Dual Loop Data Correction at Microscopic Level

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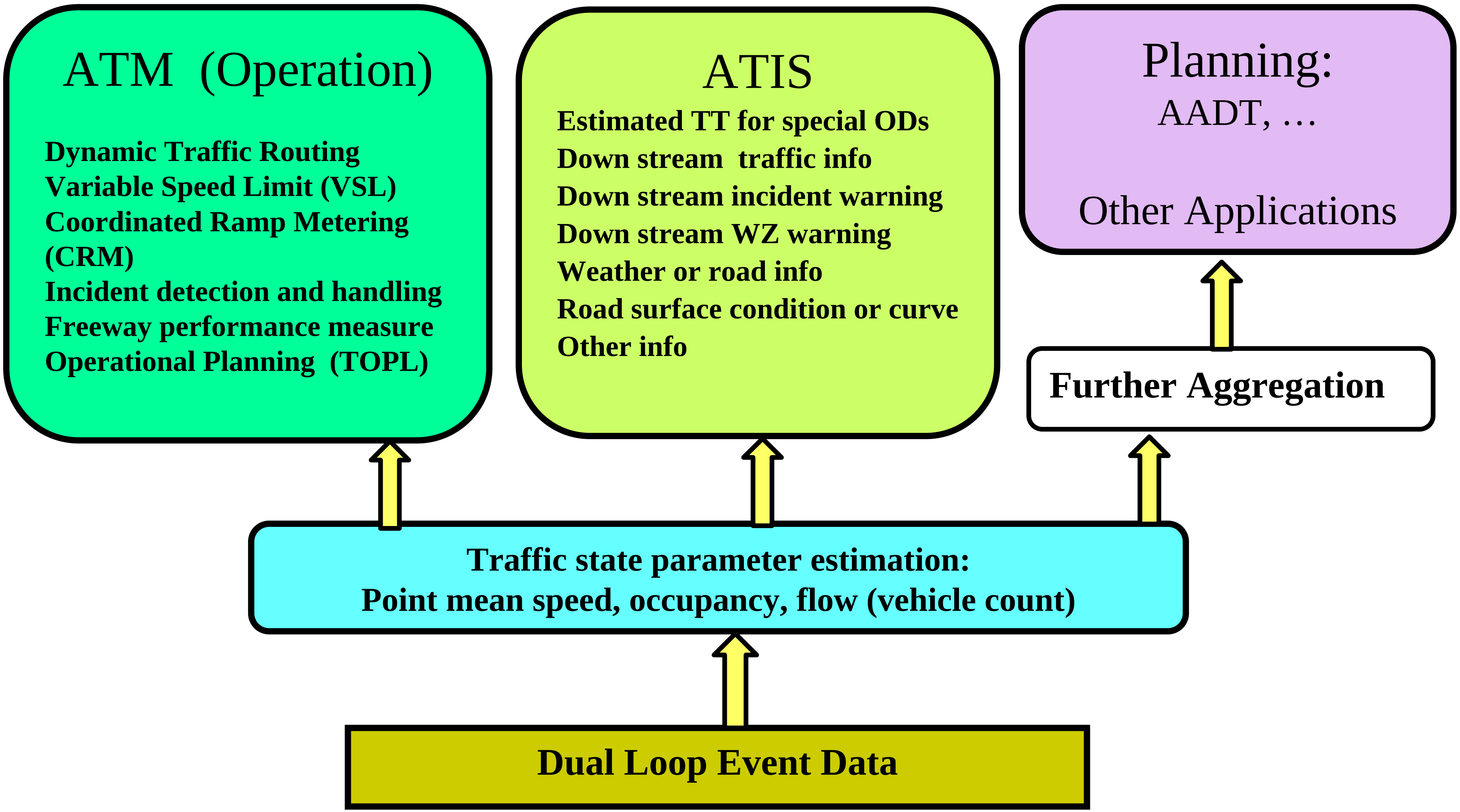
Xiao-Yun Lu, P. Varaiya, R. Horowitz
California PATH, U. C. Berkeley

J. Palen, Caltrans DRI

Outlines

- Why Data Correction in Microscopic Level?
- Brief Literature Review
- Advantage and Limit of Dual Loop Data Use
- Event Data System: Berkeley Highway Lab (BHL)
- Data Correction at Microscopic Level
- Concluding Remarks

Why Data Correction in Microscopic Level?



Why Data Correction in Microscopic Level?

- **All the data application relies on sensor data quality**
- **Event data are the closest data and lowest level data from the sensor**
- **Good event data satisfying the data requirement of all the levels**
- **Data correction in event data level**
  - **reduces data error in higher levels ➔Less burden in data processing**
  - **Better application parameter estimation**
  - **Saves resources significantly for all applications**
- **Systematic data correction need to be tightly coupled with systematic sensor fault detection**

Brief Literature Review

- **Petty, K., Small time scale analysis of the loop data, accessible at website: *ipa.eecs.berkeley.edu/~pettyk/FSP/HTML/.../small.output.ps.Z***
  - **First pointed out the problem of pulse mismatch between U-loop and D-loop in FSP study on I-880**
  - **No correction method proposed**

Brief Literature Review

- **Coifman, B., Using Dual Loop Speed Traps to Identify Detector Errors, 78th TRB Annual Meeting, Washington, DC., Jan. 1999**
  - **Provided some preliminary thought about how to match the upstream and downstream data streams into pairs;**
  - **For free flow traffic, the difference between on-times added to a running distribution for the given lane;**
  - **It recognized the difficulty of match the data when traffic is not in free-flow;**
  - **It pointed out that Cross-talk could be one reason caused such mismatch.**
  - **This work also proposed a very rough sketch but not in details as how to correct the dual loop station data;**

Brief Literature Review

- **Benjamin Coifman, Using Dual Loop Speed Traps to Identify Detector Errors, TRB Annual Meeting, Jan. 2009**
  - **Free-flow traffic assumed**
  - **Evaluating loop sensor units and detect crosstalk between sensors: (1) recording a large number of vehicle actuations during free flow traffic, (2) for each vehicle, matching actuations between the upstream and downstream loops in the given lane, (3) taking the difference between matched upstream and downstream on-times and examine the distribution on a lane-by-lane basis.**
  - **The method matches each downstream pulse to the most recent upstream pulse.**

Brief Literature Review

- Cheevarunothai, P., Wang, Y. and Nihan N.L. (2006). Identification and correction of dual-loop sensitivity problems, Transportation Research Record, No. 1945, 73-81.
  – algorithm identifies dual-loop sensitivity problems using individual vehicle data extracted from loop event data
    - (*a*) remove the sensitivity discrepancy between the two single loops
    - (*b*) adjust their sensitivities to the appropriate level
  – Features of vehicle length distribution are used to find the appropriate sensitivity levels.

Advantage and Limit of Dual Loop Data Use

- **Event Data**
  - Speed trap: good speed estimation if sensitivity levels are the same for two
  - Redundant flow or vehicle count
  - could be used to detect fault of the other such as pulse break and cross-talk, but again, they are sensitivity dependent – it should be set high enough;

