ATSPM and Signal Timing RFP Follow-up Topics and Questions:

- Product Overview and Workflow Demonstration:

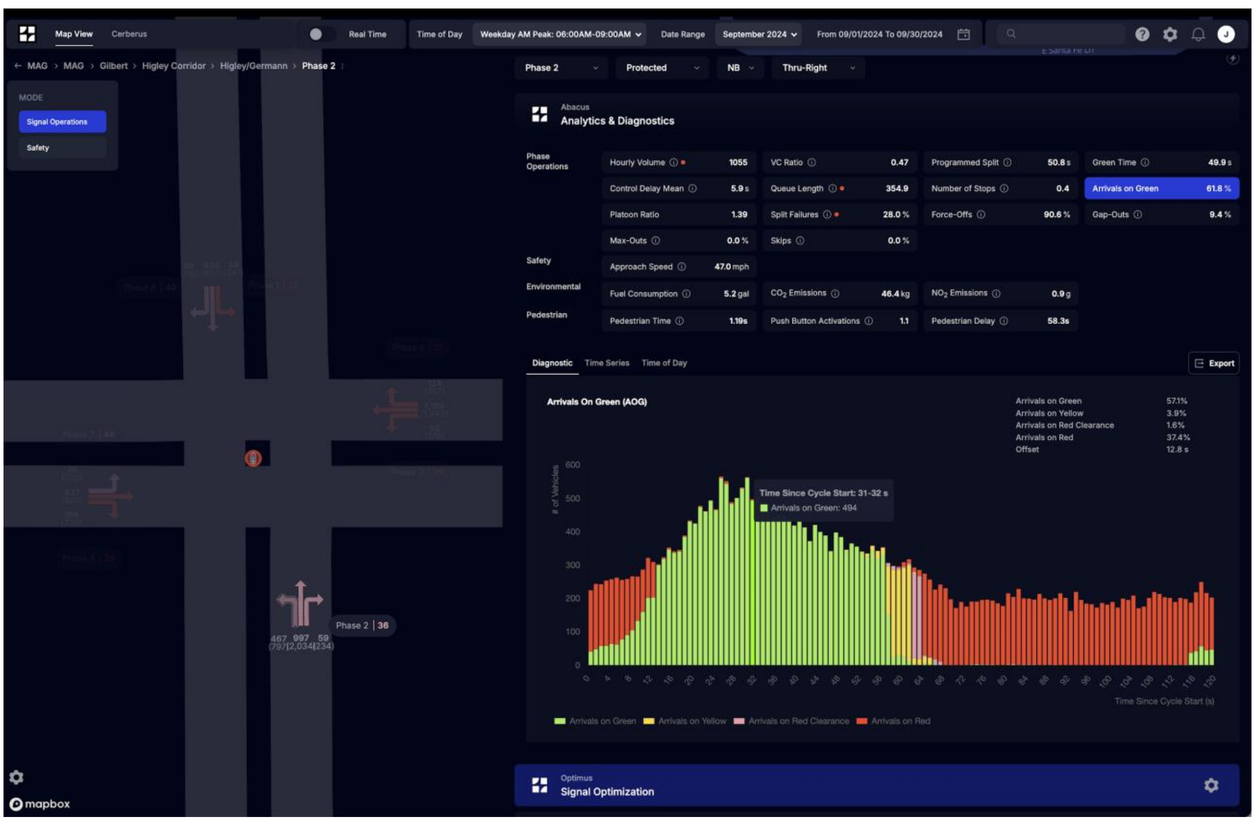
1. Please briefly show us your ATSPM and Signal Timing user interfaces and quickly do a broad overview of the process for typical workflow when evaluating and making signal timing changes. For example, you might show us how we would access the signal timing adjustment recommendations, check that the recommendations are logical, and finally steps to incorporate that timing into the controllers on the street.

