57 | 30 | 54 | 84 | 24 | 28 | 52 | 47 | 47 | 85 |
| LAX | 84 | 86 | 150 | 72 | 73 | 128 | 64 | 84 | 148 | 64 | 64 | 128 | 98 | 100 | 175 |
| LGA | 43 | 43 | 81 | 34 | 34 | 64 | 40 | 40 | 80 | 32 | 32 | 64 | 43 | 43 | 81 |
| MCO | 79 | 85 | 145 | 61 | 66 | 112 | 72 | 72 | 144 | 52 | 52 | 104 | 101 | 109 | 186 |
| MDW | 78 | 78 | 138 | 33 | 33 | 59 | 32 | 32 | 64 | 24 | 24 | 48 | 78 | 78 | 138 |
| MEM | 86 | 86 | 152 | 68 | 68 | 120 | 74 | 76 | 150 | 60 | 60 | 120 | 88 | 88 | 157 |
| MIA | 76 | 76 | 134 | 61 | 61 | 108 | 62 | 62 | 124 | 48 | 60 | 108 | 93 | 93 | 164 |
| MSP | 67 | 69 | 120 | 63 | 65 | 112 | 60 | 60 | 120 | 56 | 56 | 112 | 88 | 91 | 159 |
| ORD | 110 | 109 | 202 | 87 | 87 | 160 | 100 | 100 | 200 | 80 | 80 | 160 | 115 | 114 | 213 |
| PDX | 63 | 63 | 111 | 59 | 59 | 105 | 42 | 36 | 62 | 25 | 26 | 49 | 63 | 63 | 111 |
| PHL | 61 | 64 | 110 | 53 | 56 | 96 | 40 | 60 | 100 | 48 | 48 | 96 | 70 | 73 | 127 |
| PHX | 59 | 60 | 110 | 35 | 36 | 65 | 50 | 60 | 110 | 28 | 32 | 60 | 80 | 81 | 150 |
| PIT | 107 | 104 | 160 | 87 | 85 | 131 | 60 | 80 | 140 | 50 | 60 | 110 | 109 | 106 | 164 |
| SAN | 33 | 32 | 57 | 29 | 28 | 49 | 20 | 23 | 43 | 15 | 23 | 38 | 33 | 32 | 57 |
| SEA | 56 | 53 | 91 | 50 | 47 | 81 | 40 | 50 | 90 | 45 | 36 | 81 | 87 | 82 | 142 |
| SFO | 55 | 55 | 99 | 40 | 40 | 72 | 45 | 50 | 95 | 42 | 30 | 72 | 55 | 55 | 99 |
| SLC | 72 | 81 | 132 | 57 | 64 | 105 | 50 | 80 | 130 | 45 | 60 | 105 | 75 | 84 | 138 |
| STL | 62 | 63 | 112 | 36 | 36 | 65 | 52 | 52 | 104 | 32 | 32 | 64 | 77 | 78 | 140 |
| TPA | 69 | 69 | 119 | 50 | 50 | 87 | 55 | 55 | 110 | 40 | 40 | 80 | 69 | 69 | 119 |



# Test Cases from Demand/Capacity Combinations

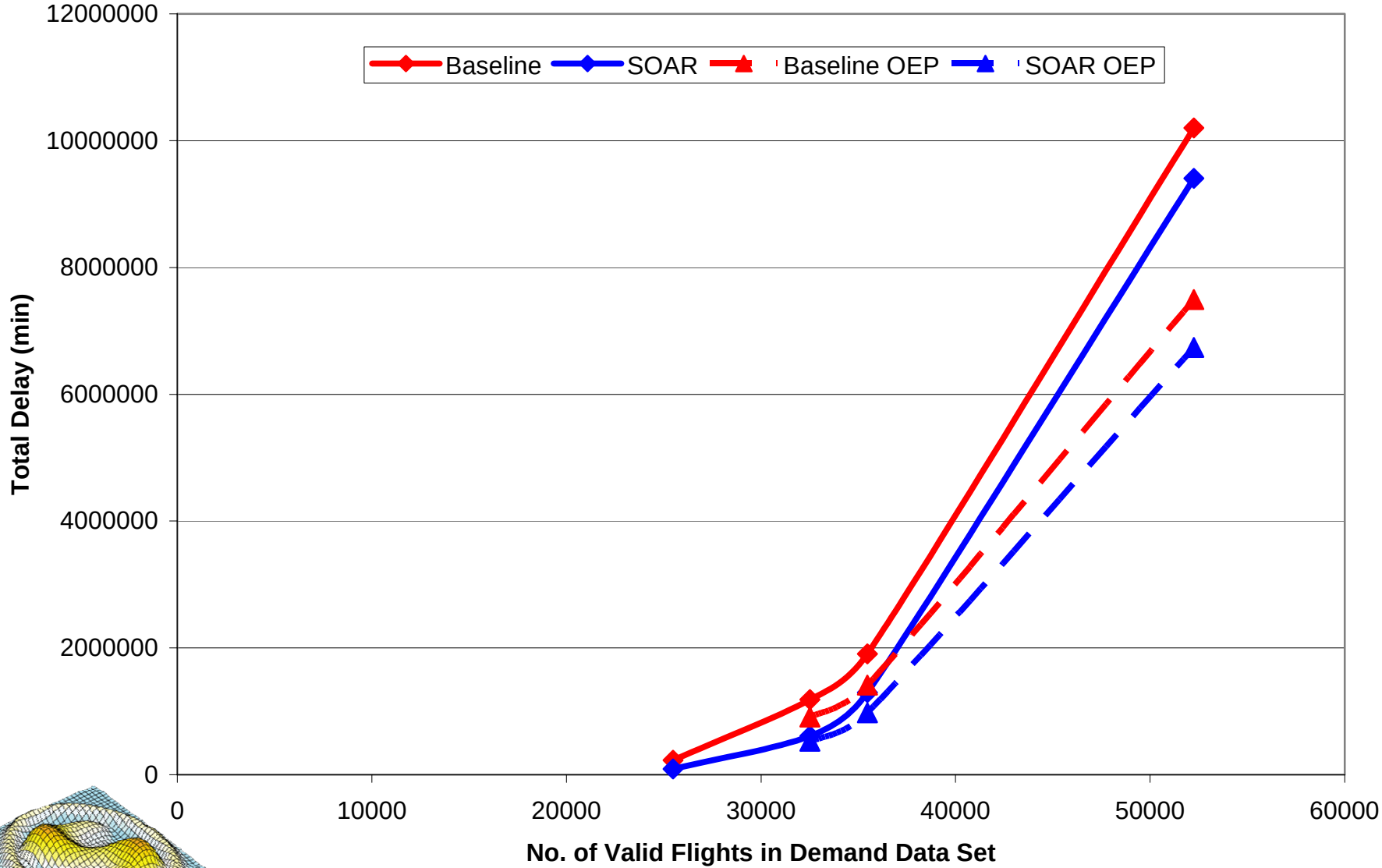
- **Analysis of OEP capacity on current demand unnecessary**
- **Total of 7 test cases selected**

