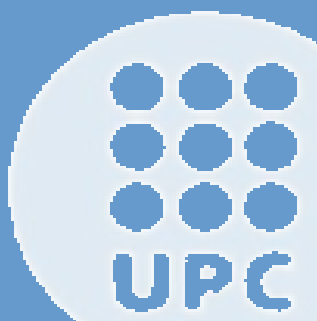




# Simulation of airborne ATFM delay and delay recovery by cruise speed reduction

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xavier.prats@upc.edu



# Road map

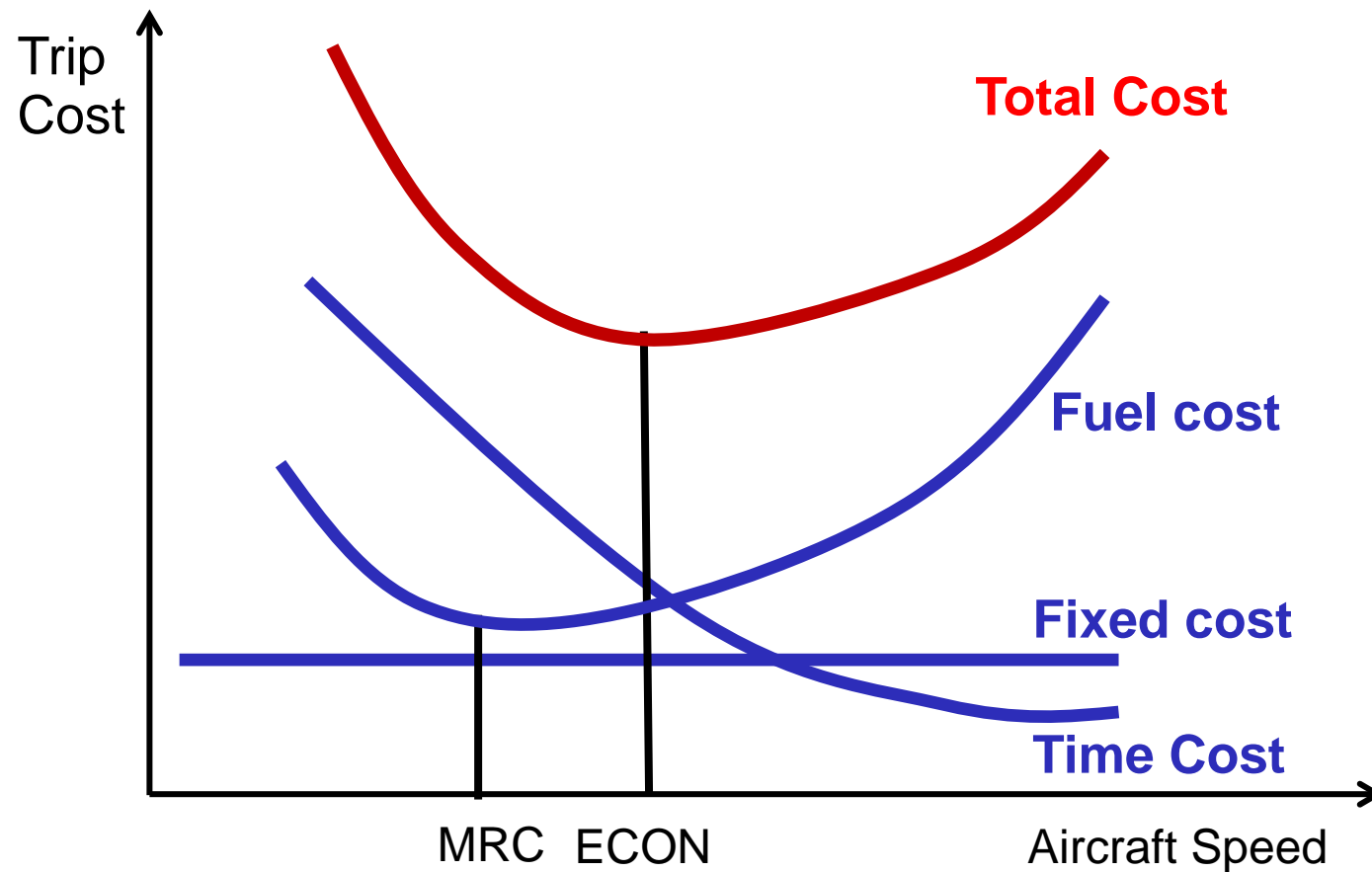


- **Introduction and Motivation**
  - Aircraft operations
  - Ground holding problem
  - Speed reduction strategies
- **Simulations**
  - Architecture
  - Data & Assumptions
- **Results**
- **Conclusions and Further work**

# Introduction and Motivation

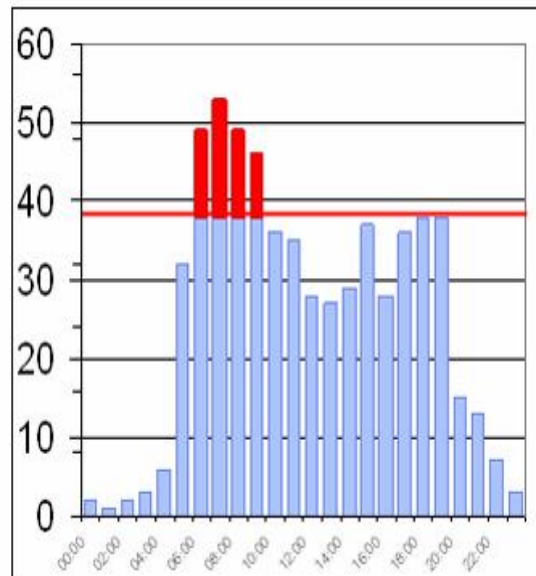


- **Aircraft operations**

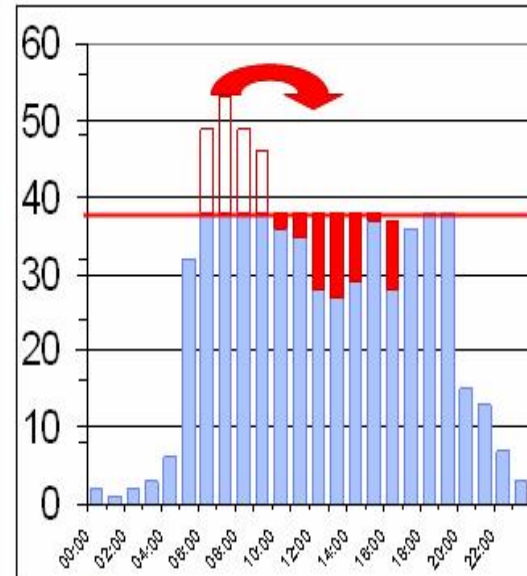


# Introduction and Motivation

- **Ground holding problem**



**Before Regulation**

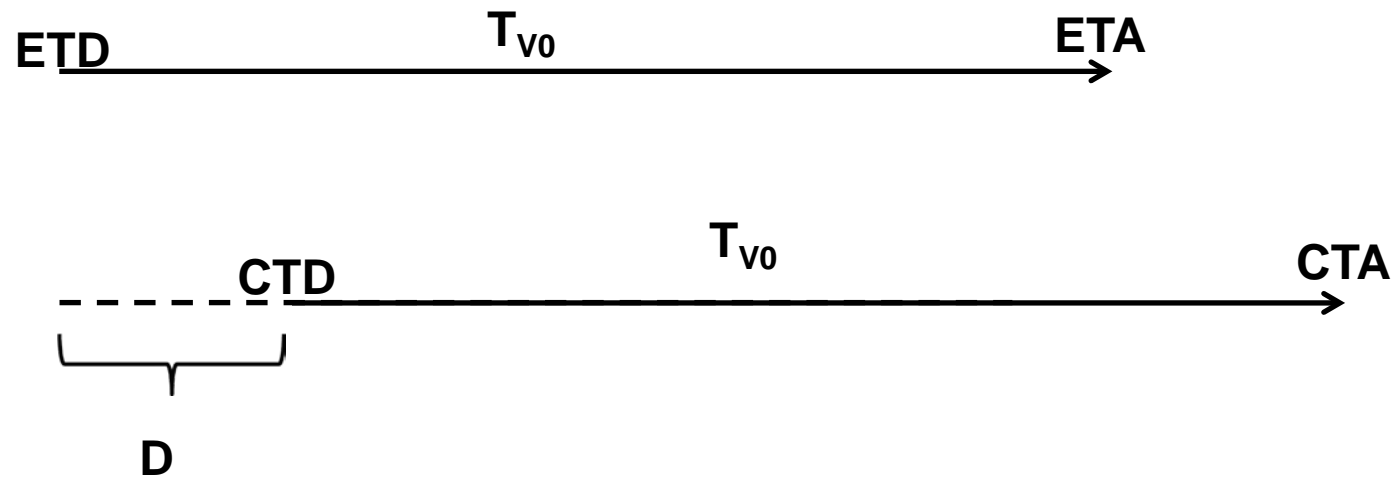


**After Regulation**

# Introduction and Motivation



- **Ground holding problem**



# Introduction and Motivation

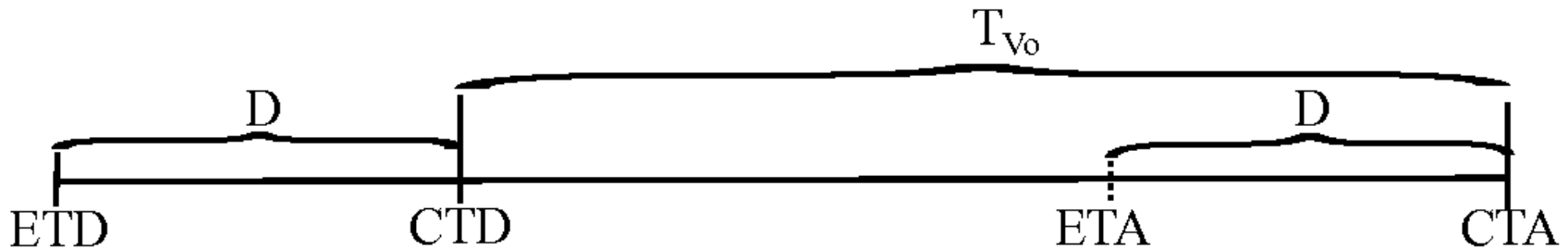


- **Example in SFO: Average SFO GDP statistics over 2005-2007 <sup>1</sup>**
  - **Initial Average Affected Flights: 79**
  - **Initial Average Total Delay (min): 3,642**
  - **Initial Average Maximum Delay (min): 98**
  - **Initial Average Delay (min): 44**
  - **Planned Average Overall Duration: 4h51**
  - **Actual Average Duration (Cancel – Start Time): 2h52**
  - **Early Average Cancel Time (Planned – Actual Duration): 1h59**