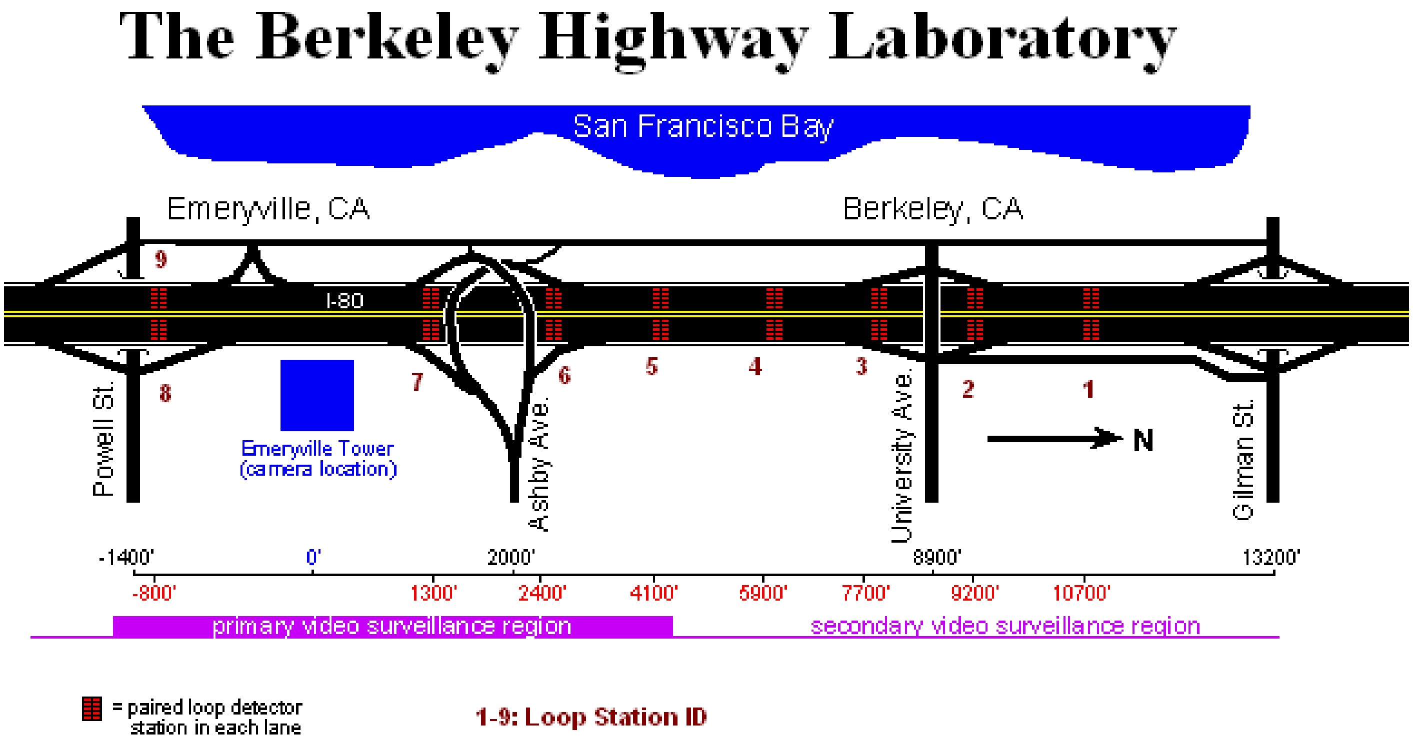
- **Limit: Occupancy and the Effective Vehicle Length depend on**
  - Sensitivity of the detector card
  - Chassis shape facing the ground;
  - The height to the ground

- **Algorithm here will not depend on vehicle length assumption**

Advantage and Limit of Dual Loop Data Use

- **30s Data**
  - Redundant flow or vehicle count
  - Cannot be used for speed estimation
  - Occupancy could chose the average of the two – no essential improvement
- **Dual Loop Information is not fully used if only 30s aggregated data available**
- **Event data passing to TMC is too much**
- **A Possible Solution:**
  - Collect data at a local data hub (control cabinet) and then send to TMC; the data hub could also be used for coordinated traffic control;
  - passing processed flow, speed and occupancy over 20s ~ 30s aggregation interval to TMC

Data System Examples: Berkeley Highway Lab (BHL)



Event Data System: Berkeley Highway Lab (BHL)

- **8 dual loop stations in two directions**
- **Station distance: 500~2100 [ft]**
- **Update rate 1s with 60Hz information for loop ON/OFF time instant**

Data Correction at Microscopic Level

- Thresholds and Bounds Determination
- Station On-Time
- Filtered Time Series Information
- Completing a Pulse (ON and OFF Time Pairs for Individual Loops)
- Correct Pulse Breaking for Individual Loops
- Correct Missing Pulse for U-loop and D-loop (Pairing dual loops)
- Preliminary Correct Sensitivity of U-loop and D-loop
- Secondary Correction of Sensitivity Problem

Thresholds and Bounds Determination

- **Bound check for individual loop: upper and lower bounds for pulse length**

$$T_{on}^{\min} \le T_{off}^{u} - T_{on}^{u} \le T_{on}^{\max}$$

$$T_{on}^{\min} \le T_{off}^{d} - T_{on}^{d} \le T_{on}^{\max}$$

$$L_{veh}^{\min} = 3m \le L_{veh} \le L_{veh}^{\max} = 18.5$$

$$L_{loop} = 6[ft] = 1.83[m]$$

$$L_{gap} = 26[ft] = 7.94[m]$$

$$V_{\max} = 70mph = 112.63[km/h] = 31.3[m/s]$$

$$V_{\min} = 5[mph] = 8[km/h] = 2.24[m/s]$$

$$T_{on}^{\min} = \left(L_{loop} + L_{veh}^{\min}\right)/V_{\max} = \left(3 + 1.83\right)/31.29 = 0.13[s]$$

$$T_{on}^{\max} = \left(L_{loop} + L_{veh}^{\max}\right)/V_{\min} = \left(18.5 + 1.83\right)/2.24 = 9.1[s]$$

Station On-Time

- **Bound check for whole dual loop station considered as a single loop**

$$T_{St}^{\min} \le T_{off}^{d} - T_{on}^{u} \le T_{St}^{\max}$$

$$T_{St}^{\min} = \left(2L_{loop} + L_{gap} + L_{veh}^{\min}\right)/V_{\max} = \left(2\times 1.83 + 7.94 + 3.0\right)/31.29 = 0.47[s]$$

$$T_{St}^{\max} = \left(2L_{loop} + L_{gap} + L_{veh}^{\max}\right)/V_{\min} = \left(2\times 1.83 + 7.94 + 18.5\right)/2.24 = 13.44[s]$$

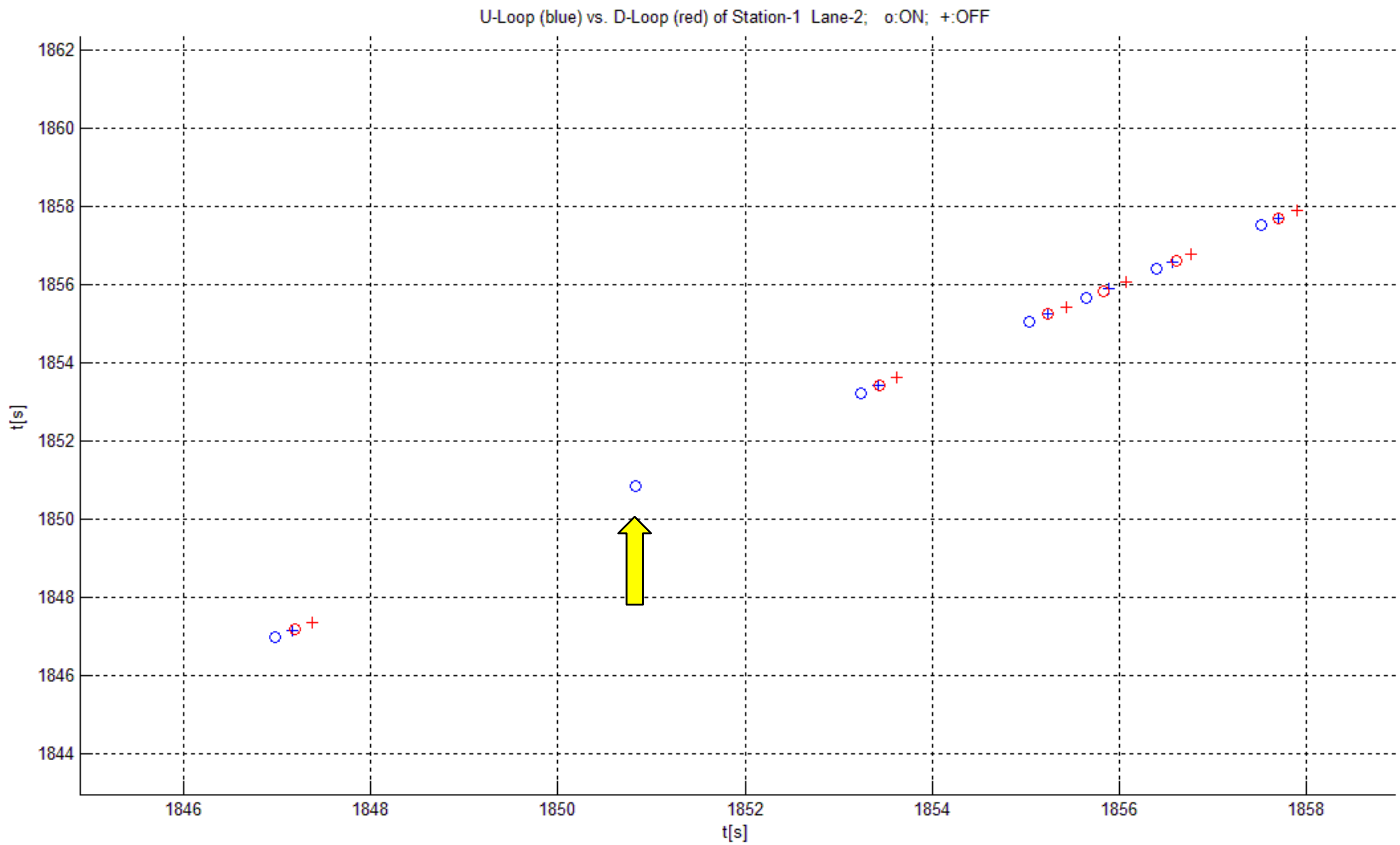
- **U-loop and D-loop Pulse Pairing Principle Two pulses satisfy this condition are considered potential pair; otherwise, the are not;**