| Demand Data Sets | Capacity Sets | |
|---|---|---|
| | ACES VFR | OEP |
| 2002 | ✓ | |
| TAF 2015 | ✓ | ✓ |
| TAF 2020 | ✓ | ✓ |
| 2×2002 | ✓ | ✓ |

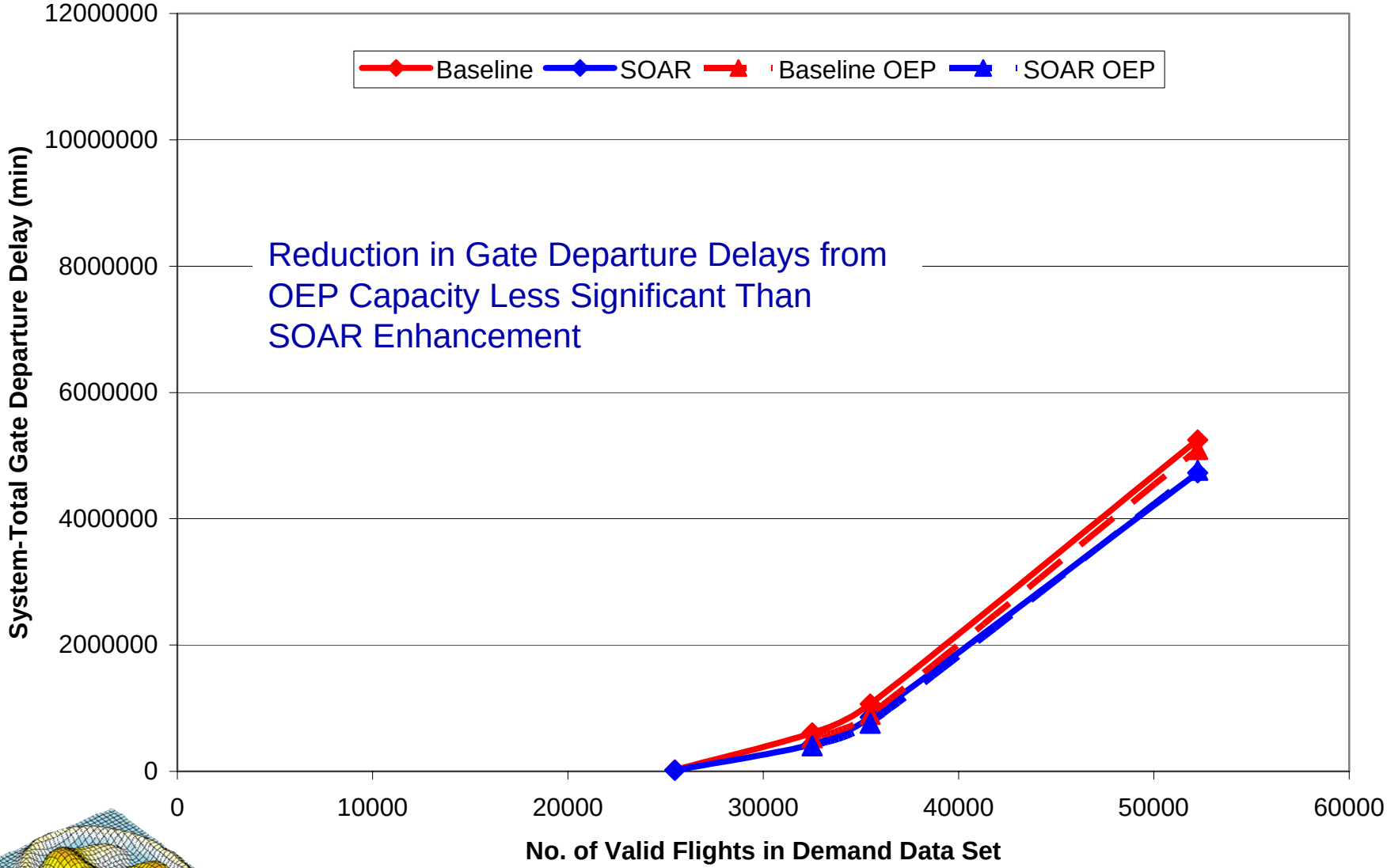
# Evaluation Results

| Concept | Capacity Set | Demand Set | Gate Departure Delay (min) | Surface Departure Delay (min) | Surface Arrival Delay (min) | Airborne Delay (min) | Block Delay (min) | Total Delay (min) |
|---|---|---|---|---|---|---|---|---|
| Baseline | ACES VFR | 2002 | 24008 | 152791 | 36023 | 15579 | 204392 | 228400 |
| | | TAF 2015 | 609435 | 401590 | 140643 | 31896 | 574128 | 1183564 |
| | | TAF 2020 | 1067897 | 550227 | 228191 | 61141 | 839558 | 1907455 |
| | | 2×2002 | 5249860 | 2201065 | 1119011 | 1629425 | 4949500 | 10199356 |