# Introduction and Motivation

- **Speed reduction strategies to deal with ground delay**

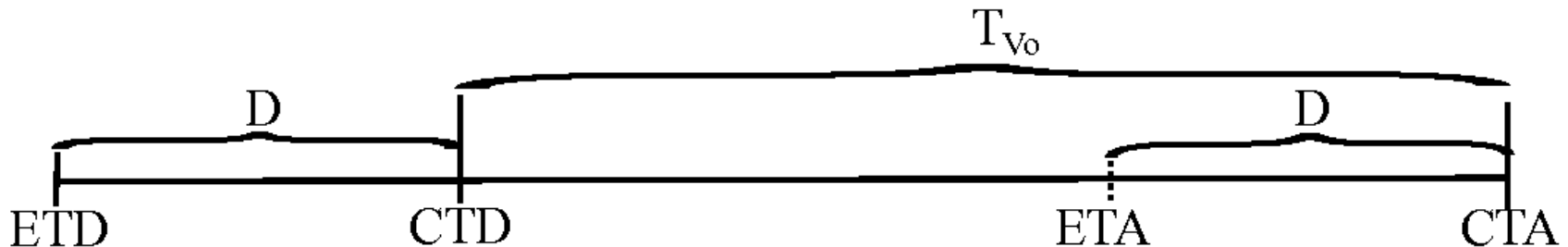
**Ground delay without speed reduction**