Typical Workflow: Evaluating and Implementing Timing Adjustments

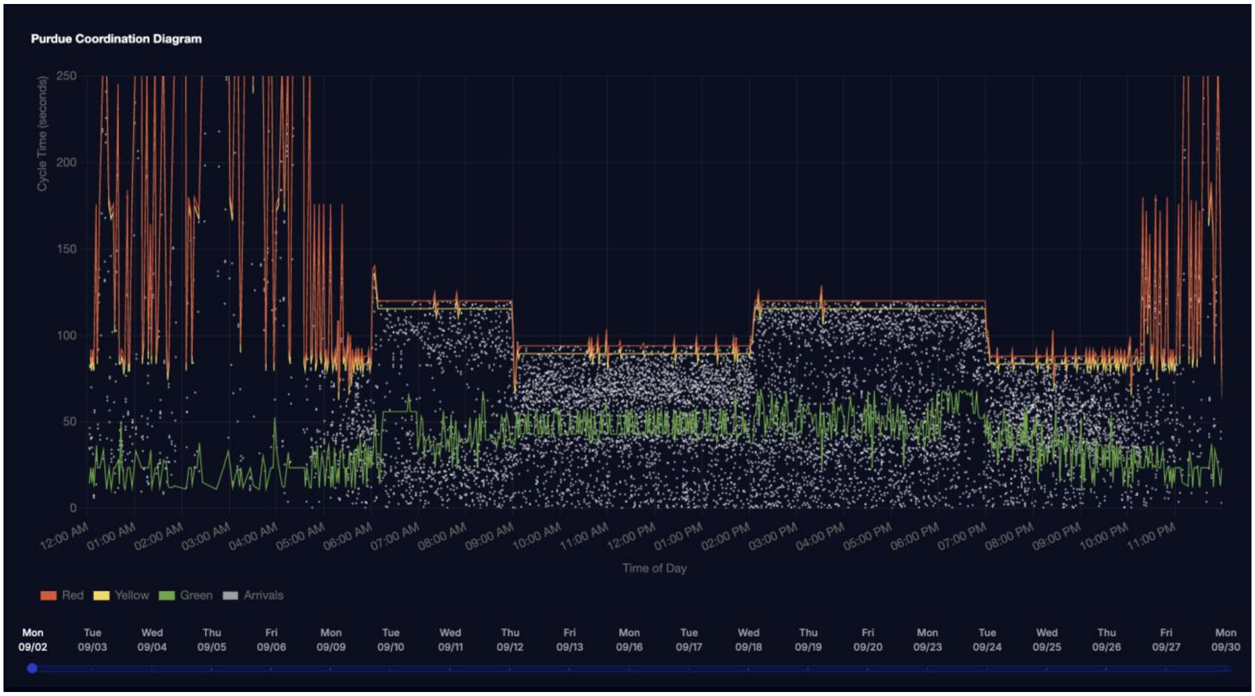
1. **Identify and Diagnose Issues (Luminus Plus)**
   - Engineers begin in Luminus Plus, where dashboards display key metrics such as delay, arrivals on green, split failures, and queue length.
   - Corridors or intersections with degraded performance are automatically flagged through the Cerberus health monitoring system.
   - Users can drill down into Purdue Coordination Diagrams, Phase Termination Charts, or Split Monitors to identify root causes of poor coordination or excessive delay.
2. **Generate Recommendations (Optimus)**
   - From the identified location, the engineer launches Optimus directly from within the same interface.
   - Optimus automatically ingests the existing MaxTime parameters (cycle lengths, splits, offsets, coordination settings) from Luminus Plus and uses those as constraints for optimization.
   - With a single click, the engineer generates an optimized timing plan. Optimus displays a complete timing table along with predicted outcomes such as improvements in travel time, arrivals on green, and intersection delay.
3. **Engineer Review and Validation**
   - All recommendations are fully transparent—no black-box automation.

- Engineers can review and adjust plan parameters directly in the interface using intuitive sliders and editable tables.
- Time-space diagrams and before-after comparisons visualize how progression and coordination improve across the corridor before deployment.