Filtered Time Series Information

- **Filtered average pulse width**
- **Filtered difference of on-times between U-loop and D-loop**
- **Filtered average pulse gaps**
- **Filtered duration of a station: difference between U-loop on-time and D-loop off-time (on-time considering dual loops as a single loop)**
- **Simple recursive algorithm to save memory - only previous measures are used**
  - **Memory of past information diminished exponentially**
  - **Flexible in in parameter choice**
  - **Good for traffic state parameter estimation**
  - **Suitable for real-time processing**

Complete ON and OFF Time Pairs for Individual Loops

- **Conducting for U-loop and D-loop individually**
- **Condition for checking for incomplete pulse**
- **Persistence Test:**
  - **to Distinguish Temporary Fault and Persistent Fault**
  - **Less than 10%**
- **Method for completing the pulse**
  - **Using filtered pulse width**
  - **Either minus or plus pulse width**


U-Loop (blue) vs. D-Loop (red) of Station-1 Lane-2; o:ON; +:OFF
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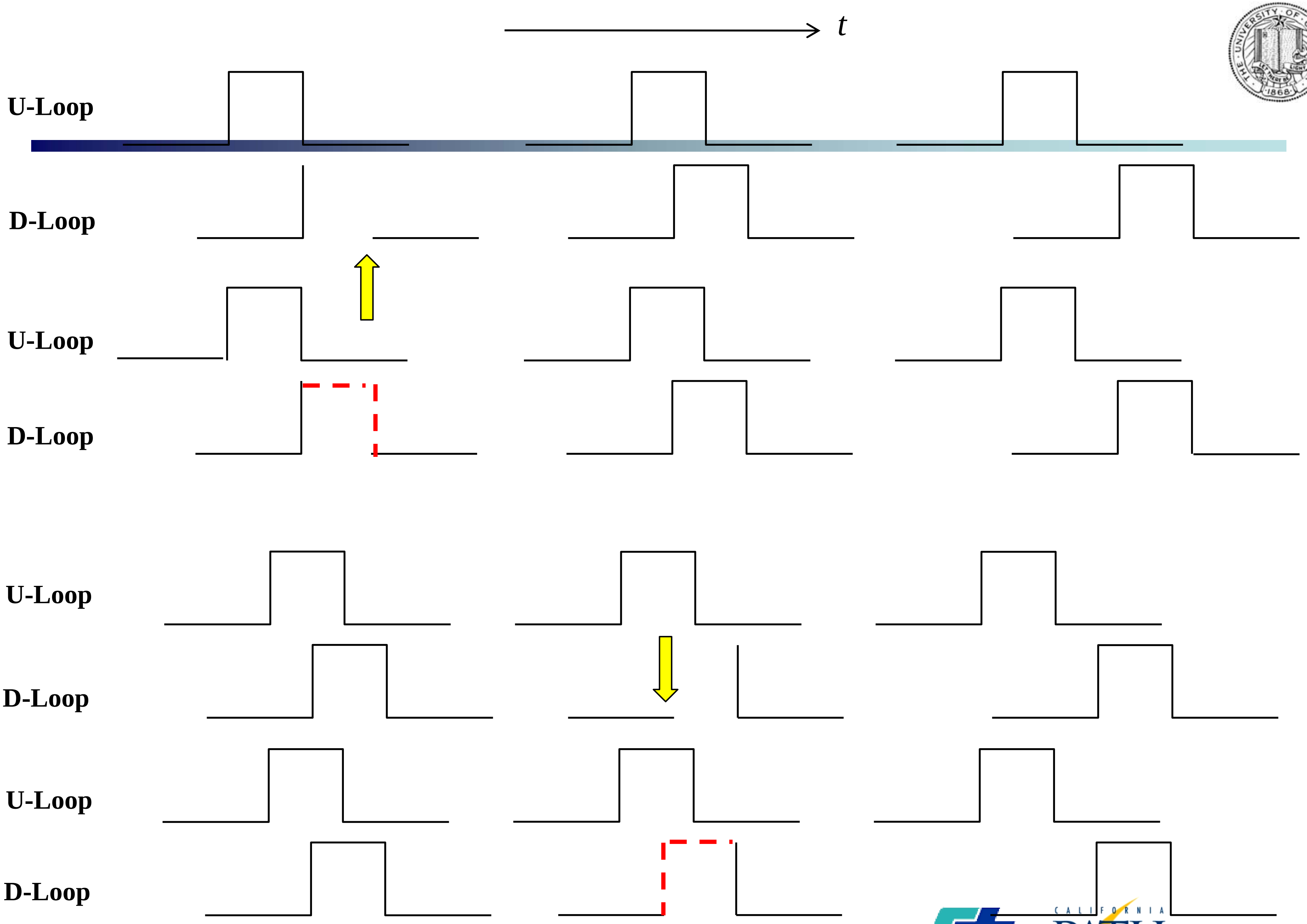
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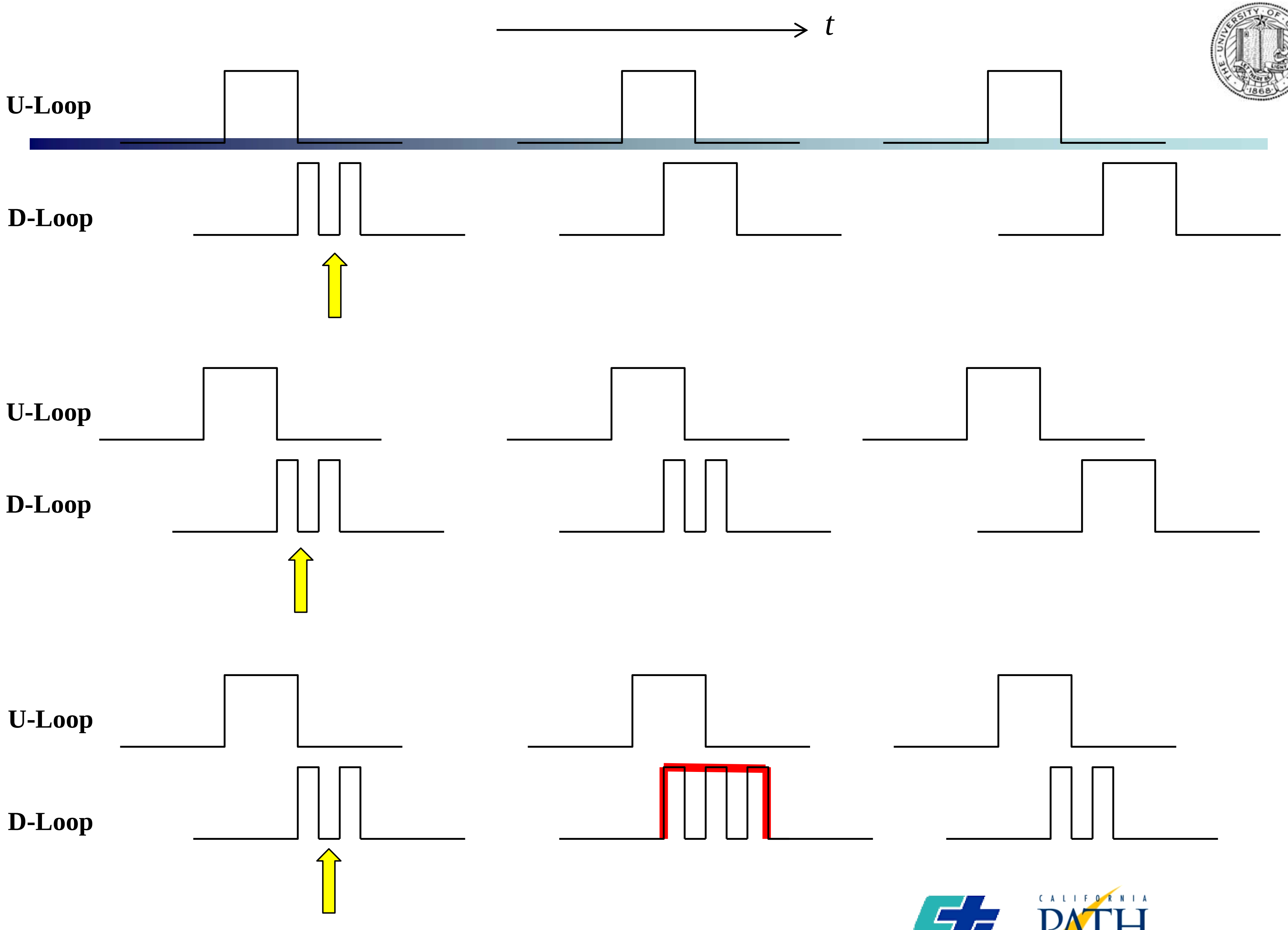
Correct Pulse Breaking for Individual Loops