| | OEP | TAF 2015 | 531308 | 273416 | 85622 | 17565 | 376603 | 907912 |
| | | TAF 2020 | 903450 | 360894 | 121591 | 28037 | 510522 | 1413971 |
| | | 2×2002 | 5097471 | 1214005 | 630795 | 550725 | 2395524 | 7493000 |
| SOAR | ACES VFR | 2002 | 17002 | 36787 | 21559 | 16450 | 74795 | 91797 |
| | | TAF 2015 | 429311 | 78348 | 64454 | 36358 | 179160 | 608470 |
| | | TAF 2020 | 859354 | 183996 | 185430 | 66671 | 436097 | 1295451 |
| | | 2×2002 | 4728364 | 1592389 | 1063386 | 2020769 | 4676543 | 9404902 |
| | OEP | TAF 2015 | 406060 | 58621 | 45919 | 18454 | 122994 | 529054 |
| | | TAF 2020 | 760777 | 100093 | 88580 | 28553 | 217227 | 978003 |
| | | 2×2002 | 4767714 | 730538 | 662185 | 579766 | 1972488 | 6740201 |

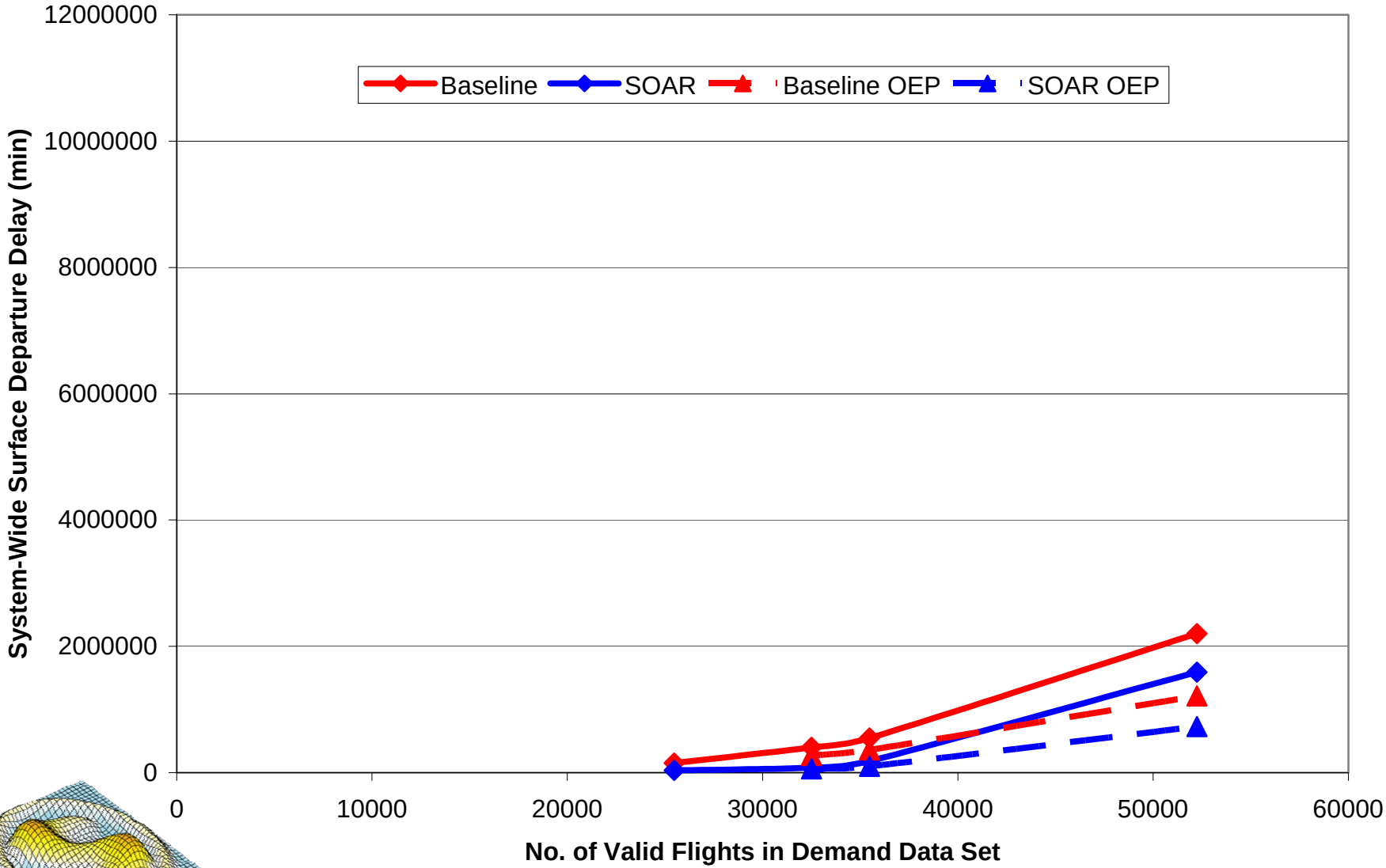
# Comparison of System-Wide Total Delays