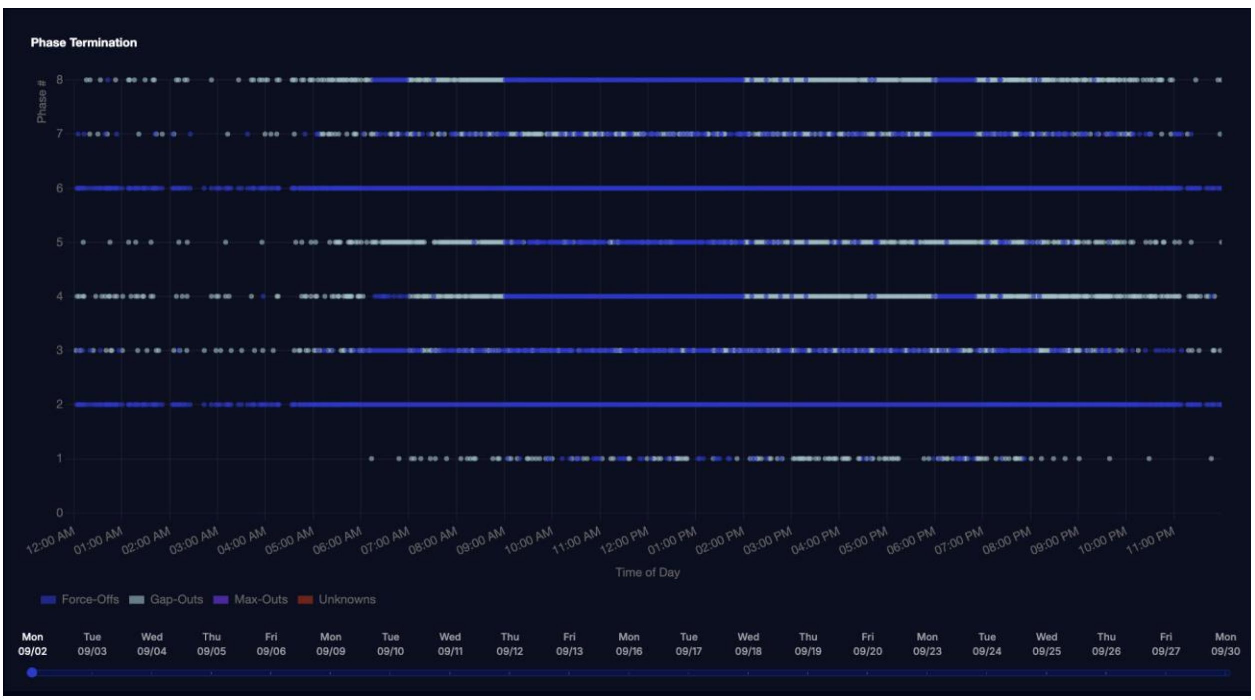
4. **Export and Deploy to Controllers**
   - Once approved, timing plans can be exported in MaxTime-compatible formats (CSV, or Excel).
   - The plans can then be uploaded into Lexington's 2070L controllers either manually via standard MaxTime workflows or through LFUCG's central ATMS if desired.
   - Luminus Plus continues to monitor the intersections post-deployment, automatically generating before-and-after performance reports to verify outcomes.



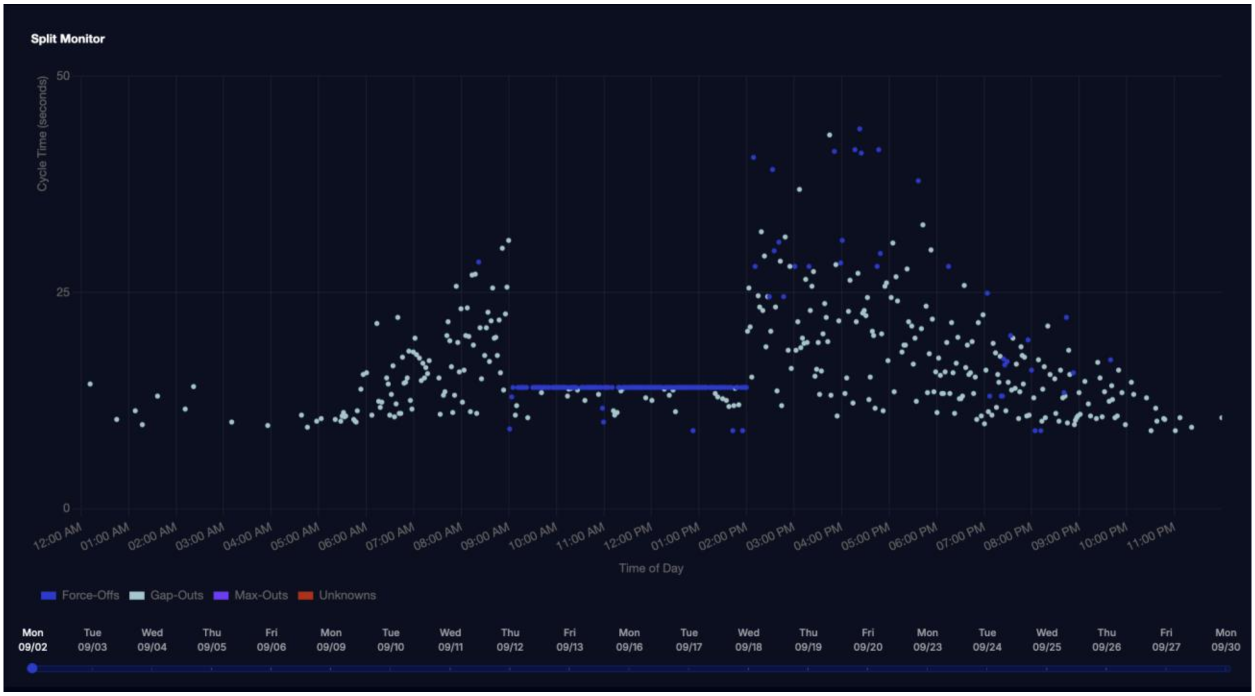
Access Historical SPMs. Using Flow Labs Luminus Plus, Engineers can access SPMs historically up to 2 years to evaluate previous conditions for proactive future operations. VDOT does not need to have ATSPM data this far back to access a number of SPMs, like AOG.