- **Conducting for U-loop and D-loop individually**
- **Persistence Test:**
  - **To continuously monitor pulse break events**
  - **Using 10% as threshold to Distinguish Temporary Fault and Persistent Fault**
- **Using the following to find broken pulses and to determine an envelop**
  - **The minimum/maximum on-time and off-time bounds**
  - **The filtered previous pulse width**
  - **The filtered previous on-time length**
- **After this step, all the pulse are complete**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Correct Missing Pulse for Dual Loops

- **Conducting for U-loop and D-loop jointly**
- **Persistence Test:**
  - **to Distinguish Temporary Fault and Persistent Fault**
  - **Less than 10%**

- **Using the following info to pair U-loop and D-loop pulses**
  - **The minimum/maximum on-time and off-time bounds**
  - **The filtered previous pulse width of the other loop**
  - **The filtered previous on-time length**
  - **The on-time length of the other loop in the dual loop station (a coupled approach)**
  - **If both are empty, it not considered as pulse missing**

Correct Missing Pulse for Dual Loops

- **Not a problem for speed estimation**
- **Low percentage missing might be caused by lane changing ➔ Potential over counting**
- **To avoid over counting, checking the percentage of pulse missing in flow estimation**
- **After 3 three steps above:**
  - **All the pulses are complete: with On and OFF times;**
  - **Pulse breaking are corrected;**
  - **Most pairs of U-loop and D-loop are paired;**
- **Using previous estimated parameters to establish conditions for checking missing pulses**

Checking Missing Pulse for Either Loop

- **Condition 1: for checking missing pulse**
  - **If**

$$T_{on}^{u}\left(k\right)-T_{on}^{u}\left(k-1\right)>T_{on}^{d}\left(k\right)-T_{on}^{d}\left(k-1\right)+\Delta_{pls}$$

$$T_{off}^{d}\left(k\right)-T_{on}^{u}\left(k\right)>T_{St}^{\max}$$

➔ U-loop missing a pulse

  - **If**

$$T_{on}^{d}\left(k\right)-T_{on}^{d}\left(k-1\right)>T_{on}^{u}\left(k\right)-T_{on}^{u}\left(k-1\right)+\Delta_{pls}$$

$$T_{off}^{d}\left(k\right)-T_{on}^{u}\left(k\right)>T_{St}^{\max}$$

➔ D-loop missing a pulse

$\Delta_{pls}>0$ **- time threshold for pulse missing**

Checking Missing Pulse for Either Loop

- **Condition 2: for checking missing pulse**
  - **If**

$$T_{on}^{u}(k)-T_{on}^{u}(k-1)>\beta\left(T_{on}^{d}(k)-T_{on}^{d}(k-1)\right)$$
$$T_{off}^{d}(k)-T_{on}^{u}(k)>T_{St}^{\max}$$

➔ **U-loop missing a pulse**

  - **If**

$$T_{on}^{d}(k)-T_{on}^{d}(k-1)>\beta\left(T_{on}^{u}(k)-T_{on}^{u}(k-1)\right)$$
$$T_{off}^{d}(k)-T_{on}^{u}(k)>T_{St}^{\max}$$