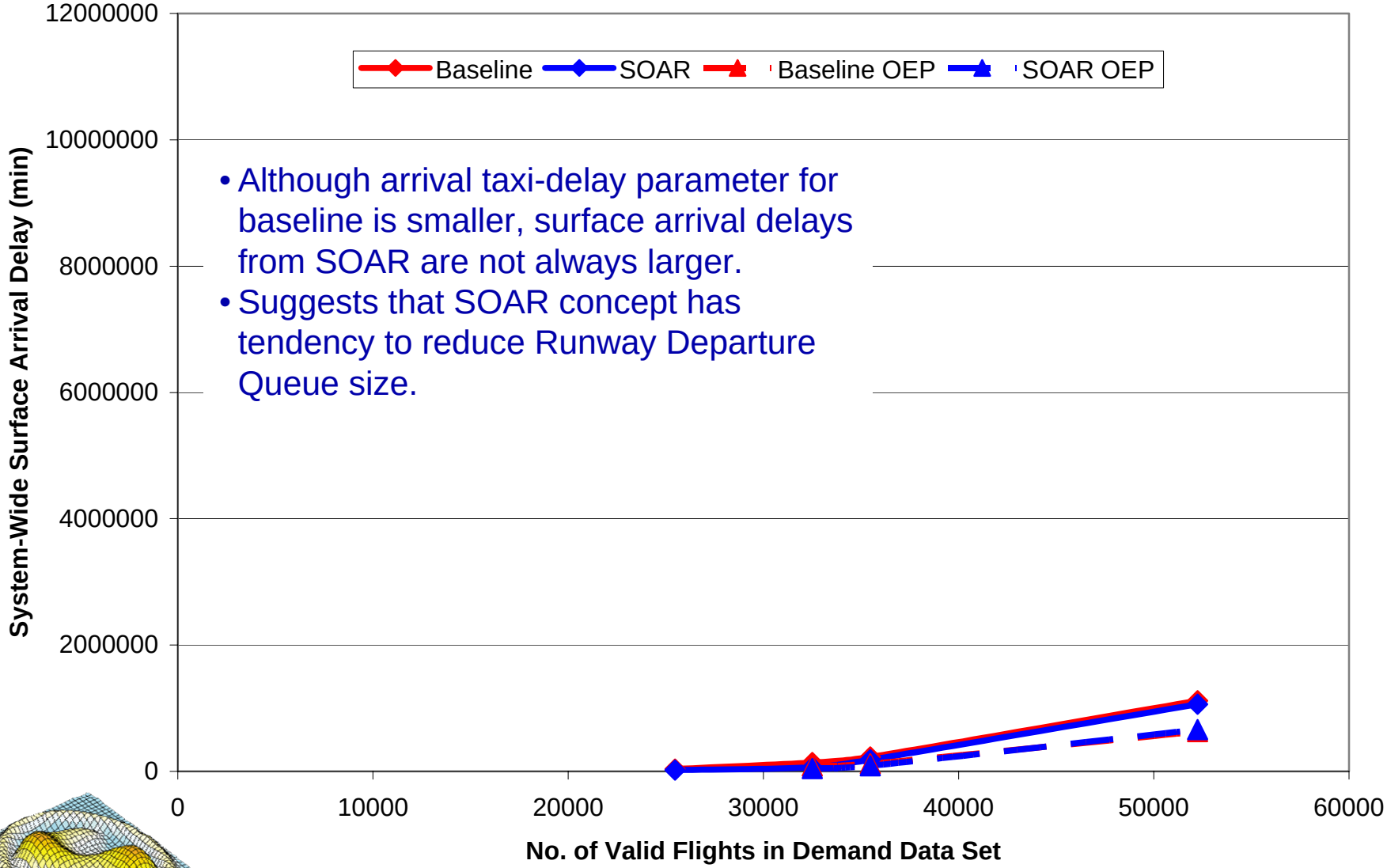
# System-Wide Gate Departure Delays



# System-Wide Surface Departure Delays

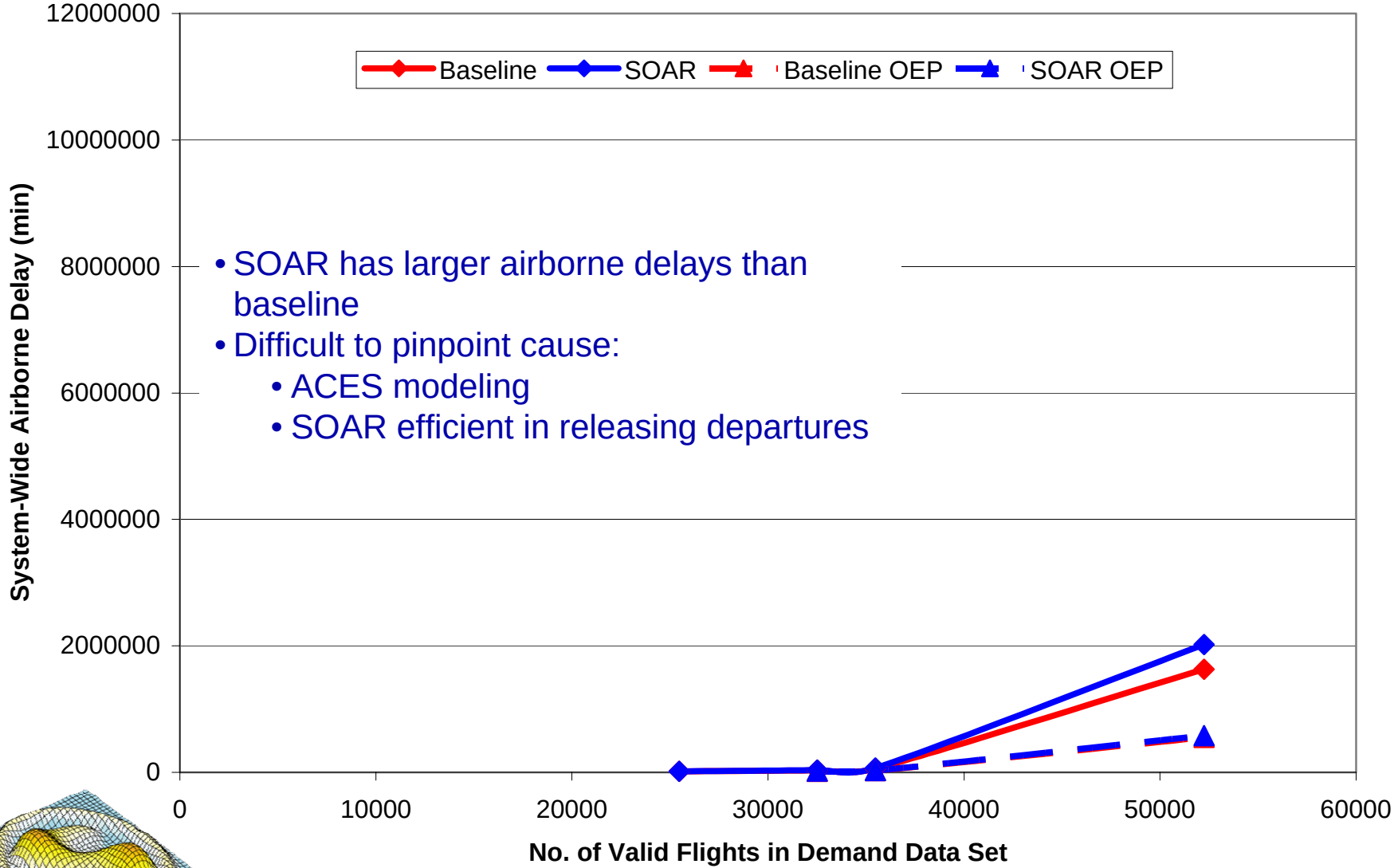


# System-Wide Surface Arrival Delays



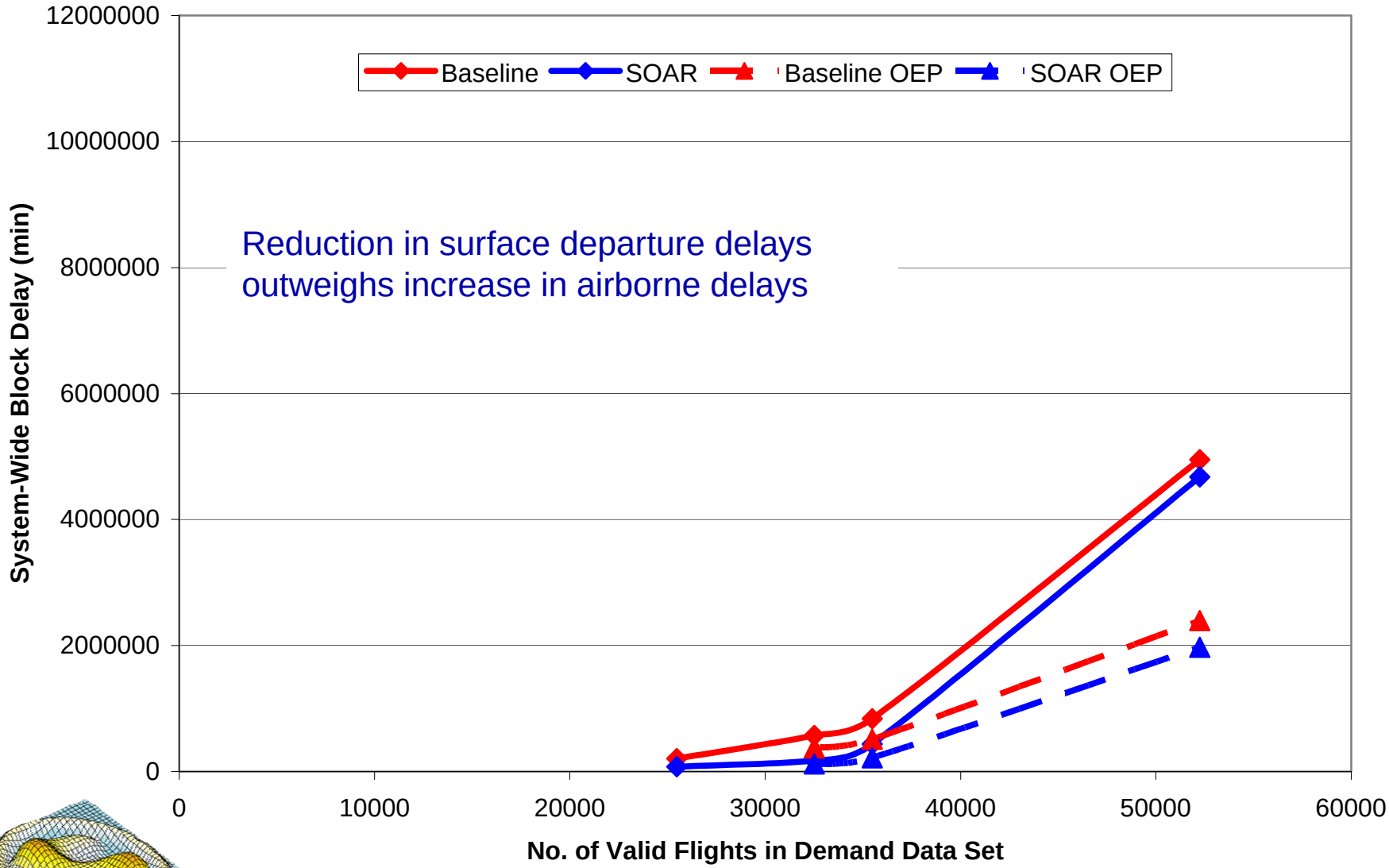

- Although arrival taxi-delay parameter for baseline is smaller, surface arrival delays from SOAR are not always larger.
- Suggests that SOAR concept has tendency to reduce Runway Departure Queue size.