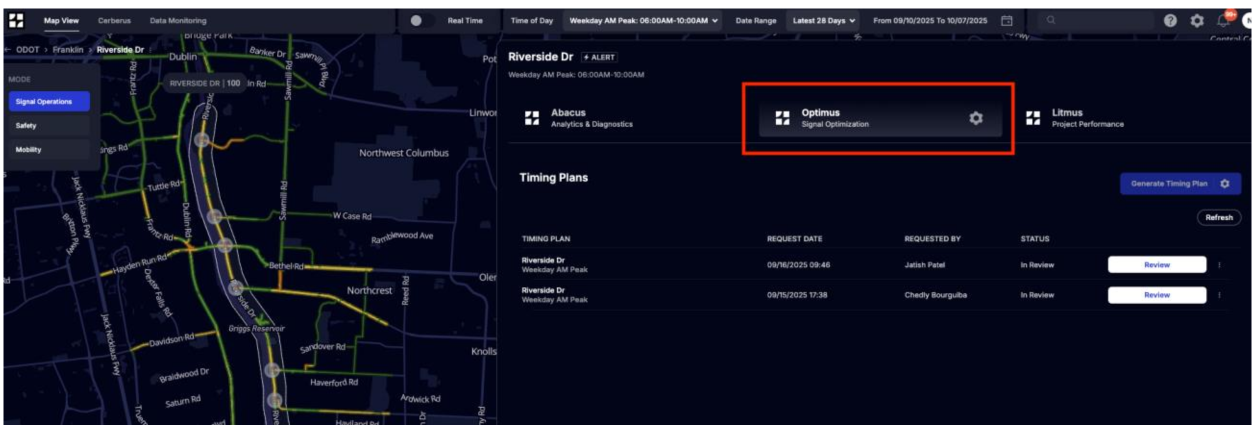
Purdue Coordination Diagram. Flow Labs offers a new spin on traditional ATSPM charts such as Purdue Coordination Diagrams. Easily slide the scale from day to day to see changes in arrival patterns across weekdays, weekends, or specific days in time.



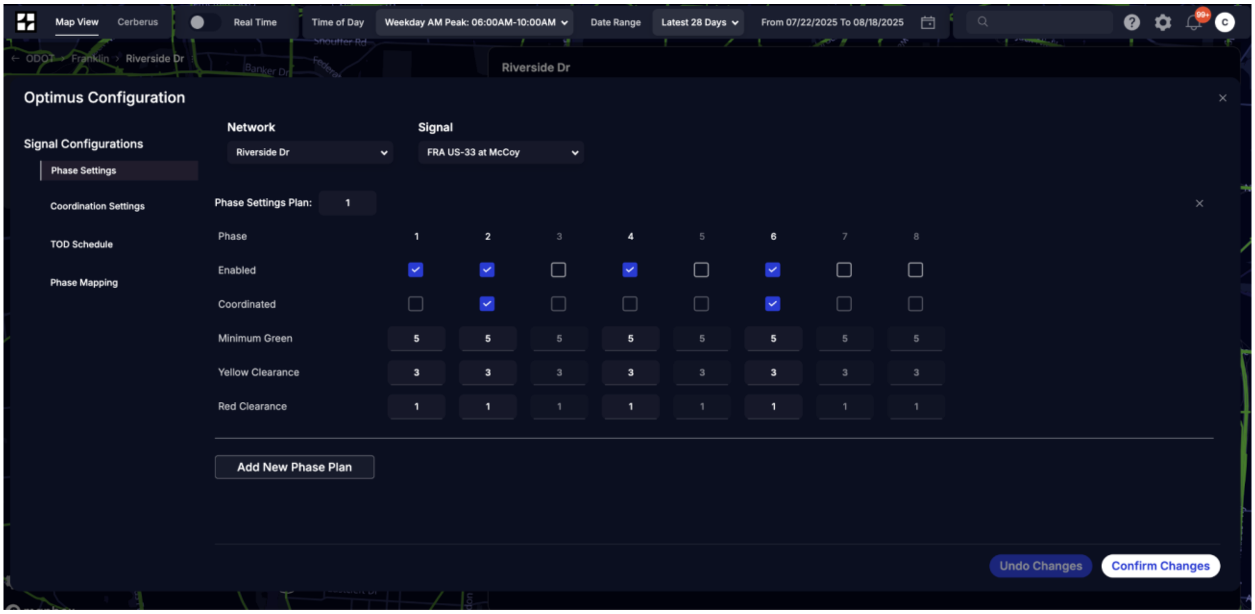
Phase Termination Diagram. Visualizes the reason each signal phase ends — whether by gap out, max out, force off, or skip — across multiple cycles. It helps engineers quickly identify phases consistently using all green time, signaling potential operational inefficiencies or faulty detections.