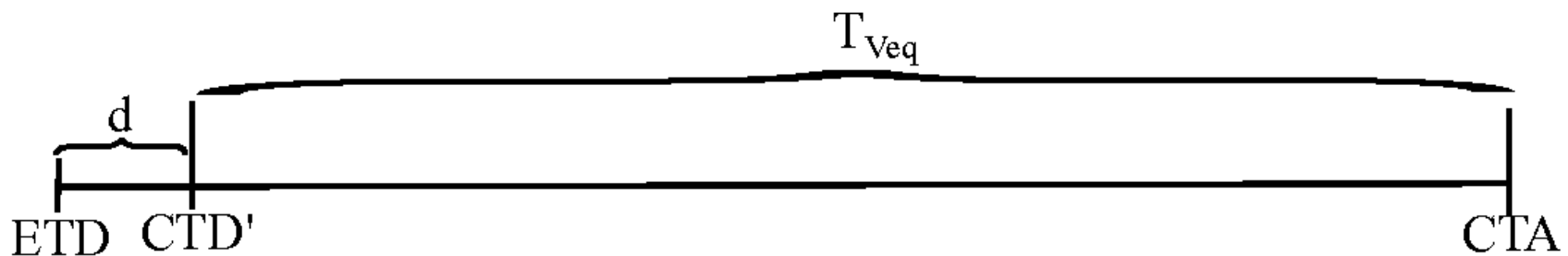
# Introduction and Motivation

- **Speed reduction strategies to deal with ground delay**

## Ground delay without speed reduction



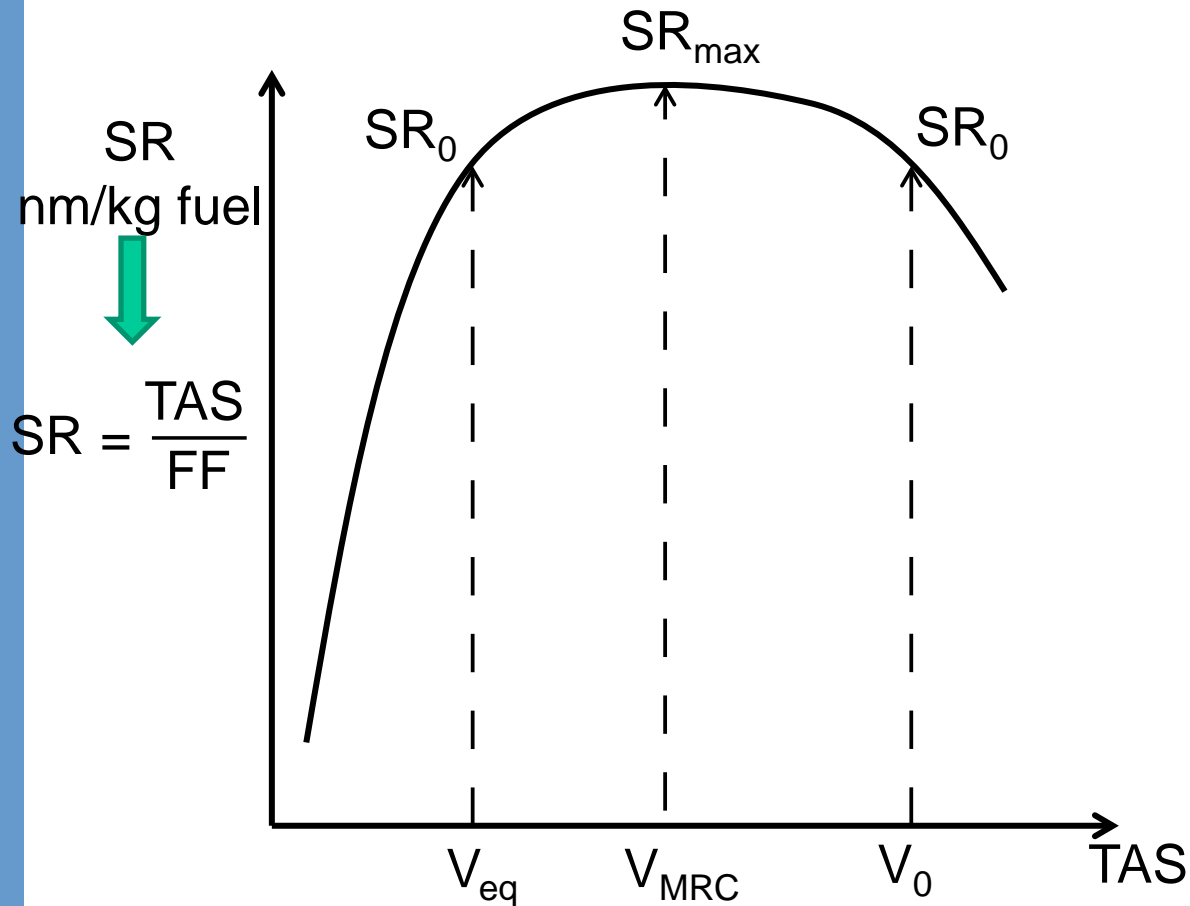
## Ground delay with speed reduction





# Introduction and Motivation

- **Speed reduction strategies to deal with ground delay:**



**SR curve in function of:**

- FL
- Weight

**Ve<sub>q</sub> in function of:**

- SR curve
- $V_0$

**Airborne delay in function of:**

- $V_0 - V_{eq}$

# Introduction and Motivation



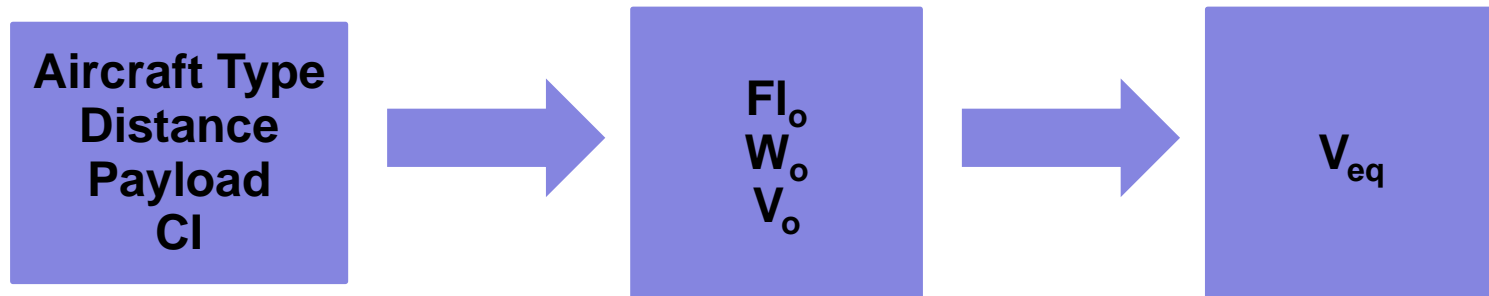
- **Aircraft operations**

$$CI = \frac{\text{Time cost}}{\text{Fuel cost}} \text{ Kg/mn}$$



CI = 0 → MRC speed  
CI (0,MAX) → Vo speed  
CI = MAX → Max speed