# System-Wide Airborne Delays

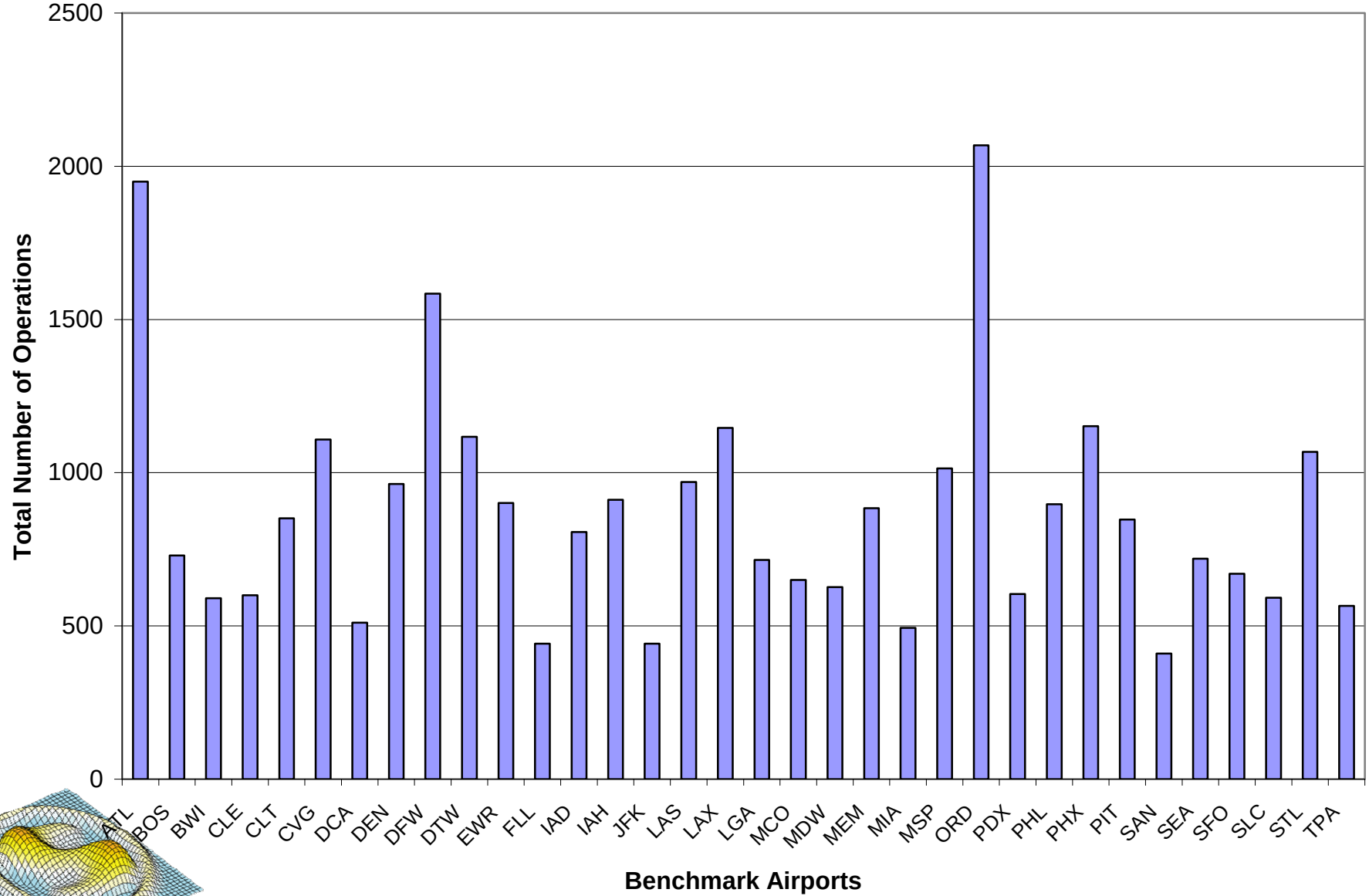



- SOAR has larger airborne delays than baseline
- Difficult to pinpoint cause:
  - ACES modeling
  - SOAR efficient in releasing departures