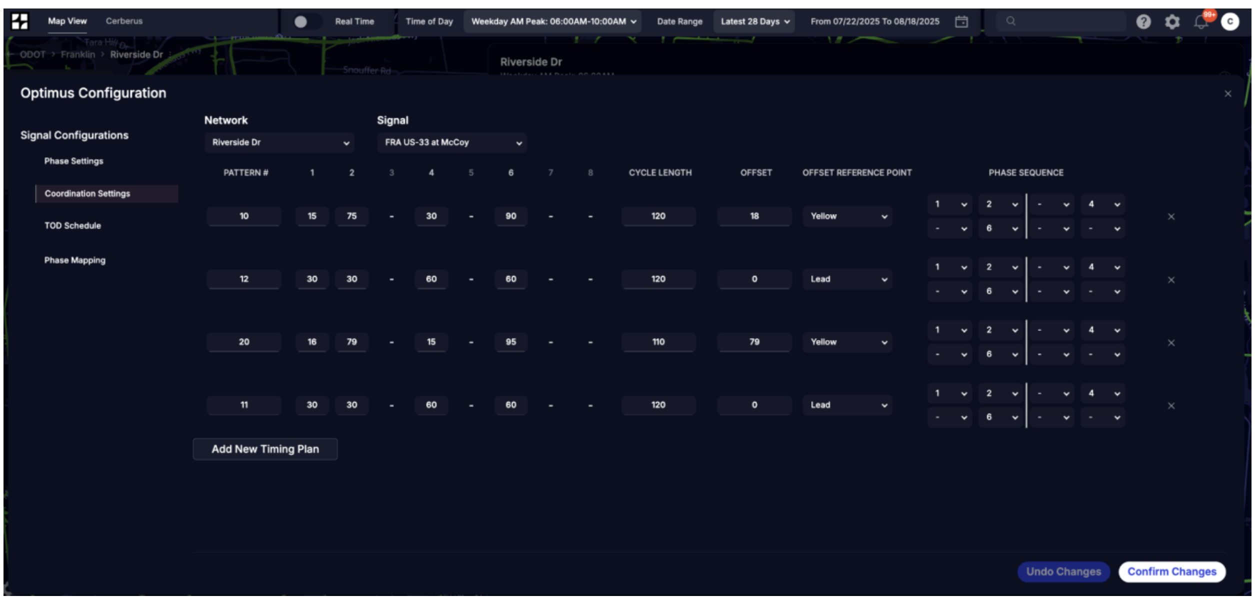
Split Monitor. Combines phase duration plots with termination type, pedestrian activity, and programmed splits to show how effectively each phase uses its allocated green time. Engineers use it to assess split utilization, coordination effectiveness, and whether timing adjustments or parameter tuning are needed.