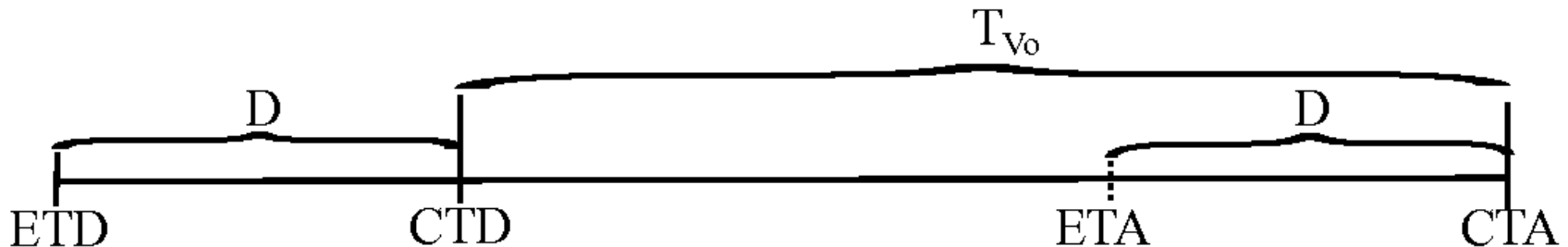
# Introduction and Motivation



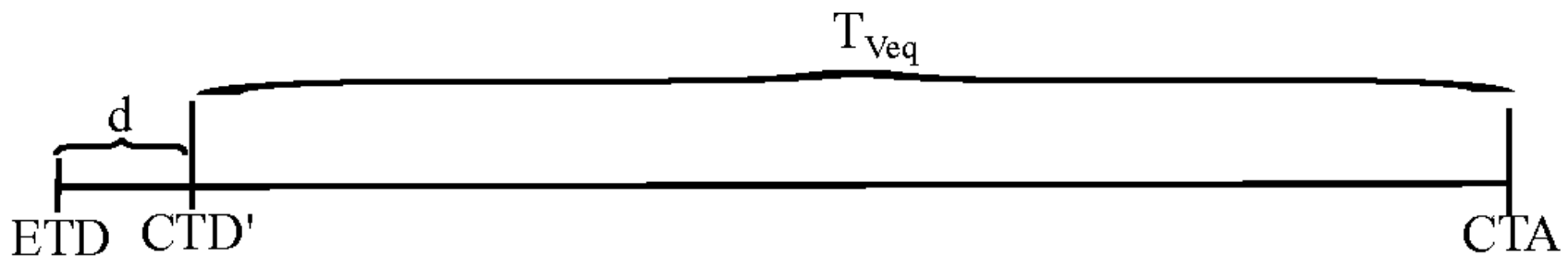
# Introduction and Motivation

- **Speed reduction strategies to deal with ground delay**

## Ground delay without speed reduction



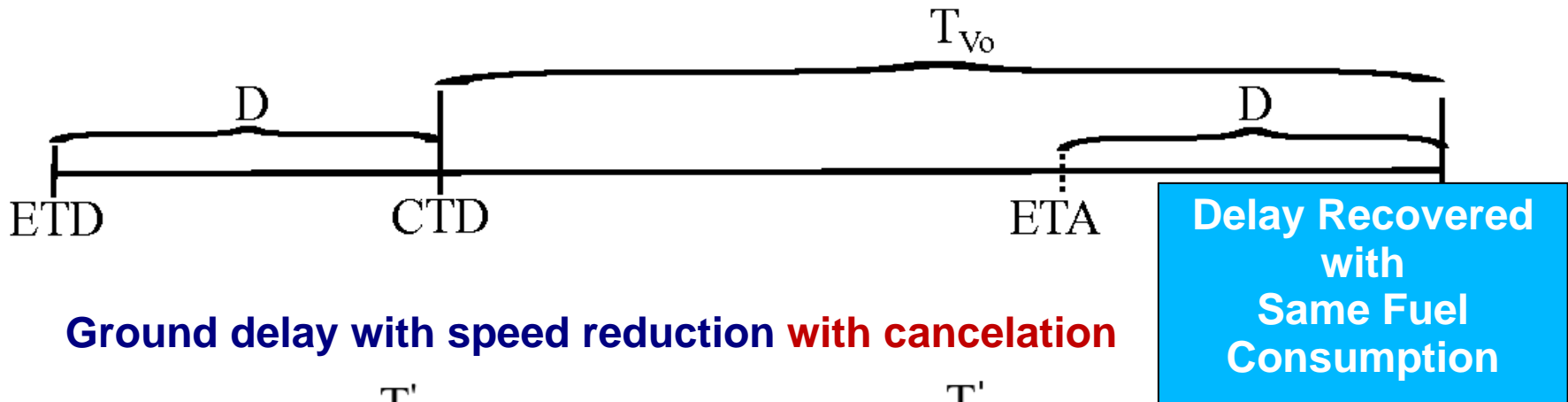
## Ground delay with speed reduction



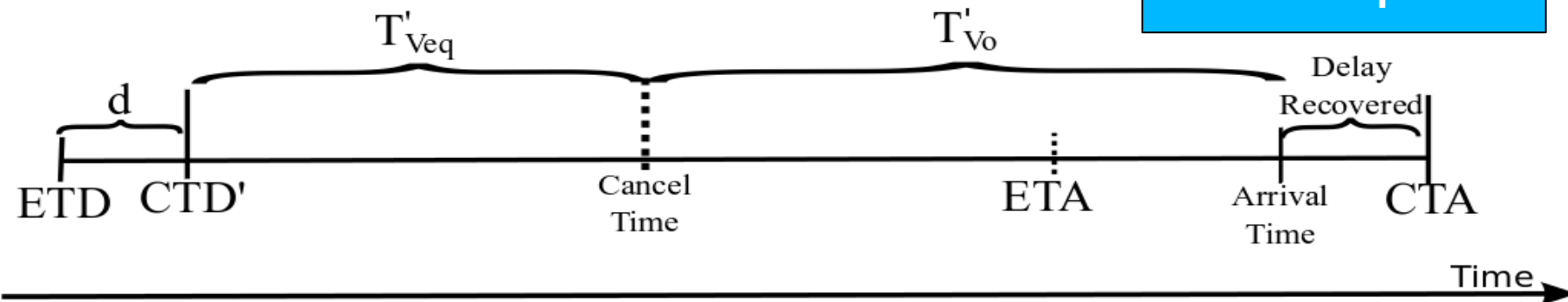
# Introduction and Motivation

- Speed reduction strategies to deal with ground delay

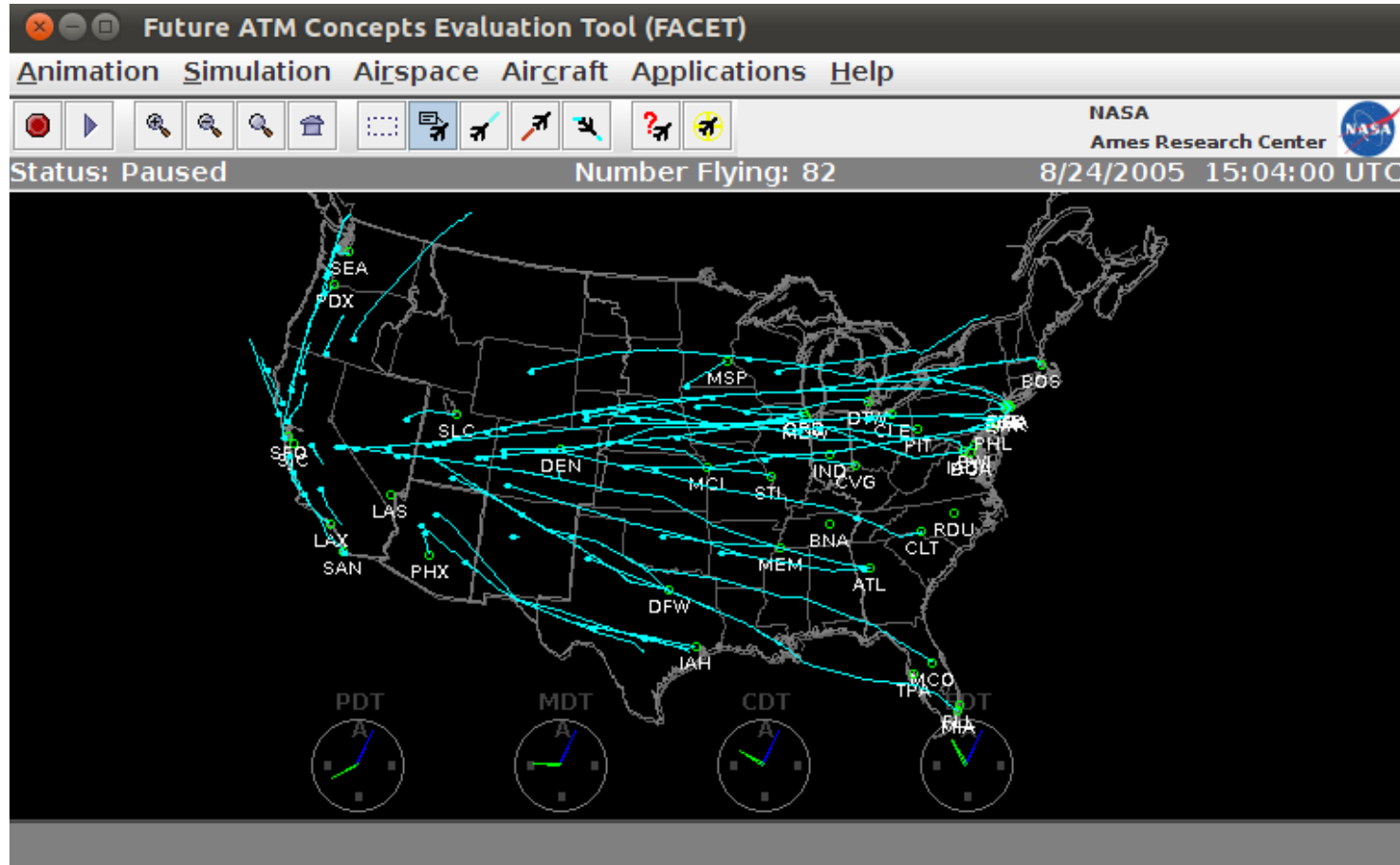
## Ground delay without speed reduction



## Ground delay with speed reduction with cancellation



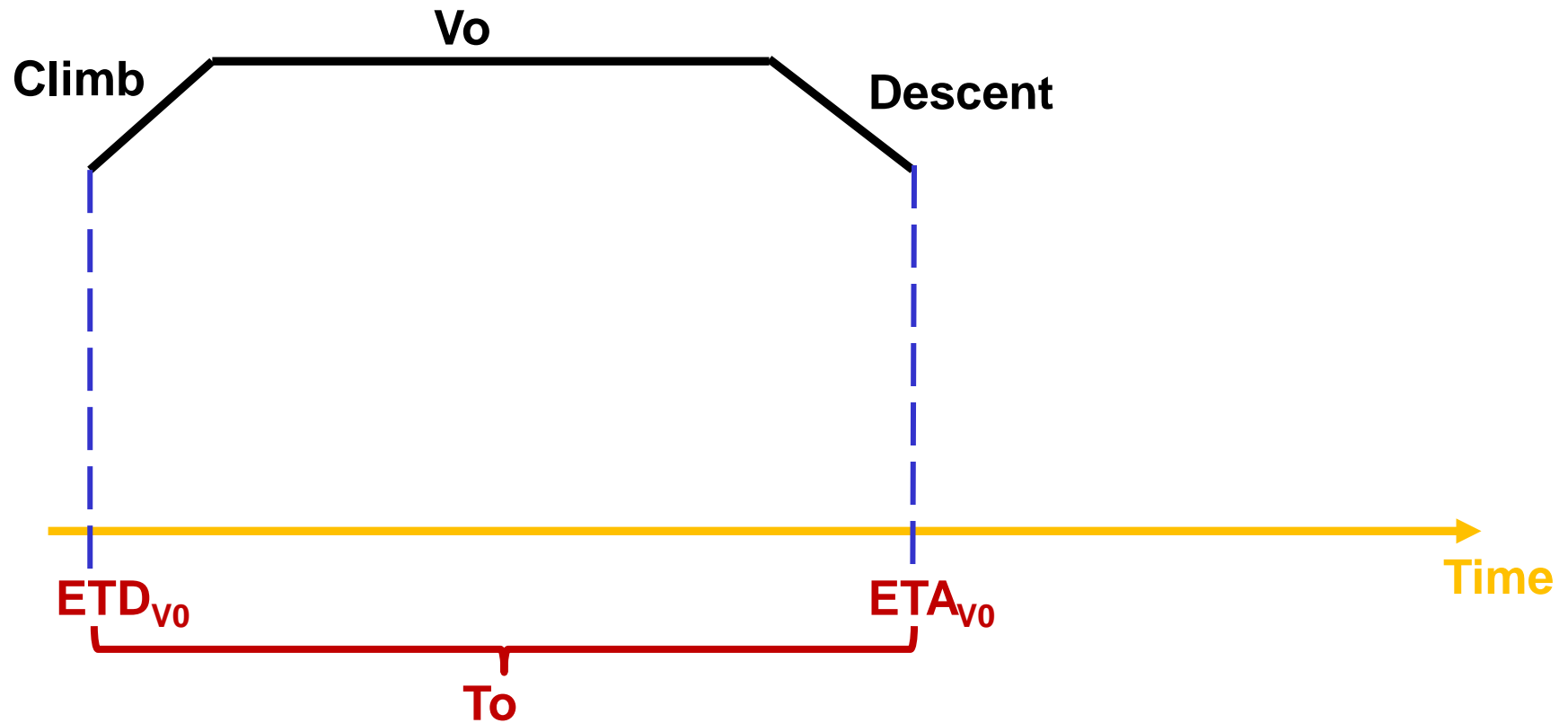
# Simulations



# Simulations



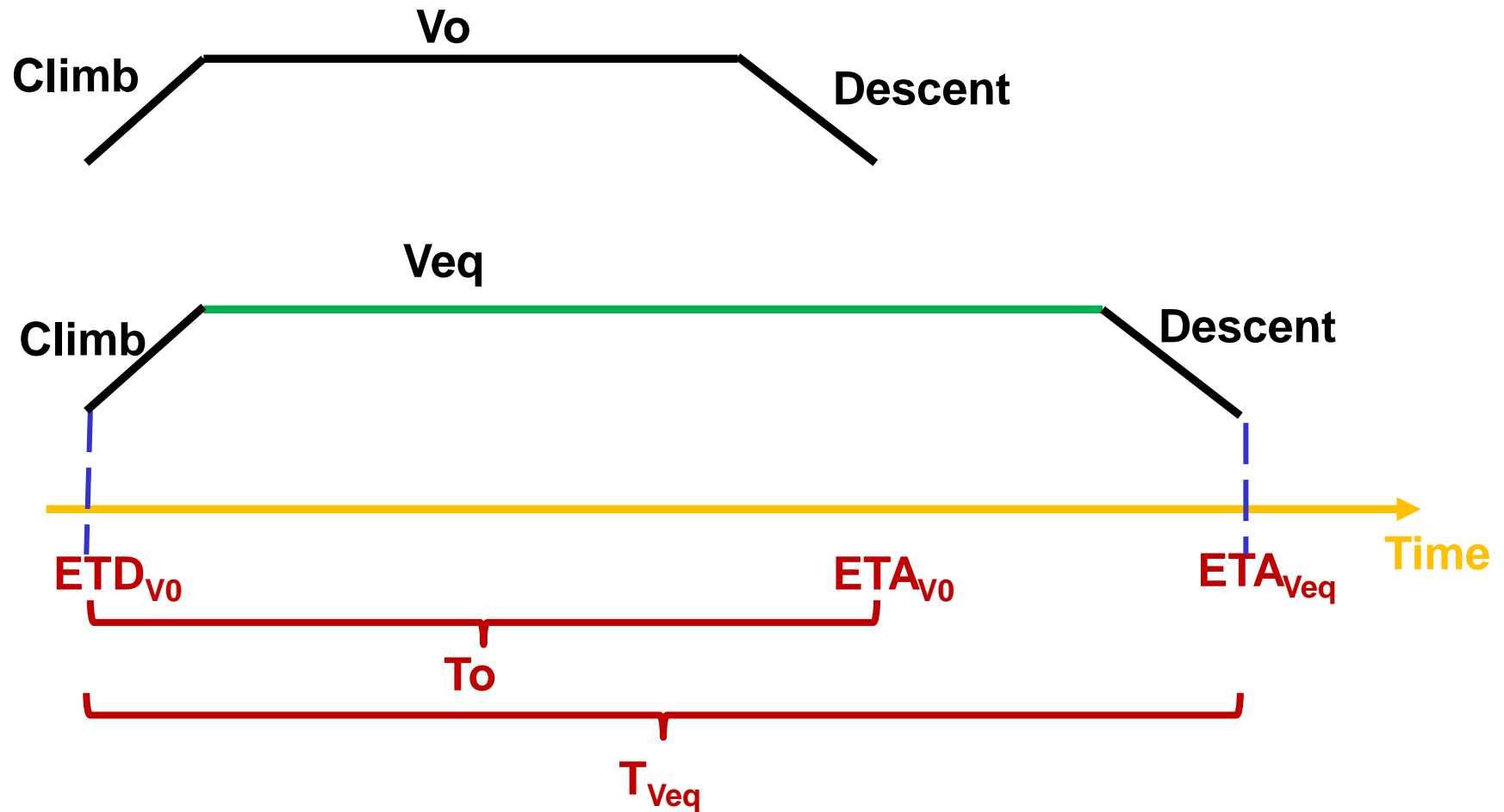
- Simulate an aircraft flying at  $V_{eq}$