➔ **D-loop missing a pulse**

- $\beta -$ **parameter to be calibrated**

Filtered time sequence information

- **Condition 3: for checking missing pulse**
  - **If**

$$T_{on}^{d}(k) < T_{on}^{u}(k)$$

$$T_{on}^{d}(k) > T_{on}^{u}(k-2)$$

$$T_{off}^{u}(k-1) < T_{on}^{d}(k) - \Delta_{on}^{u}(k-1) - \Delta_{gap}$$

➔ Insert a missed pulse for U-loop data series

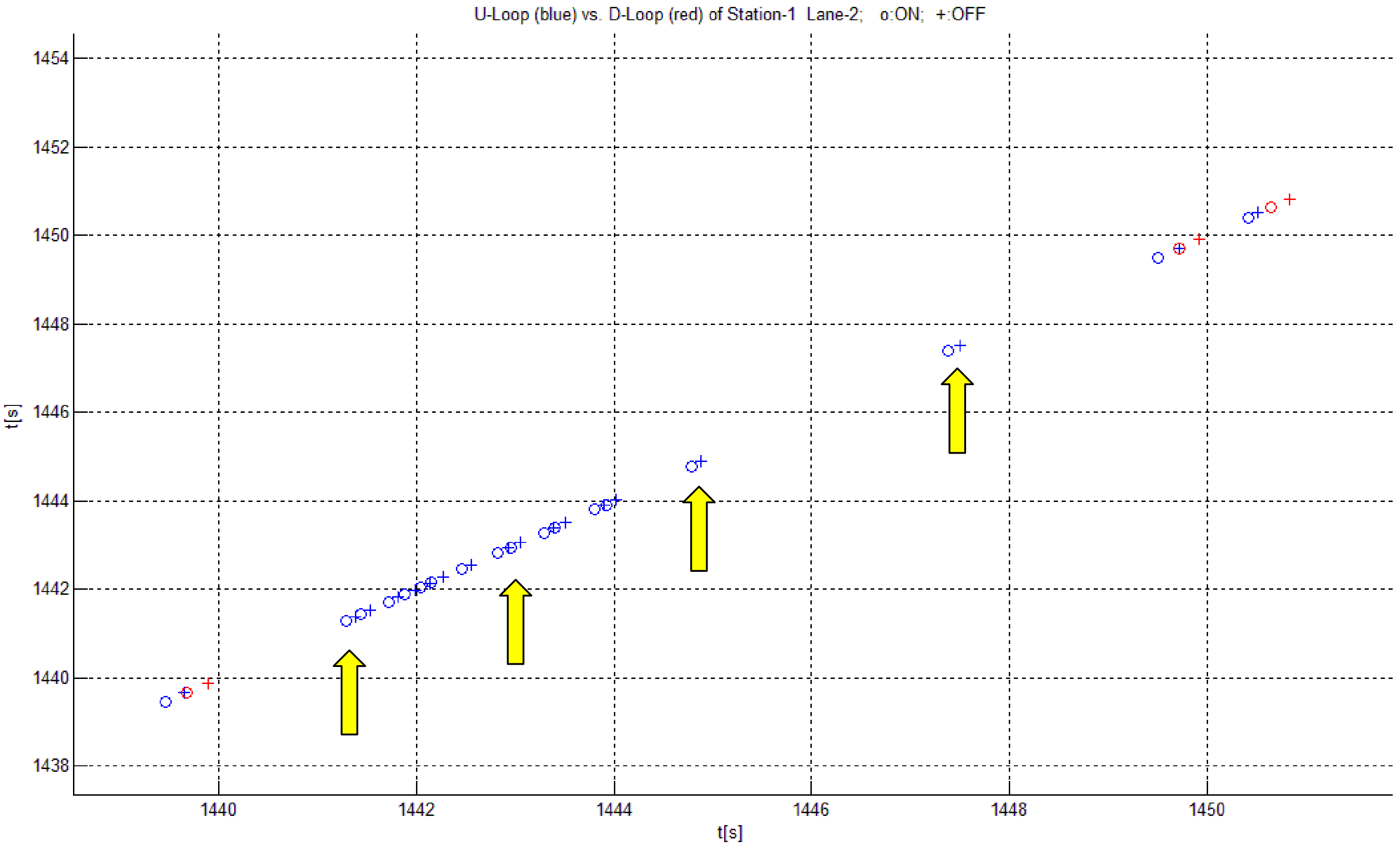
Checking Missing Pulse for Either Loop

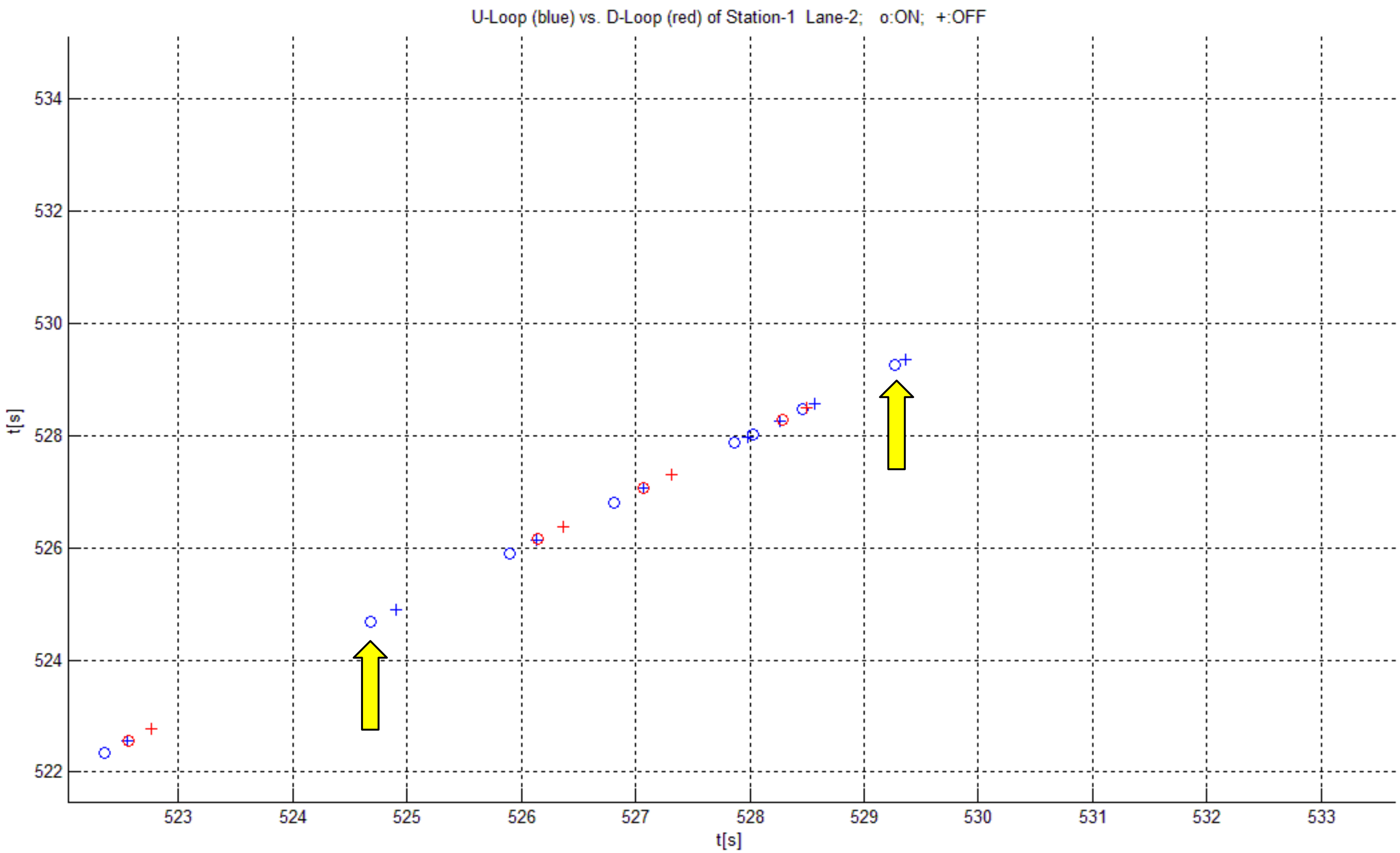
– **If**

$$T_{on}^{d}(k) > T_{on}^{u}(k)$$
$$T_{off}^{d}(k) - T_{on}^{u}(k) > \Delta_{on}^{st}(k-1)$$
$$T_{off}^{u}(k) + \Delta_{on}(k-1) + \Delta_{gap} < T_{St}^{\max}$$