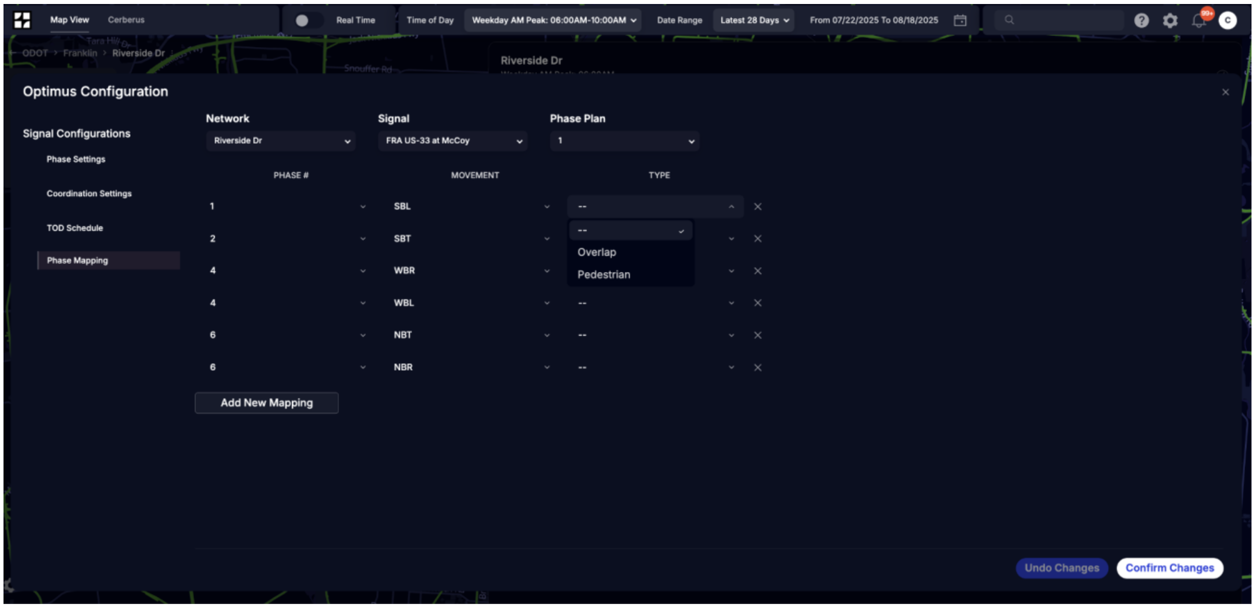
Optimus. Built right into the Luminus Plus platform, Optimus is easy to access and use.



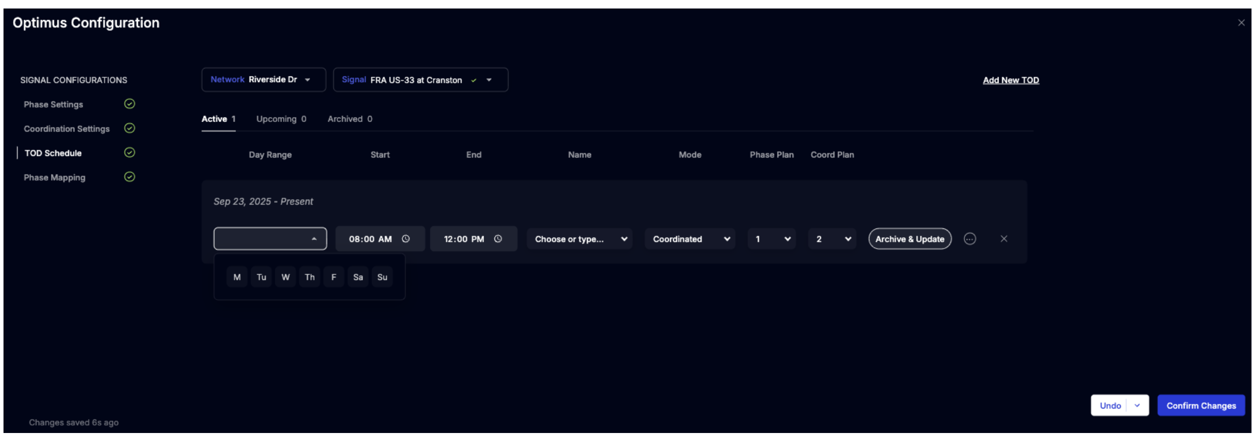
Optimus Phase Settings Parameters. Although Optimus can pull phase settings directly from the controllers using Luminus Plus, an engineer can also manually enter the data using the Optimus Configuration wizard.