# Simulations



- Simulate an aircraft flying at  $V_{eq}$

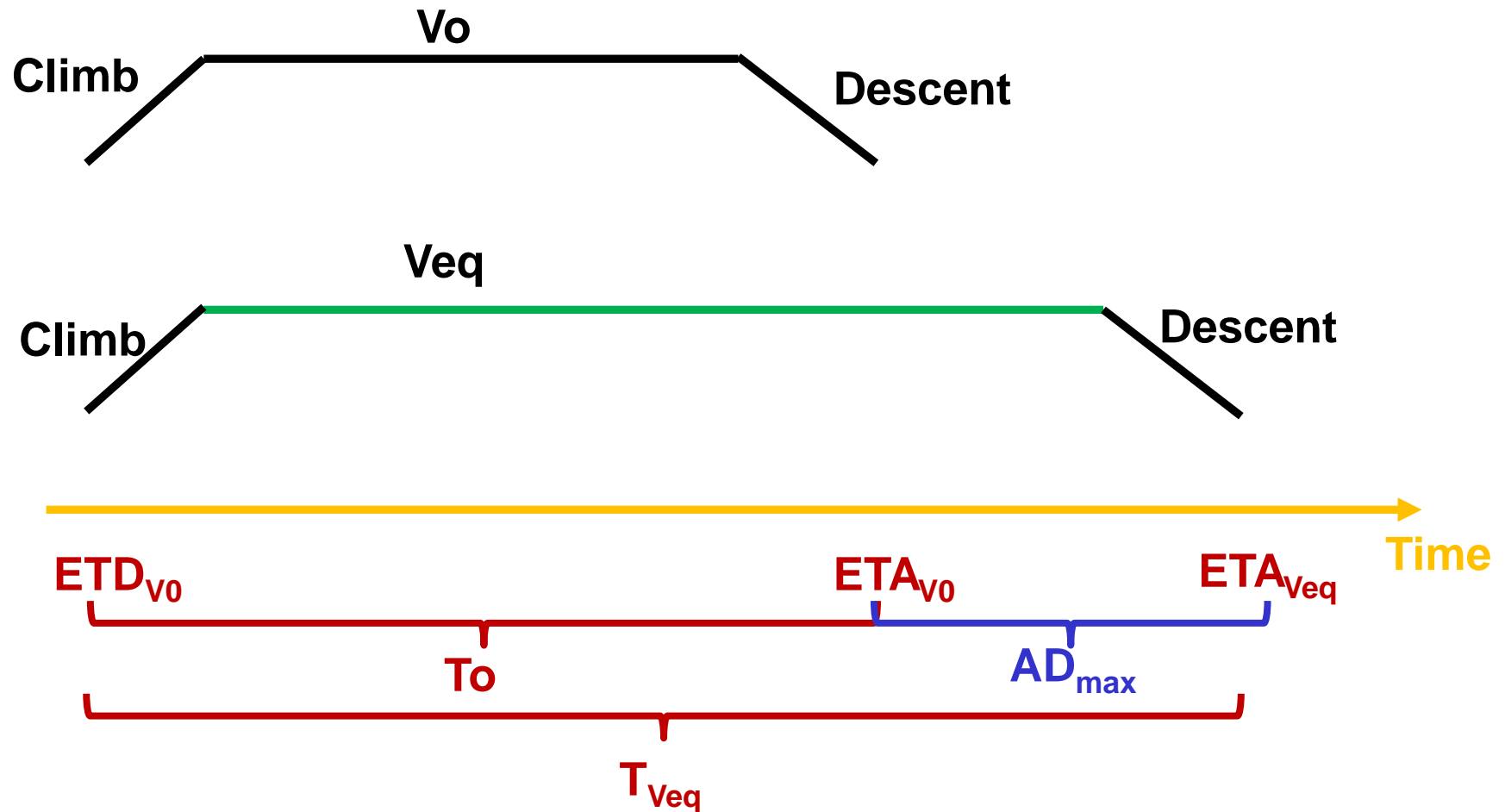




# Simulations

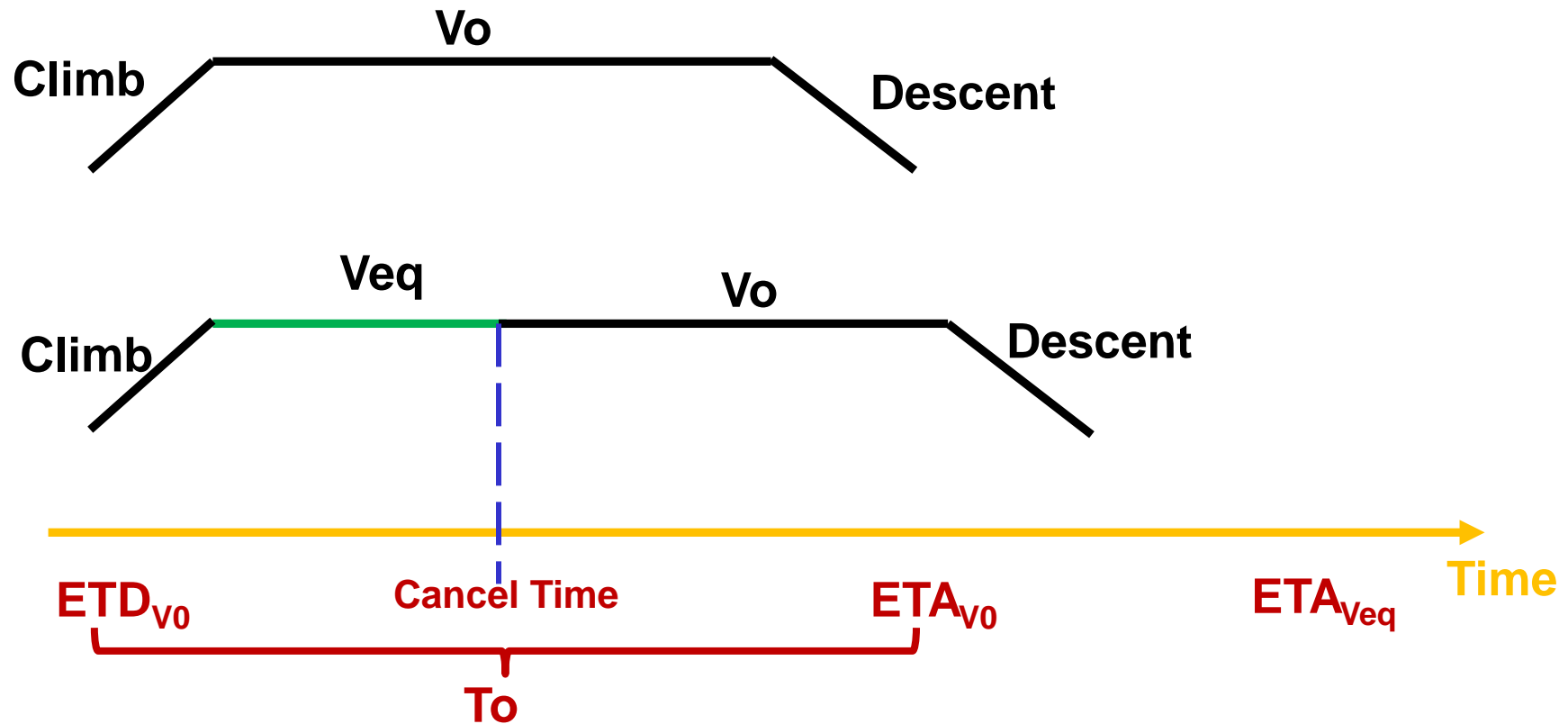


- Simulate an aircraft flying at  $V_{eq}$



# Simulations

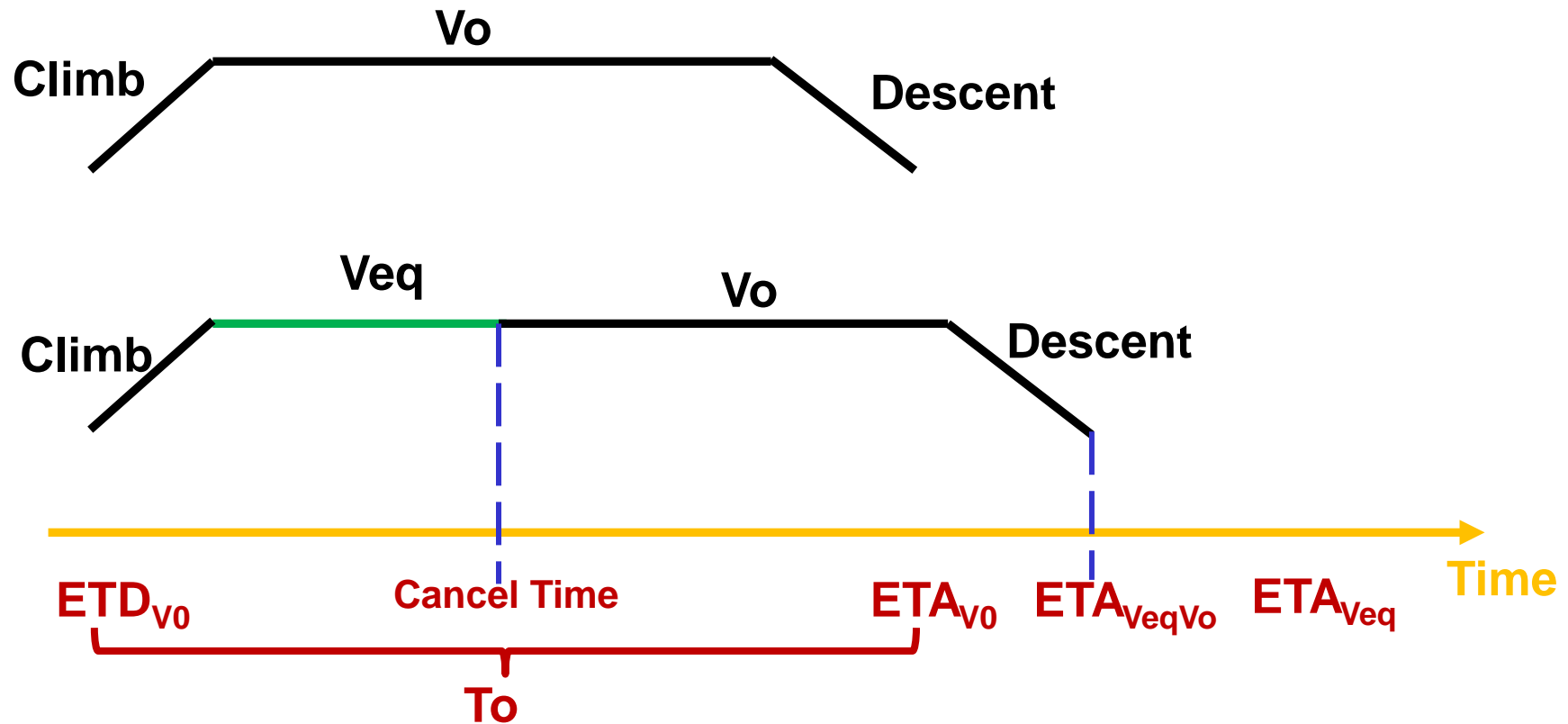
- Simulate recovery delay if at a given moment change to  $V_0$