➔ **Insert a missed pulse to D-loop data series**

D-loop Pulse Missing for a Period of Time





U-Loop (blue) vs. D-Loop (red) of Station-1 Lane-2; o:ON; +:OFF
534
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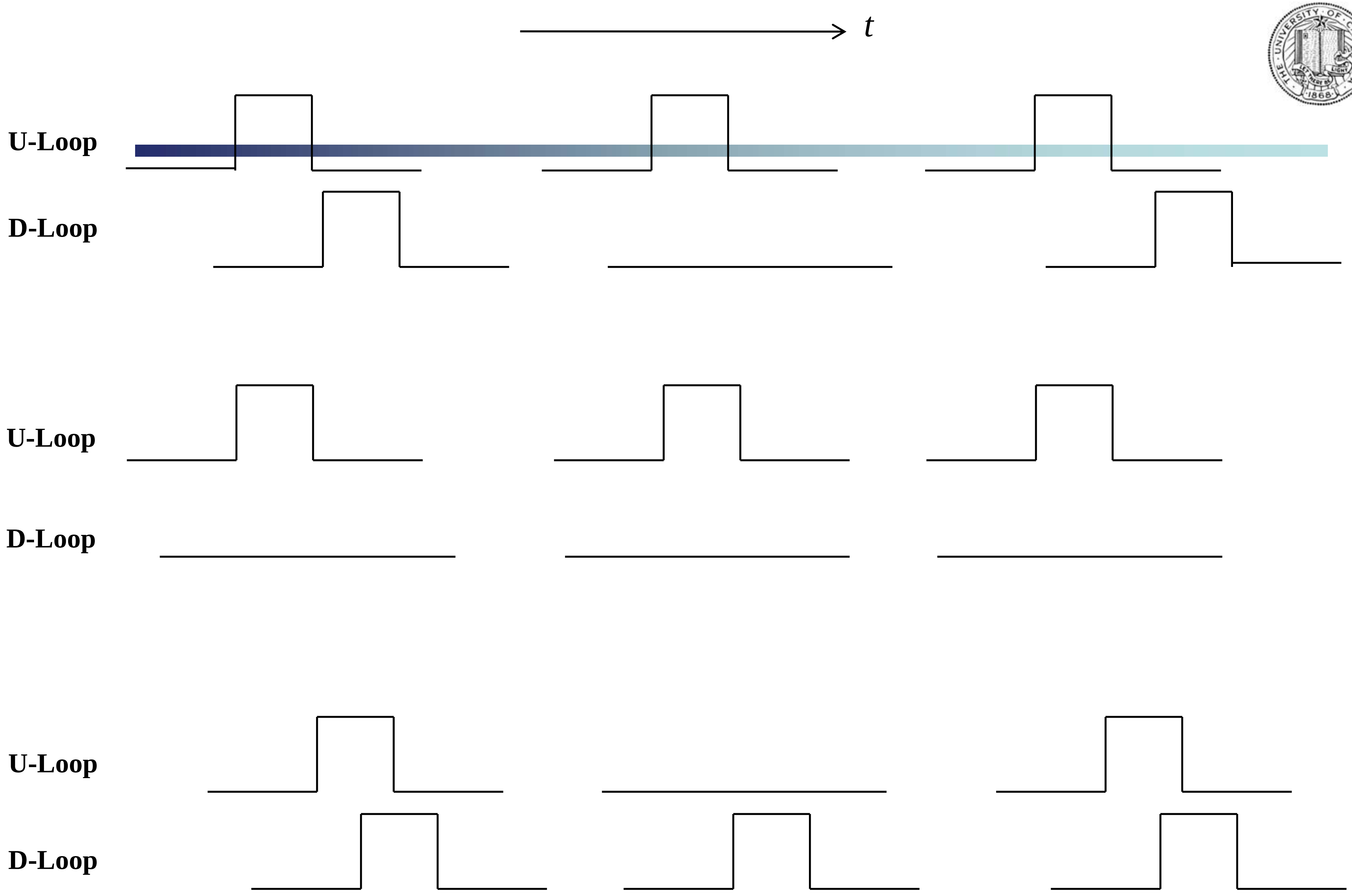
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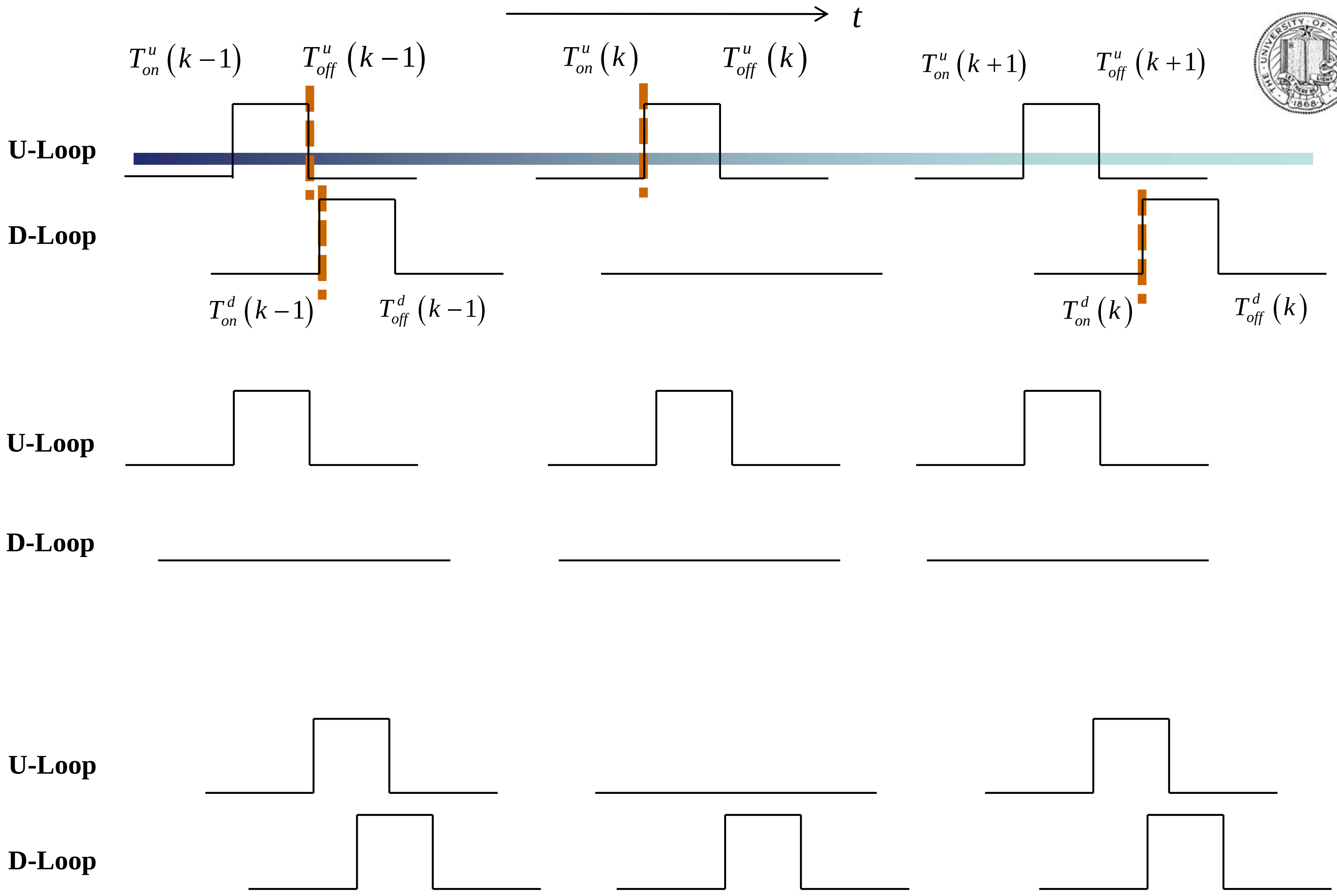
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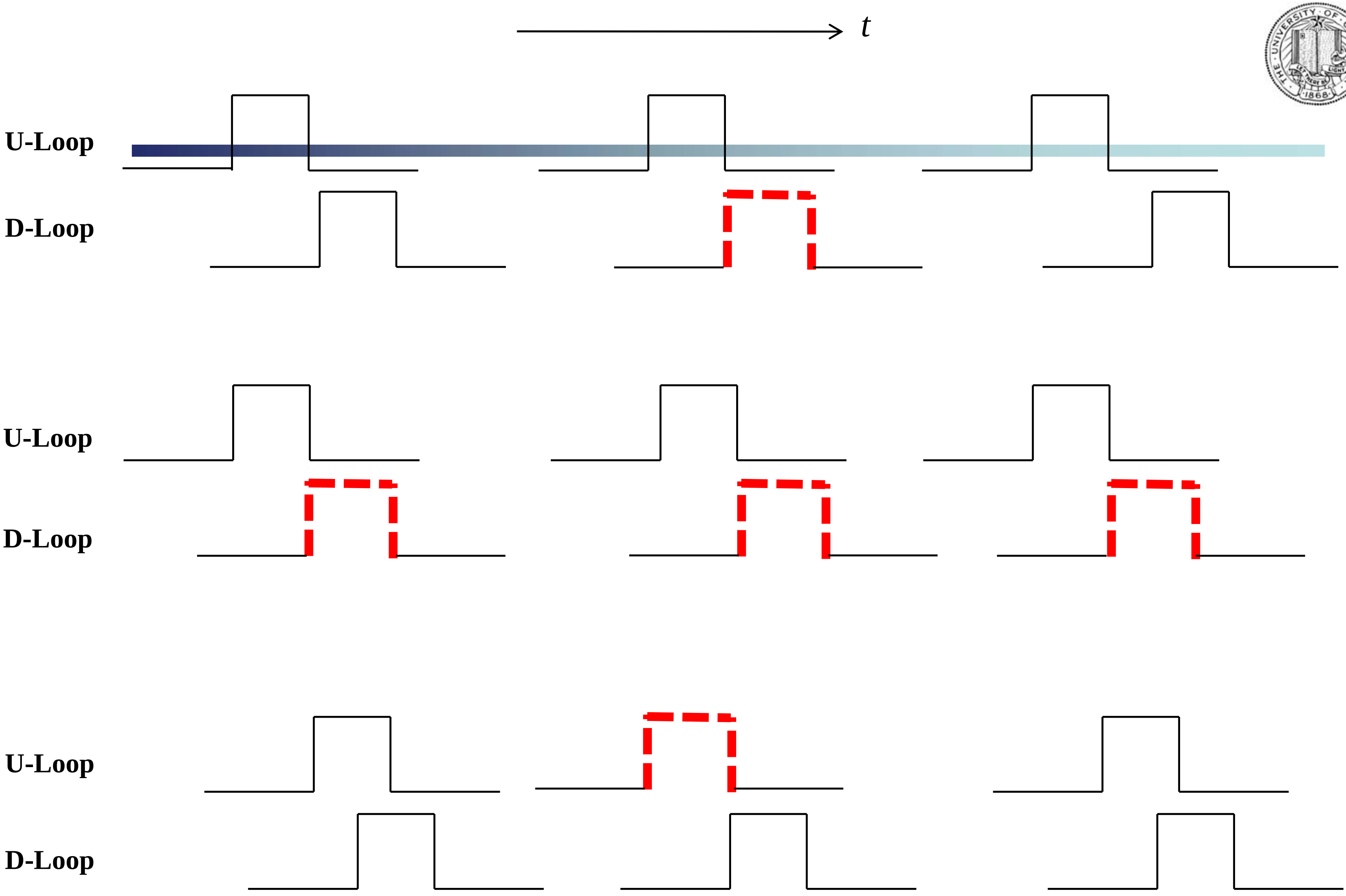
$T^u_{on}(k-1)$
$T^u_{off}(k-1)$
$T^u_{on}(k)$
$T^u_{off}(k)$
$T^u_{on}(k+1)$
$T^u_{off}(k+1)$
U-Loop
D-Loop
$T^d_{on}(k-1)$
$T^d_{off}(k-1)$
$T^d_{on}(k)$
$T^d_{off}(k)$
U-Loop
D-Loop
U-Loop
D-Loop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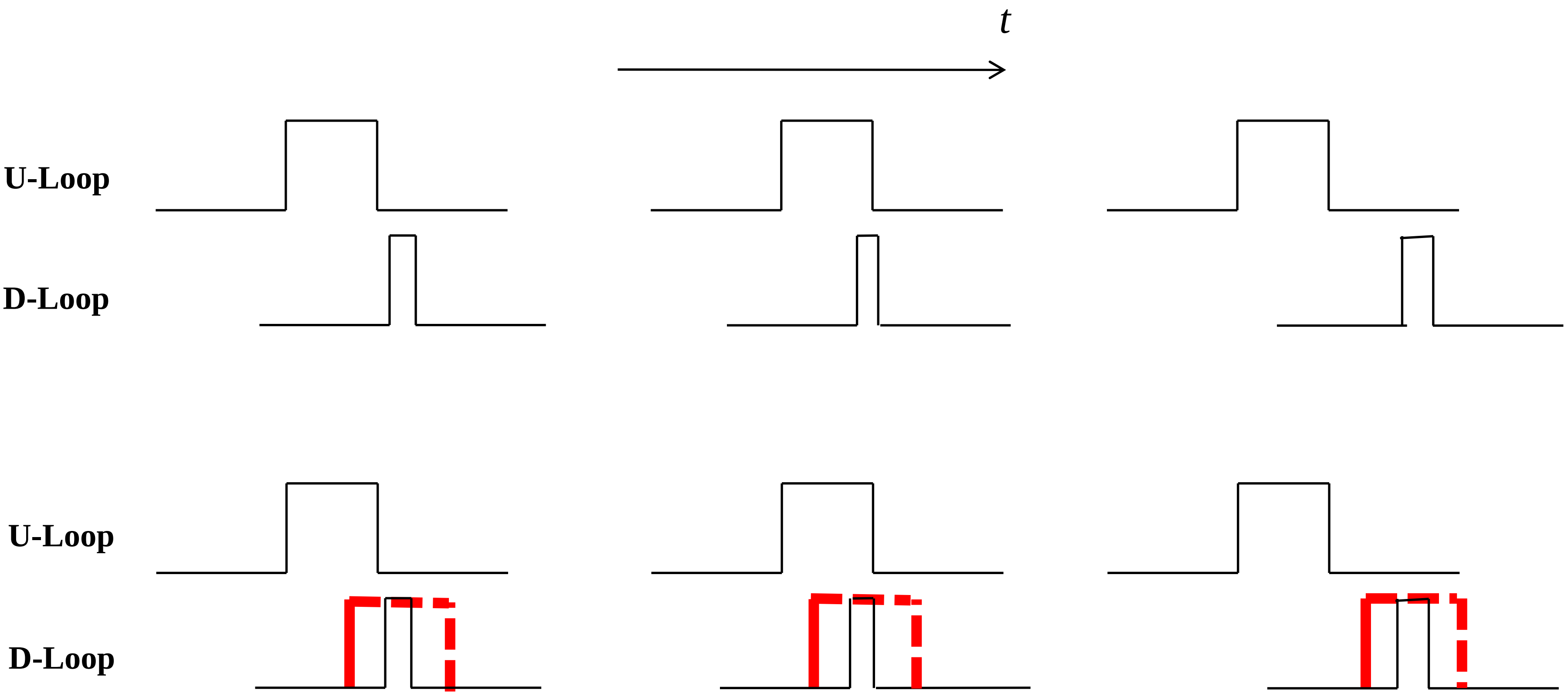
U-Loop
D-Loop