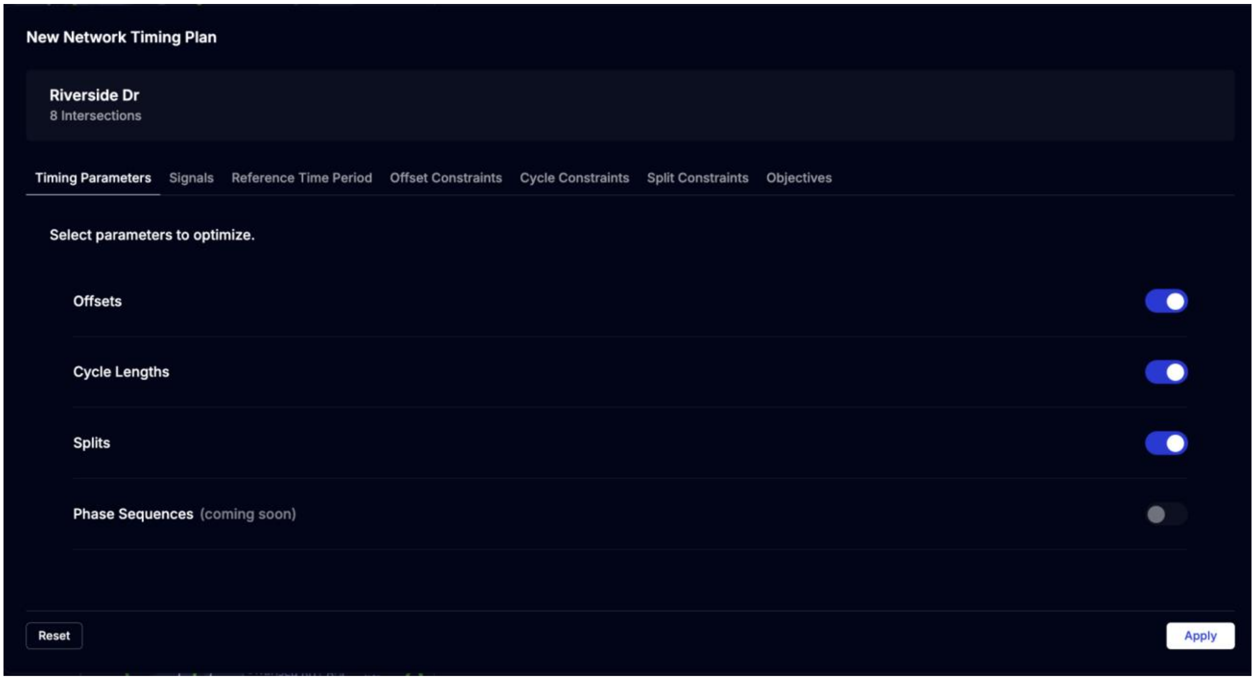
Optimus Coordination Settings Parameters - Can be manually or automatically configured via Luminus Plus.



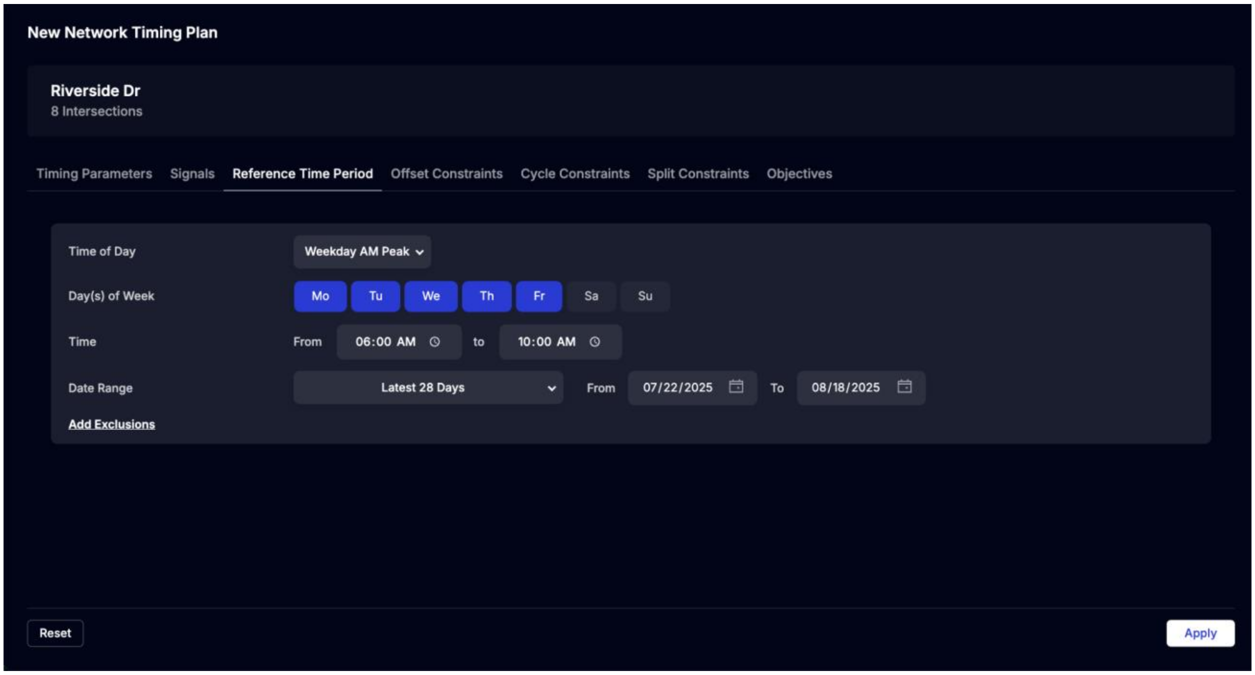
Optimus Phase Mapping Parameters - Can be manually or automatically configured via Luminus Plus.