# Simulations

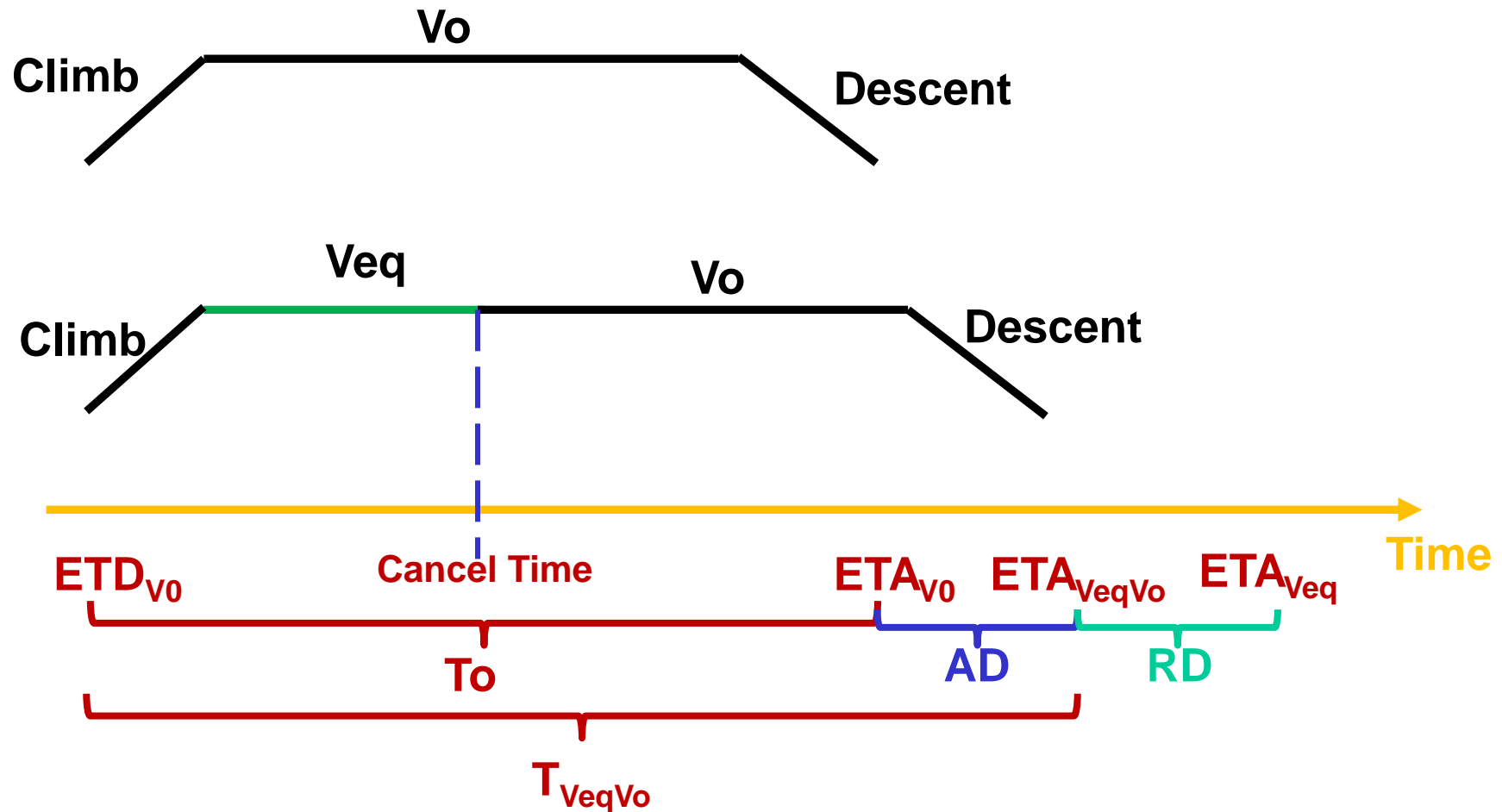


- Simulate recovery delay if at a given moment change to  $V_0$



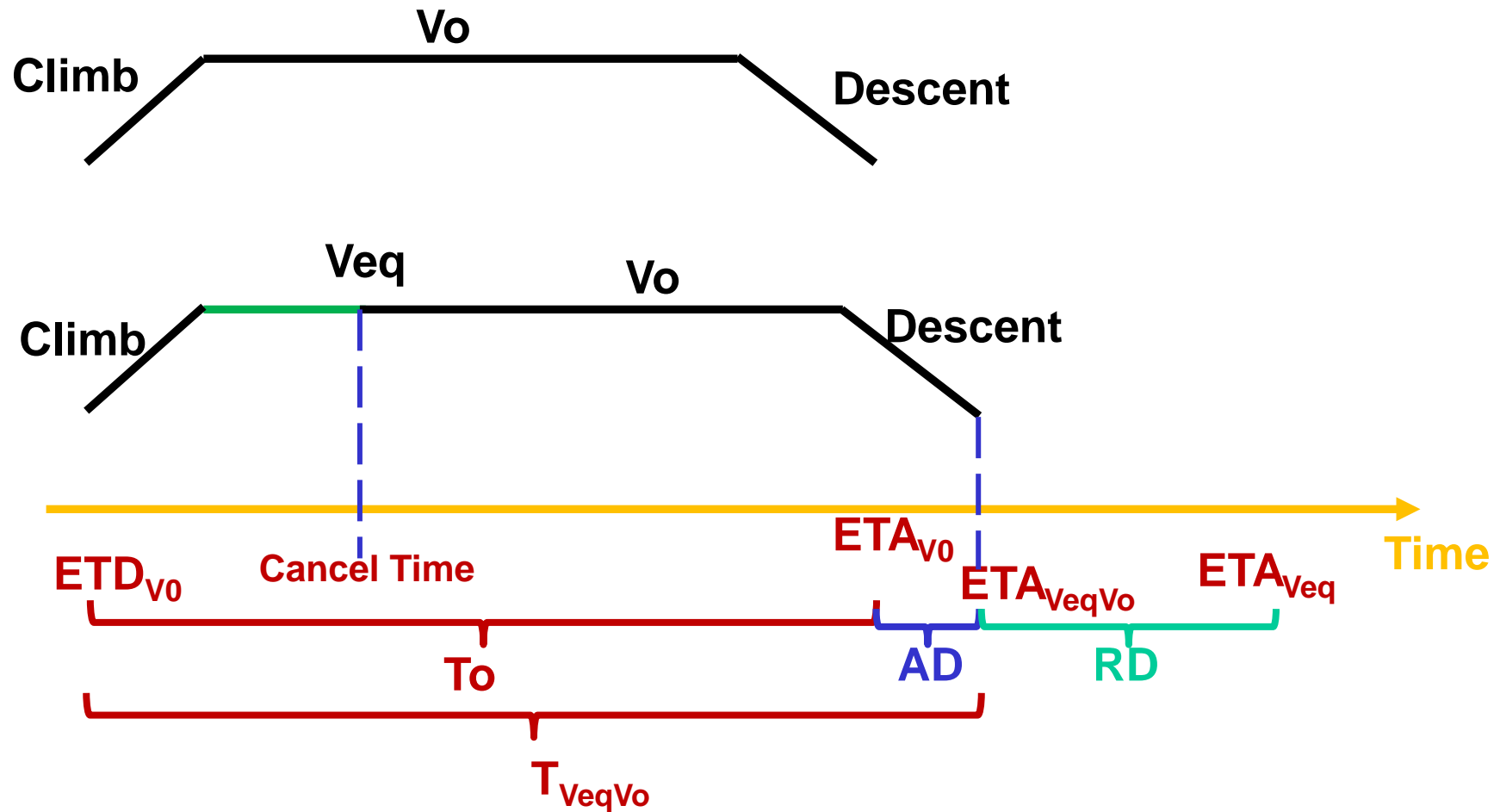
# Simulations

- Simulate recovery delay if at a given moment change to  $V_0$



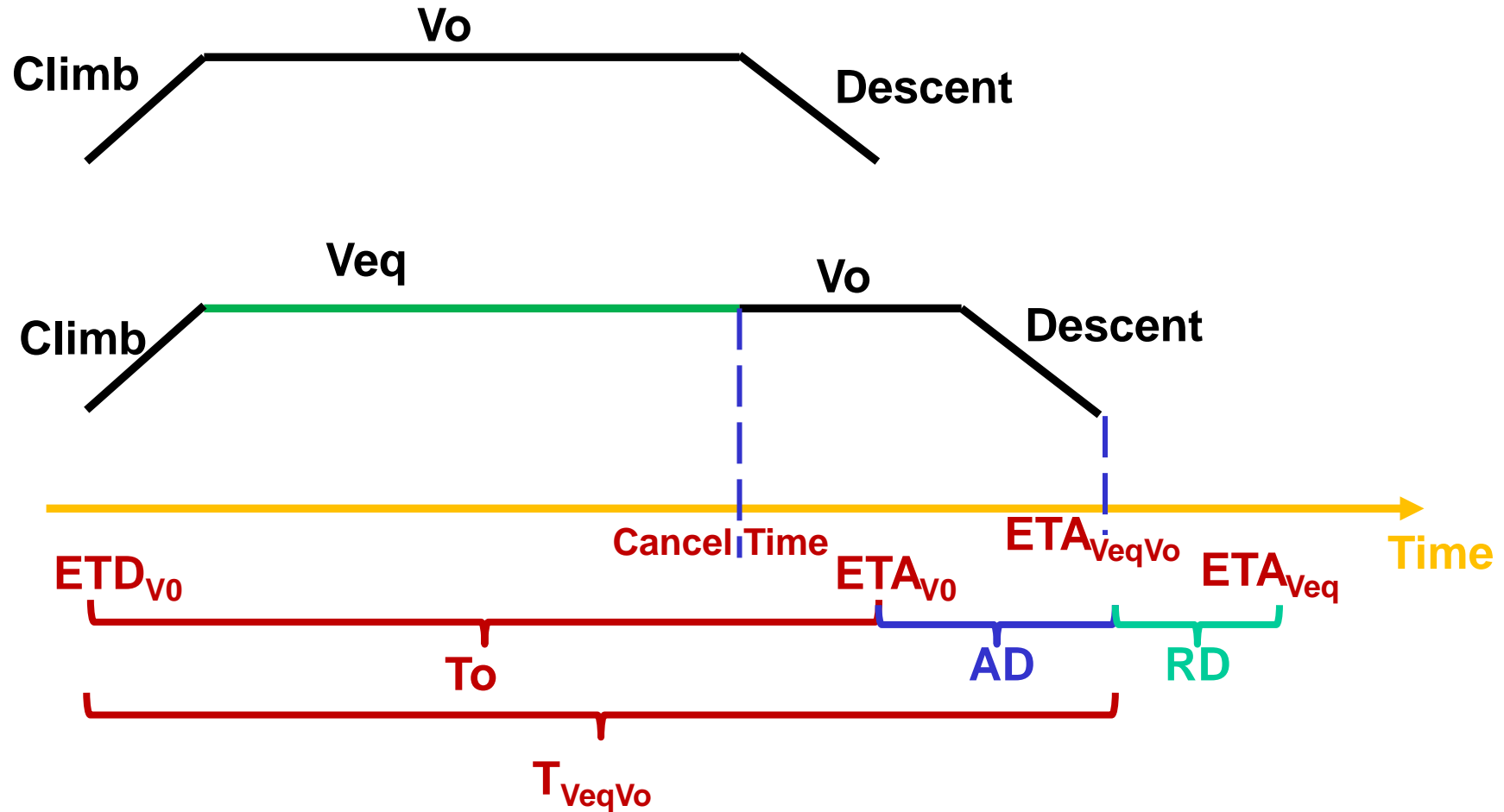
# Simulations

- Simulate recovery delay if at a given moment change to  $V_0$



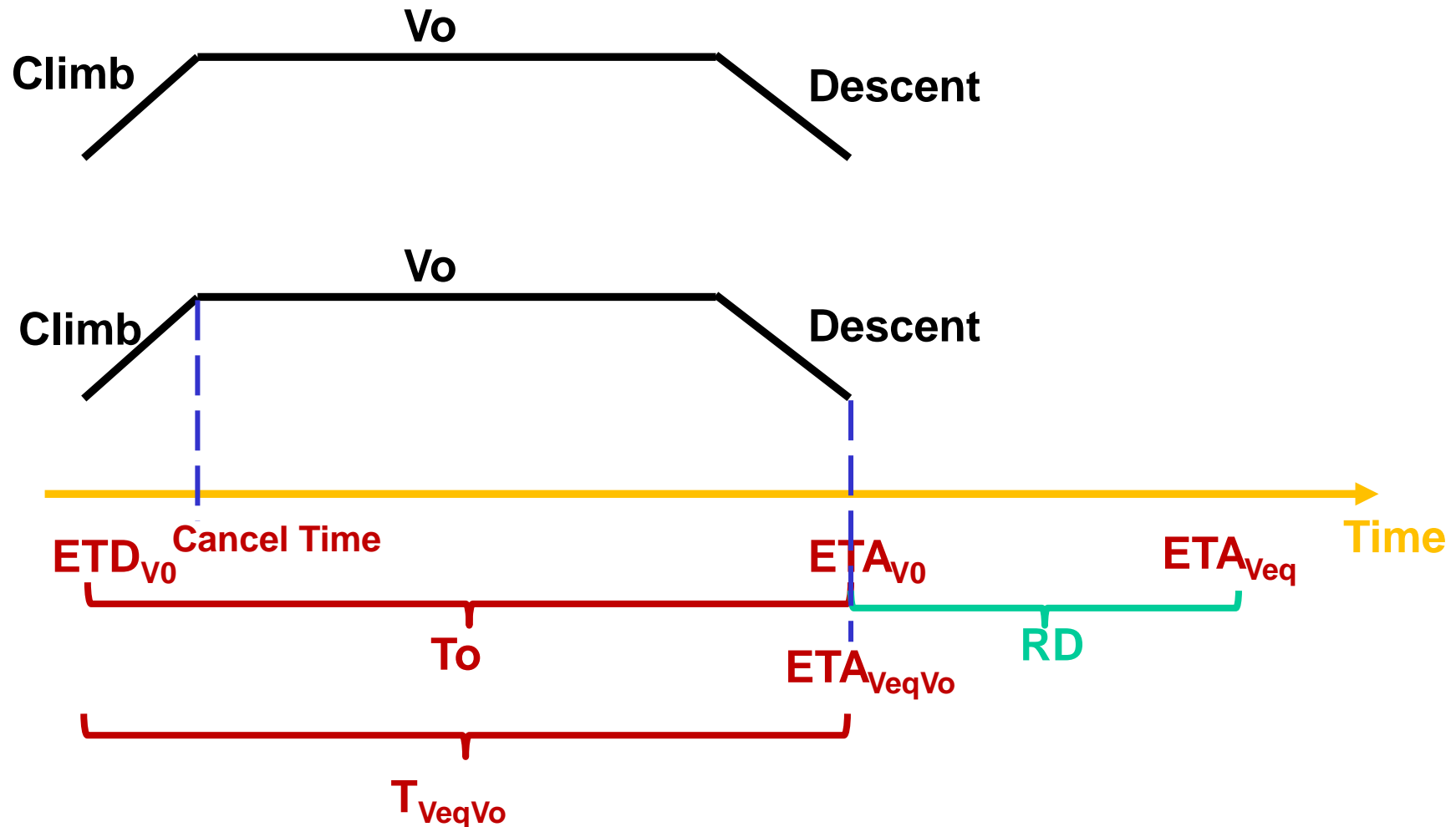
# Simulations

- Simulate recovery delay if at a given moment change to  $V_0$



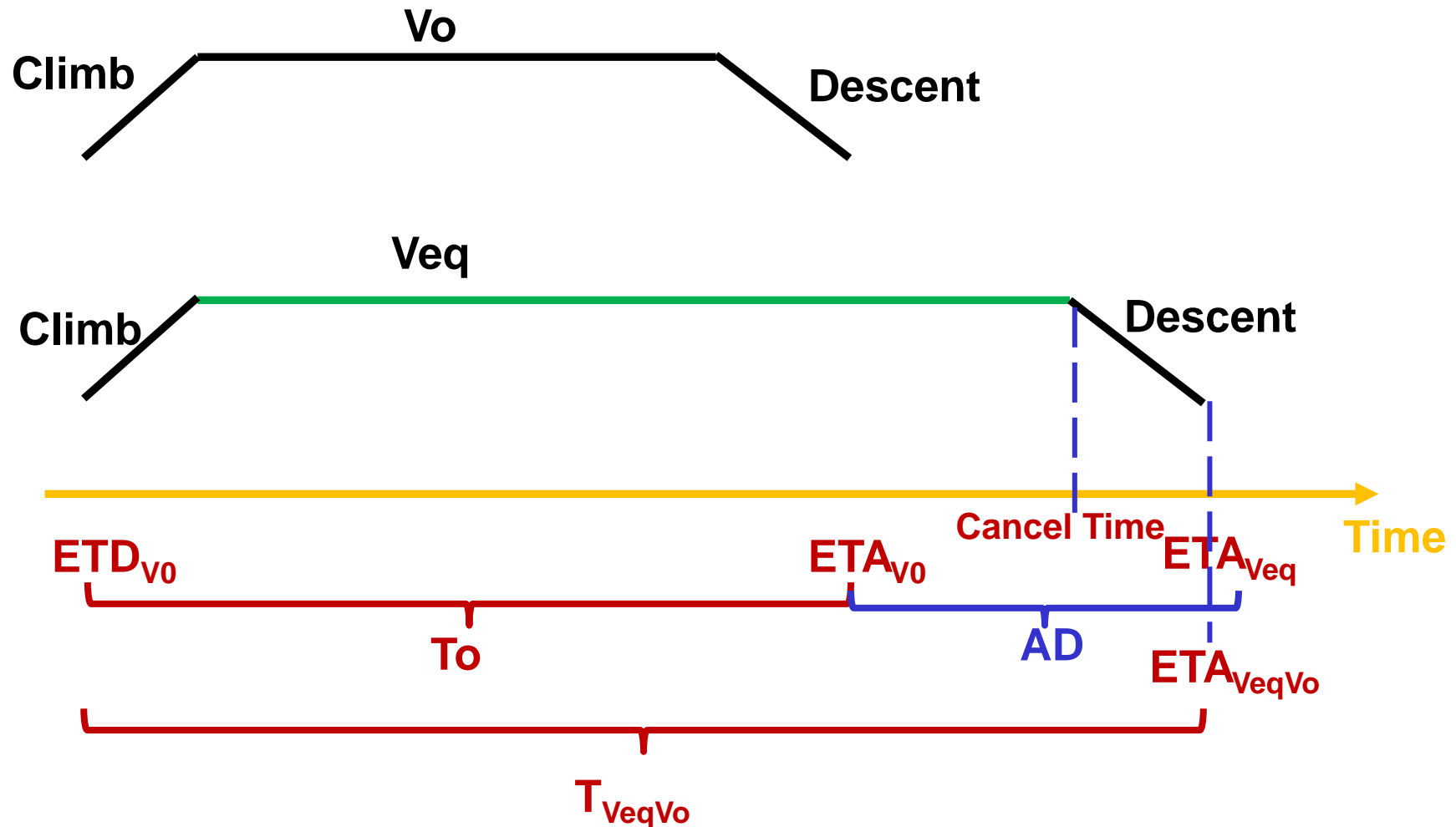
# Simulations

- Simulate recovery delay if at a given moment change to  $V_0$



# Simulations

- Simulate recovery delay if at a given moment change to  $V_0$

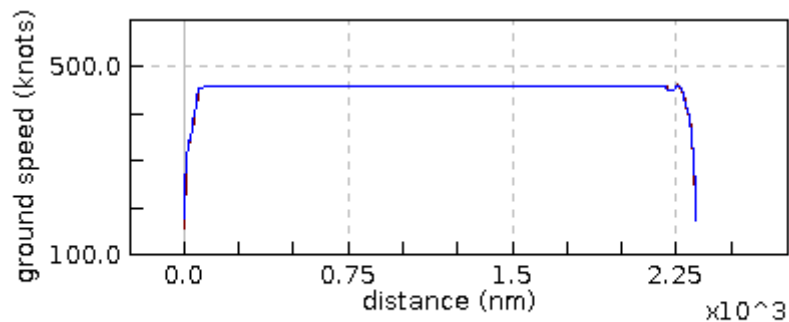




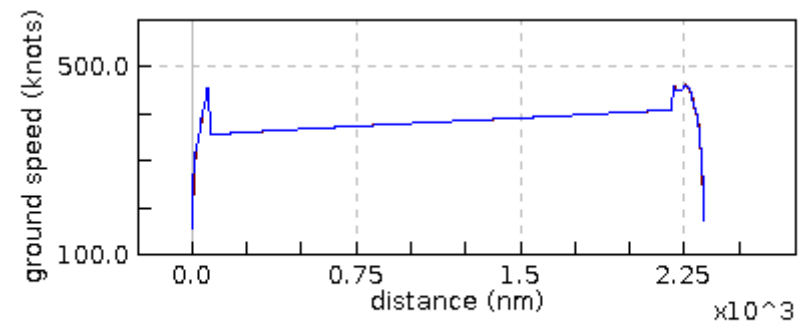
# Simulations



- **Simulate an aircraft flying at  $V_{eq}$**
- **Simulate maximum air delay**
- **Simulate recovery delay if at a given moment change to  $V_0$**
- **Not to simulate a GDP**