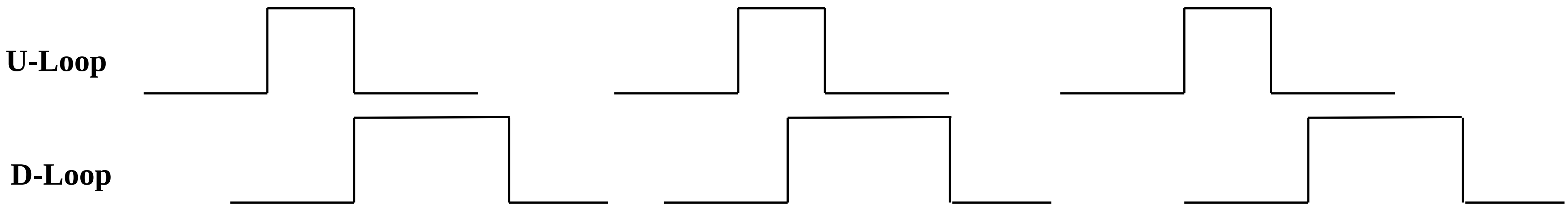
Preliminary Correct Sensitivity Problem

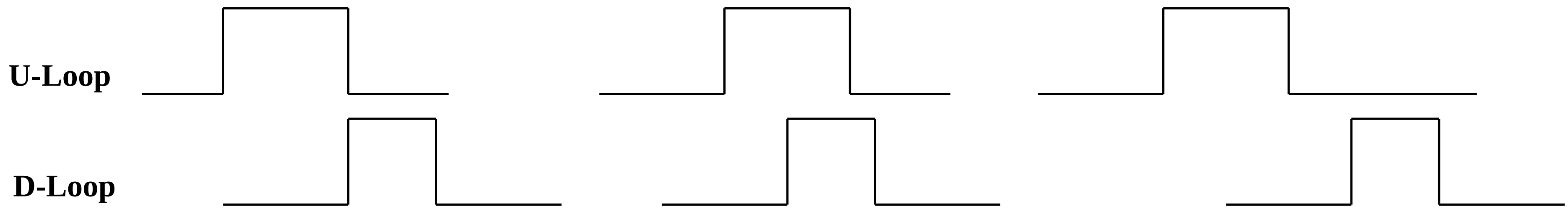
- **Objective:** To match the sensitivity level of two loops
- Same sensitivity level (high enough) for both U-loop and D-loop will produce good speed estimation, but not necessarily occupancy
- Good occupancy (density) estimation requires proper sensitivity for both loops
- If one of them (but not both) is Too High or Too Low