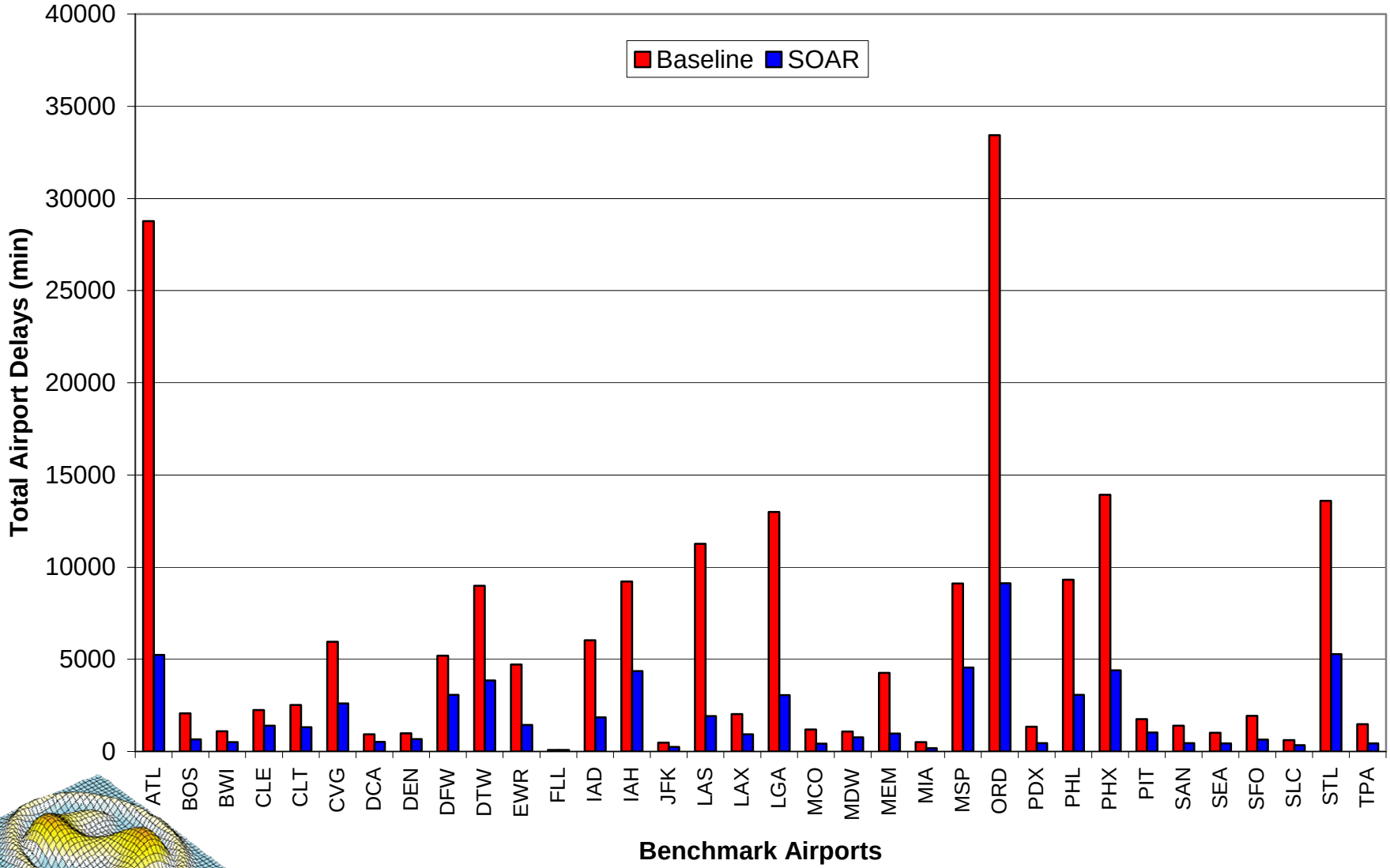
# System-Wide Block Delays



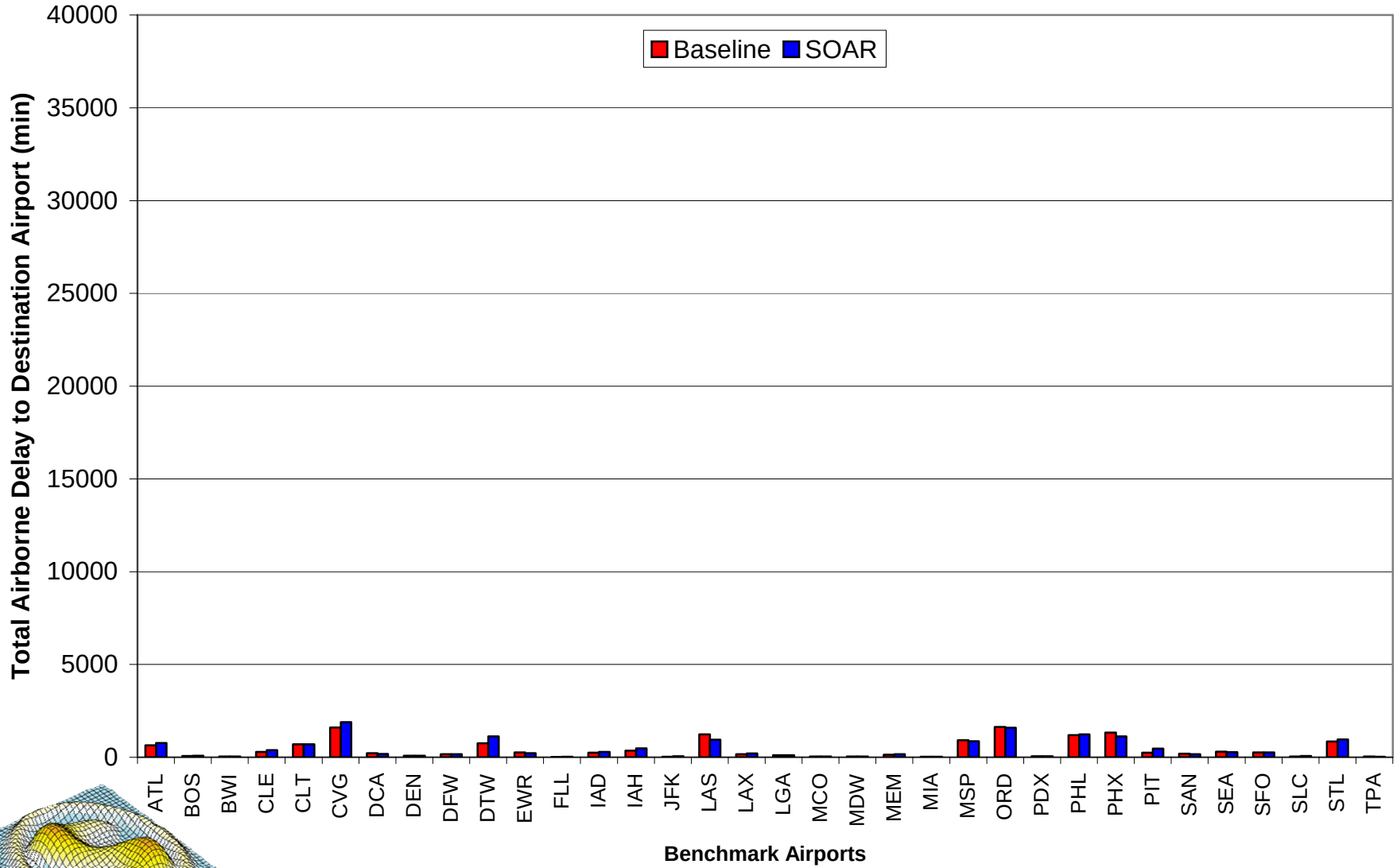
# Number of Operations at Benchmark Airports from 2002 Demand



# Comparison of Total Delays within Airport for 2002 Demand



# Comparison of Total Airborne Delays to Destination Airport for 2002 Demand



# Lessons Learned

- **ACES taxi-delay model has software bug for arrival traffic.**
  - **This allegedly has been resolved in ACES Build 3.**
- **ACES taxi-delay model is not amenable to adjustment for producing delays consistent with GoSim and ASPM data.**
  - **ACES parameters could not be tuned to deliver adequate departure taxi delay.**
  - **Value used appeared to be a local maximum, not entirely consistent with rest of parameter behavior.**
  - **New surface operation model will likely be needed for ACES.**
- **ACES has AOC software agent to model connection delays and cancellations, but model has not been tested and activated.**
  - **New AOC model including tail-number tracking will be evaluated.**
  - **Model enhancement may be required to adequately model traffic ripple effects as a consequence of AOC decisions.**

# Issues/Challenges about Assessment

**SOAR-specific**

- **Lack of surface operation performance for all relevant airports**
- **Formulation of throughput and taxi-delay models as functions of surface traffic**
- **Lack of appropriate model for AOC decisions**

**General**

- **ACES complexity: difficult to fully understand all its capabilities and limitations (fact vs. fiction, reality vs. artifact)**
- **Computationally intensive**
- **Lack of robustness for ACES version used for evaluation**
- **Capabilities for cost/benefit analyses**
- **No specific functionality for human-factors evaluation**