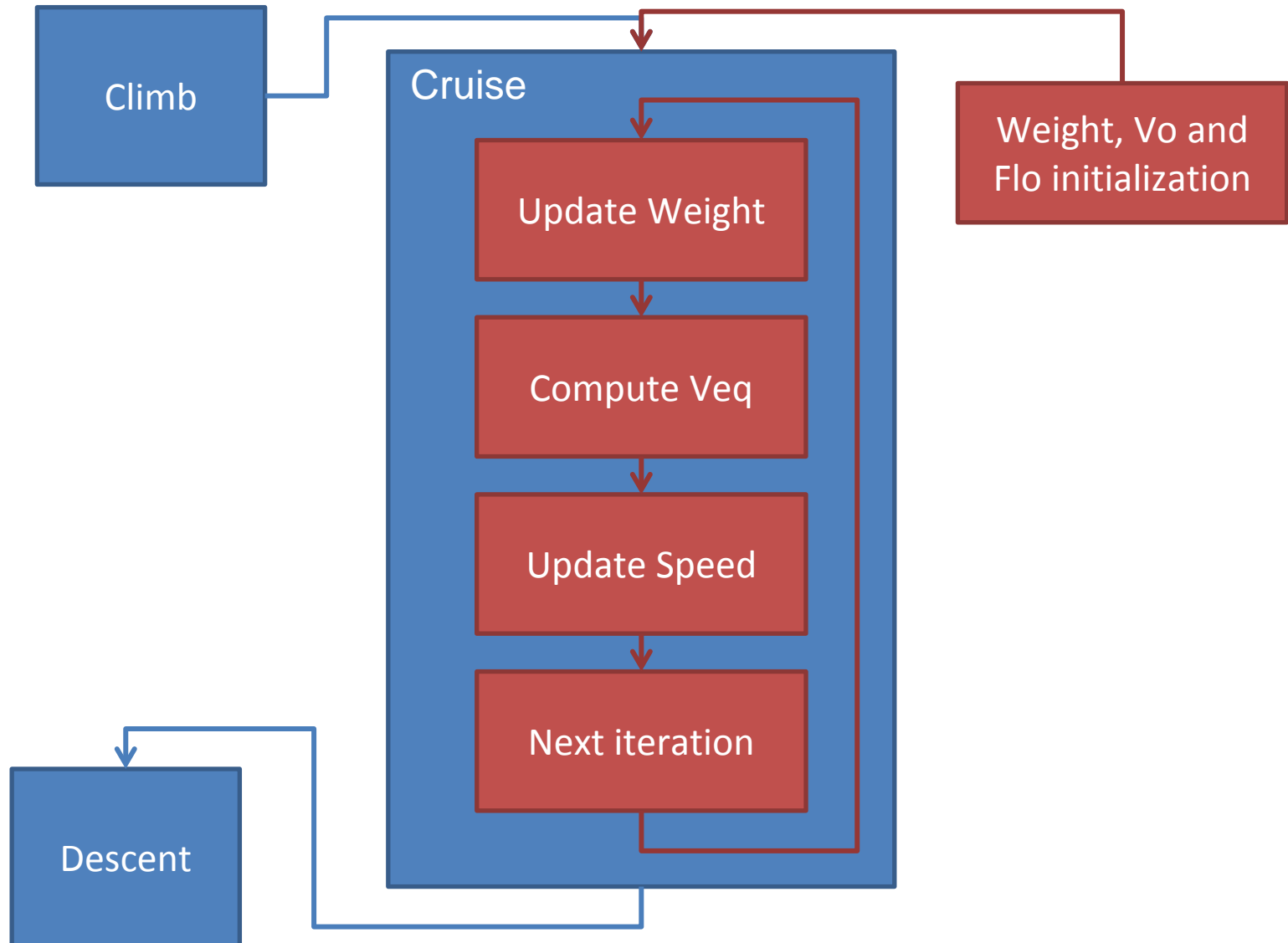


Aircraft in filter SFO



Aircraft in filter SFO

# Simulations



# Simulations



- **Data & Assumptions**
  - **Enhanced Traffic Management System (ETMS) data**
    - **August 24, 2005**
    - **Destination SFO**
    - **437 flights**

# Simulations



- **Data & Assumptions**
  - **Aircraft type assignment to equivalent Airbus types**

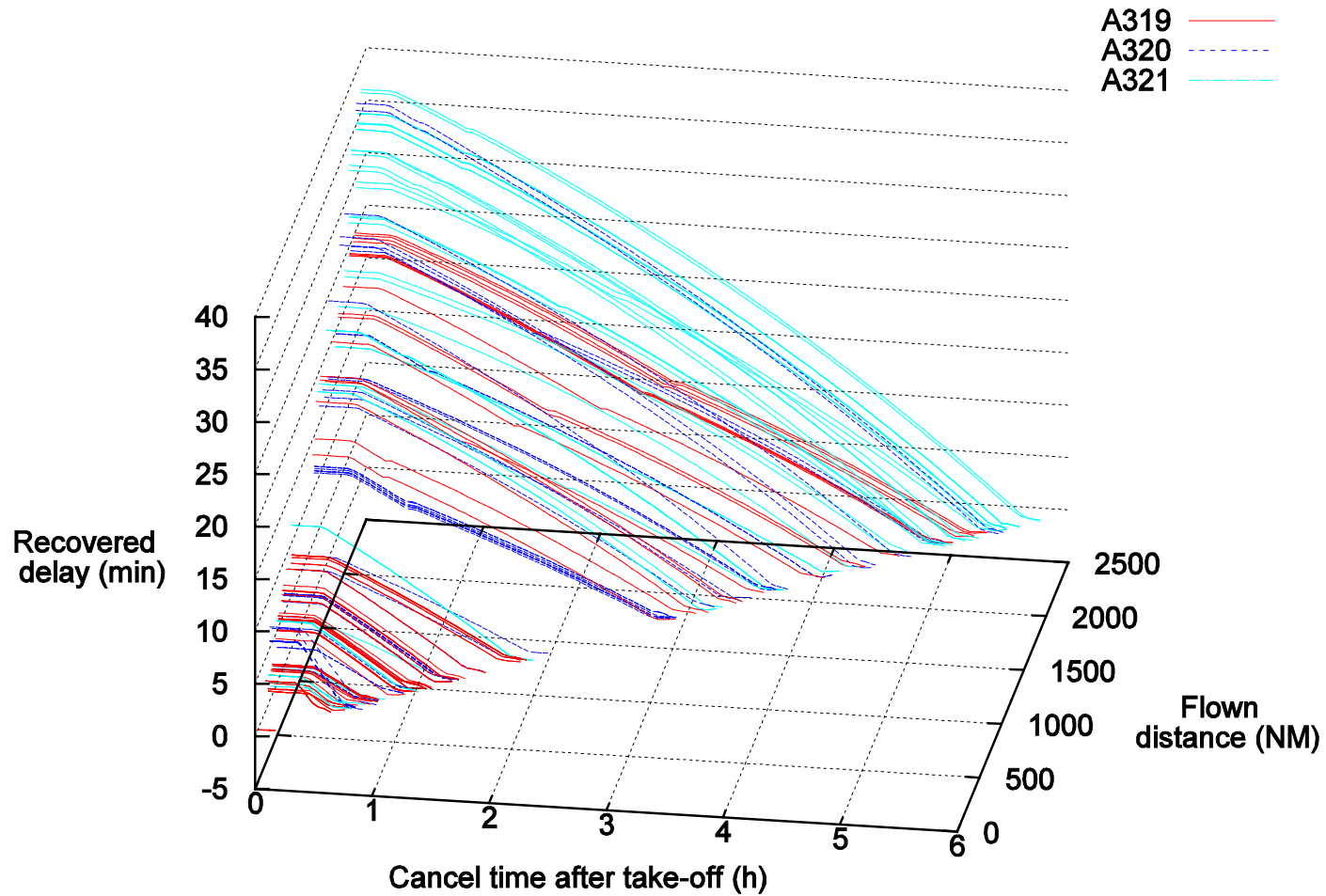
AC Family	AC Types
A300	A300, A310
A319	A319, B727, B737-200, DC-9, MD-90, E-147, CRJ-200, CRJ-700
A320	A20, B737-400, B737-500, B737-800, B737-900, MD-80
A321	A321, B757
A330	A330, B767, B777, DC-10
A340	A340, B747