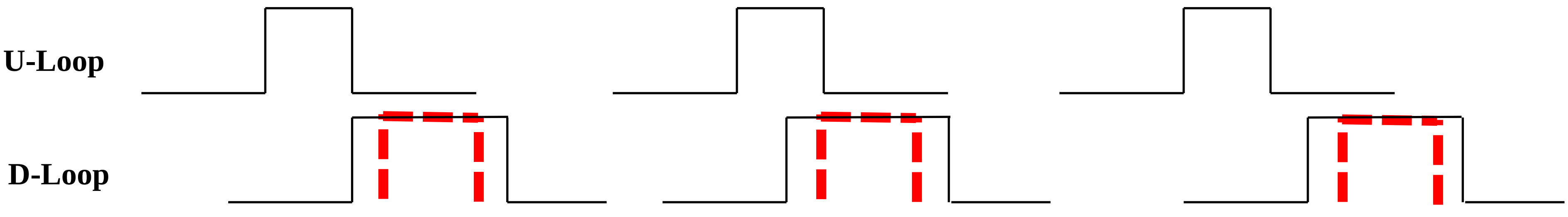
Too Low



Too High



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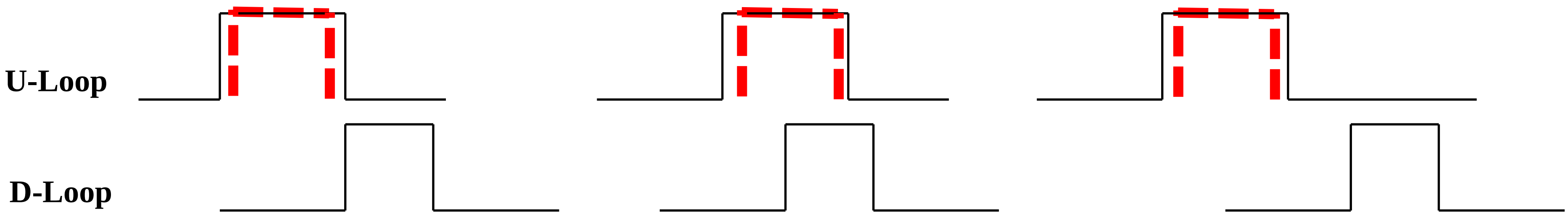
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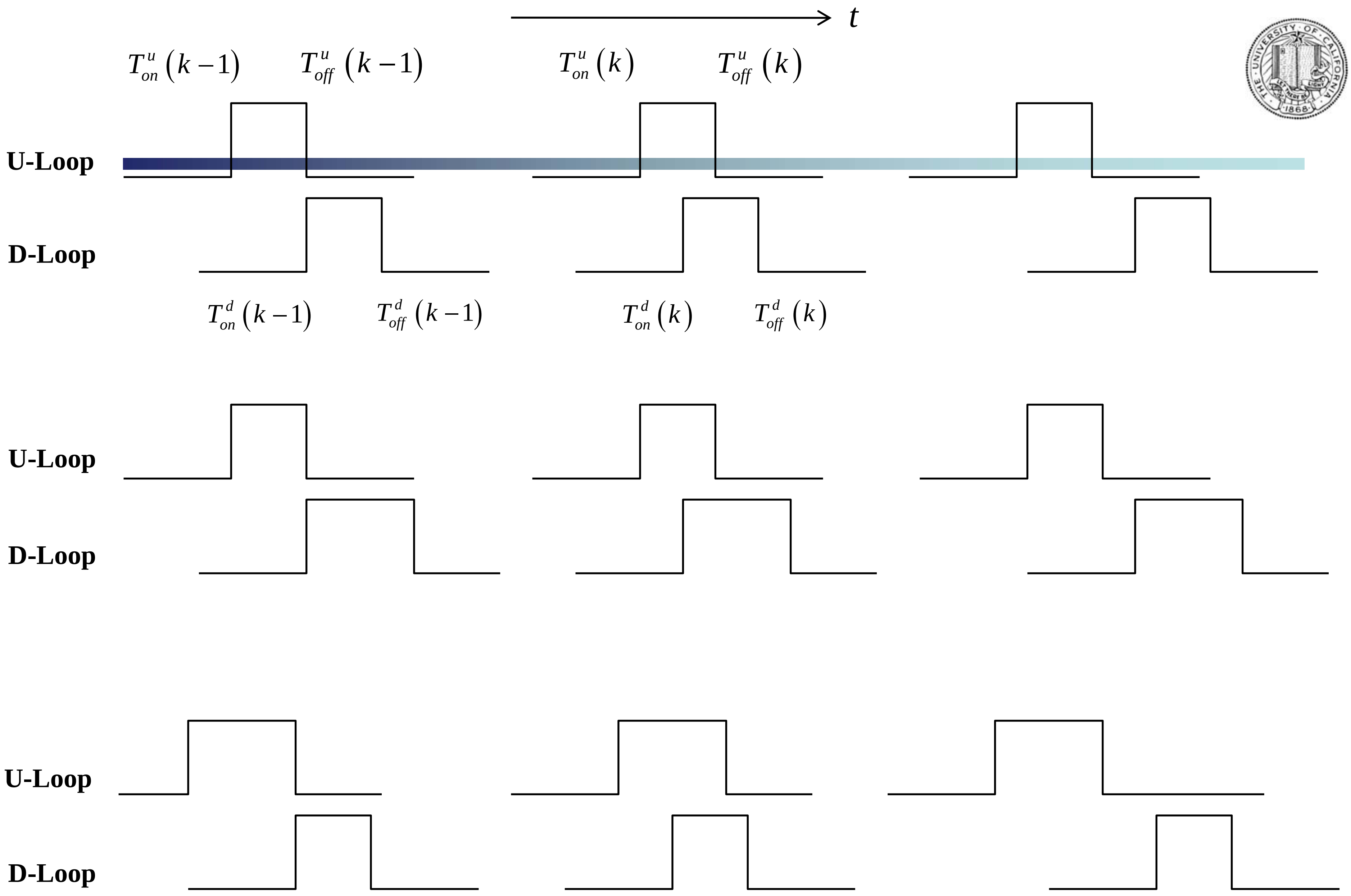
D-Loop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$T_{on}^{d}(k-1)$
$T_{off}^{d}(k-1)$
$T_{on}^{d}(k)$
$T_{off}^{d}(k)$
U-Loop
D-Loop
U-Loop
D-Loop

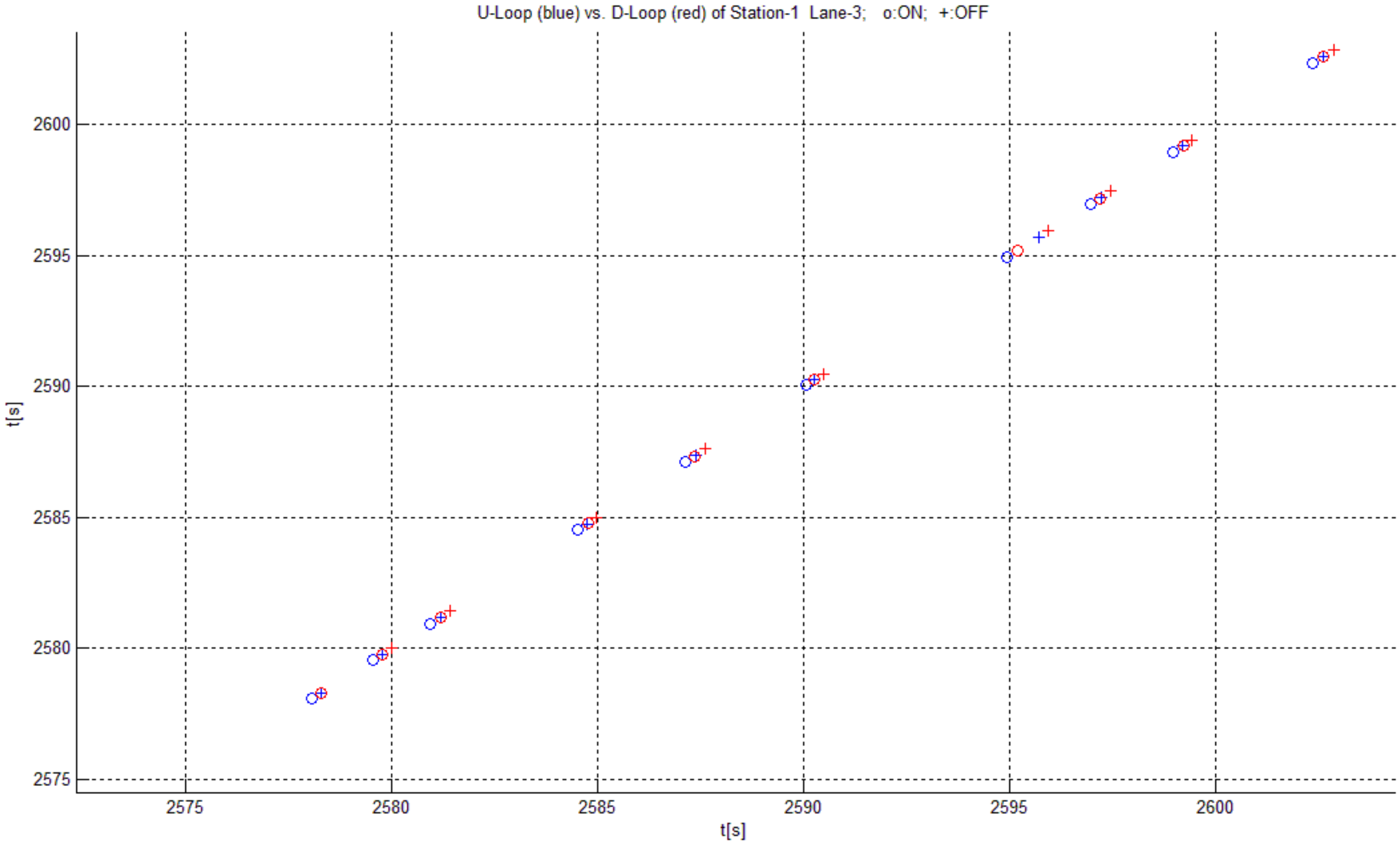
Refined Correct of Sensitivity

- **Using speed information**

- **Estimating average vehicle length in free-flow traffic hours**
  - **Speed has good estimation**
  - **Regulate Pulse width:**
    - **Drop pulses with too large and too small occupancy**
    - **Filtering pulse width with exponential filter**
  - **Estimate vehicle length based on speed and filtered occupancy**

- **Persistence test**

- **Refined Correction of Sensitivity**
  - **Determine sensitivity correction factor**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t[s]
t[s]
2575
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Concluding Remarks

- All the data application relies on sensor data quality
- Event data are the closest and lowest level data from the sensor
- Data correction in event data level reduces data error in higher levels
- Data correction for temporary faults
  - In-complete pulse
  - Pulse breaking
  - Missing pulse
  - Sensitivity (2 steps)
- Using filtered time series information with exponential filter
- Algorithm are simple suitable for achieved data and real-time processing
- After data correction, traffic state parameter estimation is straightforward
- Sensitivity correction is still underway

Thank You!

Please send questions and comments to: ***xylu@path.berkeley.edu***