# Simulations

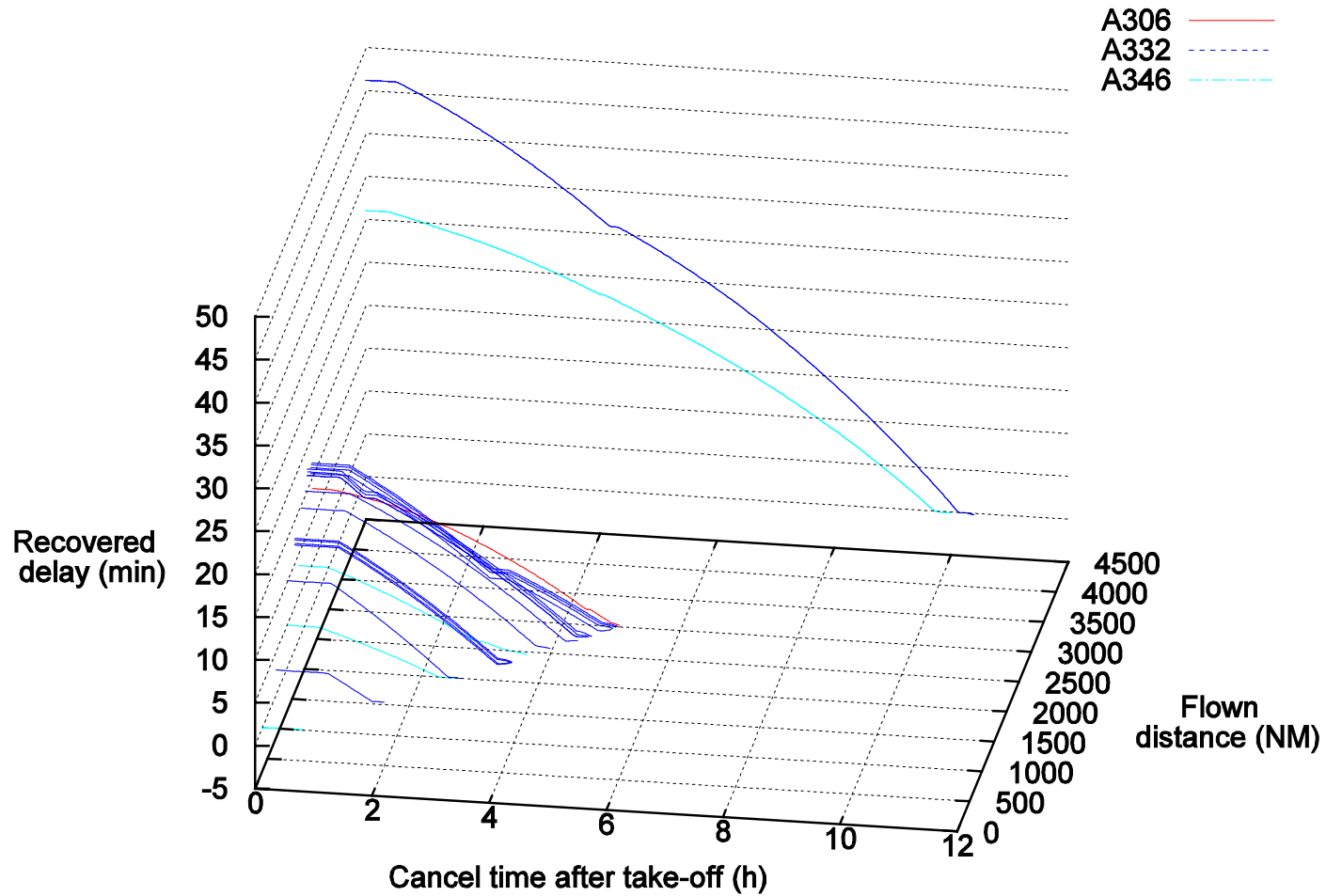


- **Data & Assumptions**
  - **Aircraft type assignment to equivalent Airbus types**
  - **CI 60 kg/min**
  - **80% load factor**

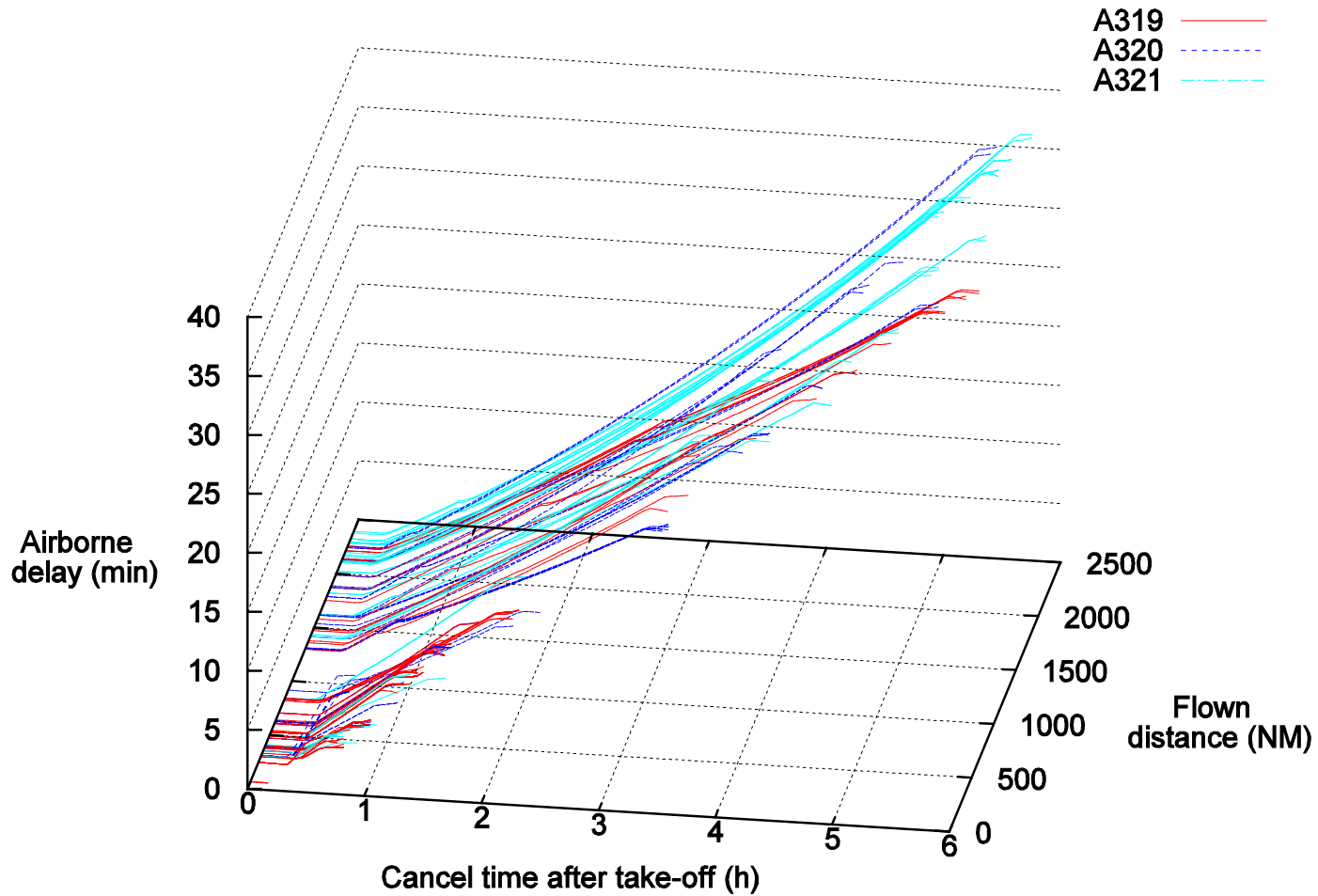
# Results



# Results

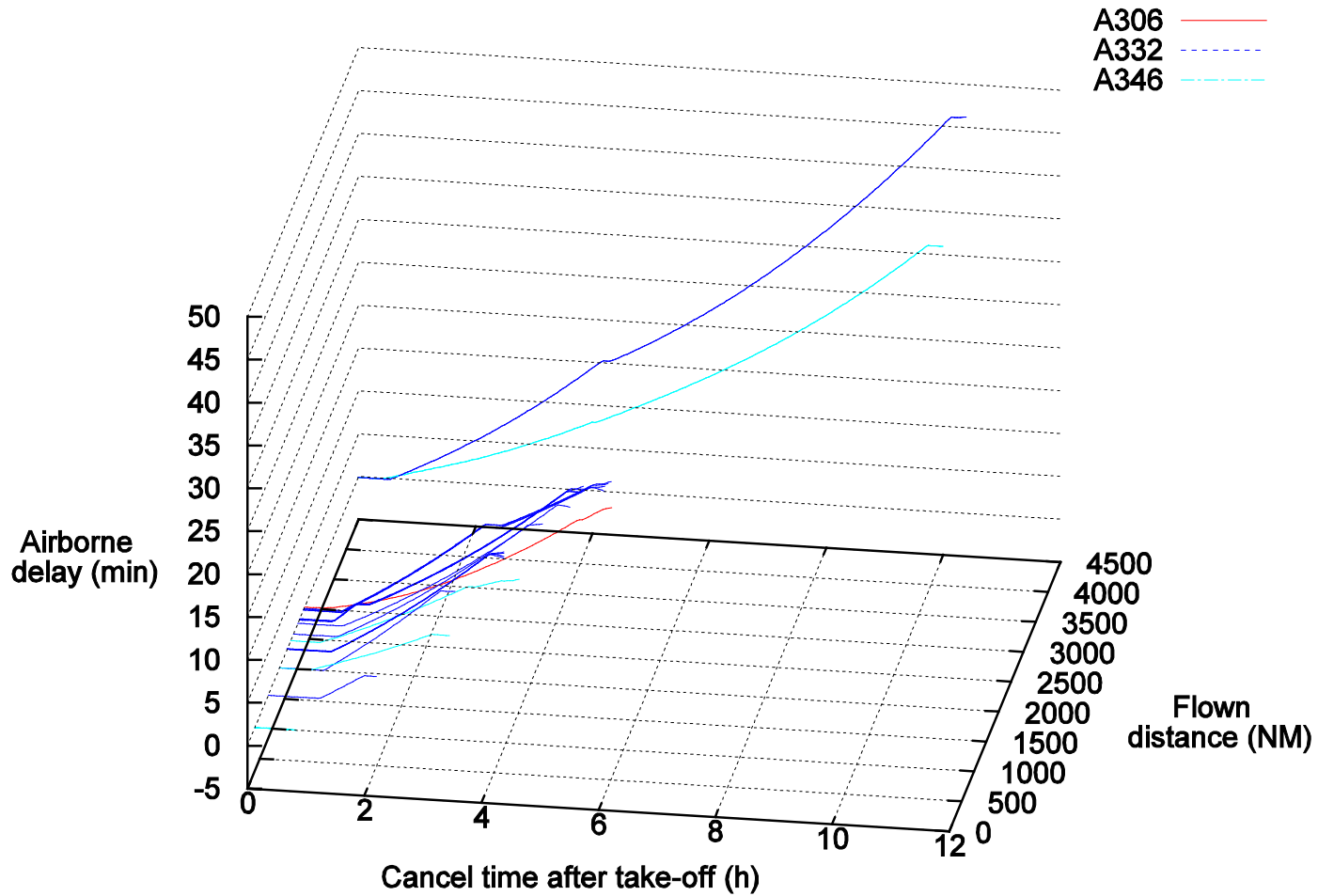


# Results





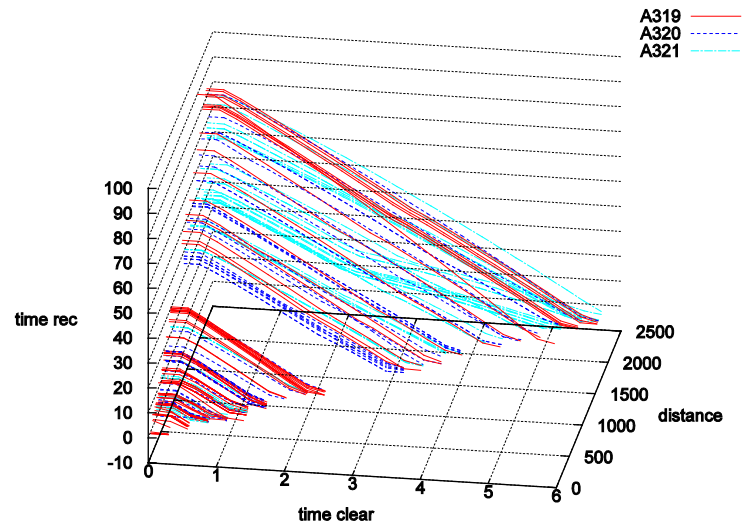
# Results



# Conclusions and Further work



- **Cruise speed reduction simulated with FACET**
- **Airborne delay and recovery time computed for each flight**
- **Results independent of destination**
  - **Dependence only on the flight characteristics**
- **Quite linear dependency on the parameters**
- **Potential feasibility for a fitting equation getting:**
  - **$Ad=f(acType,payload,distance,CI,cancelationTime)$**
  - **$Rd=f(acType,payload,distance,CI,cancelationTime)$**
- **Need for a sensibility study**
- **Apply this concept to a particular ground holding**



**Thank you!**