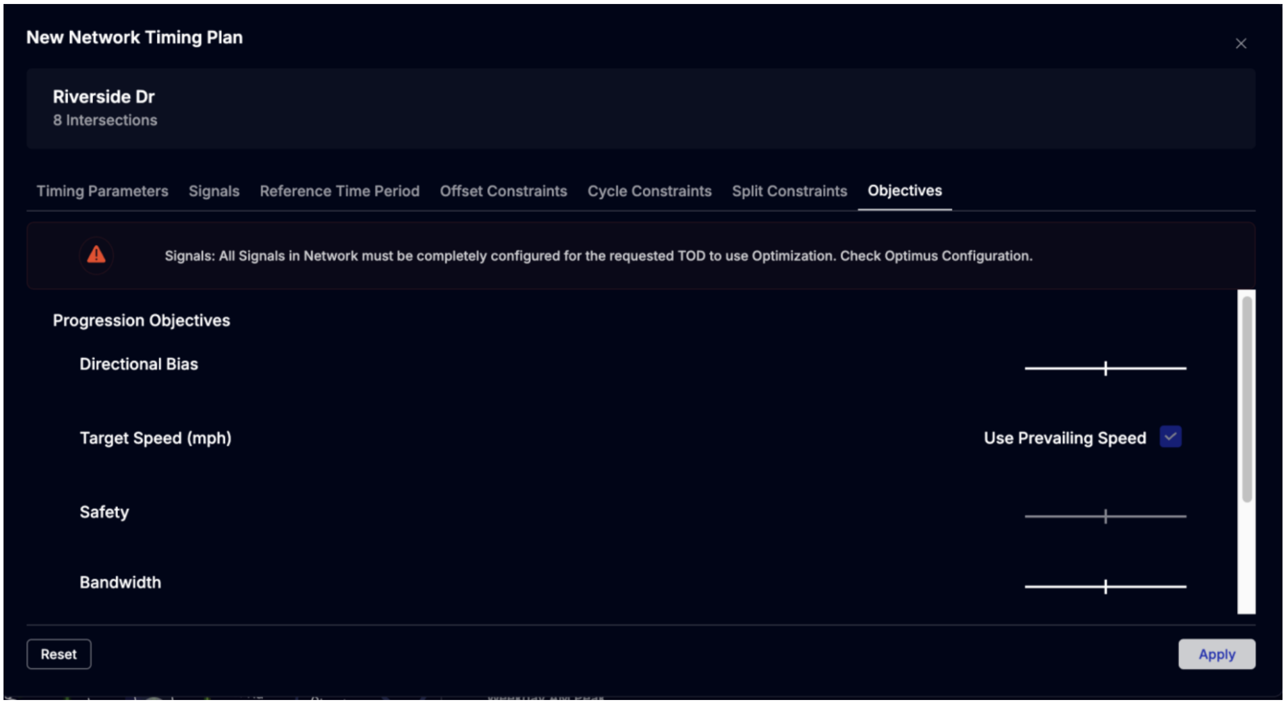
Optimus TOD Schedule Configuration. Create timing plans for any time of day, day of the week, weekday vs weekend, or traffic pattern identified by Luminus Plus as needing to be optimized. This gives Engineers complete control on how they retime signals across the corridor.



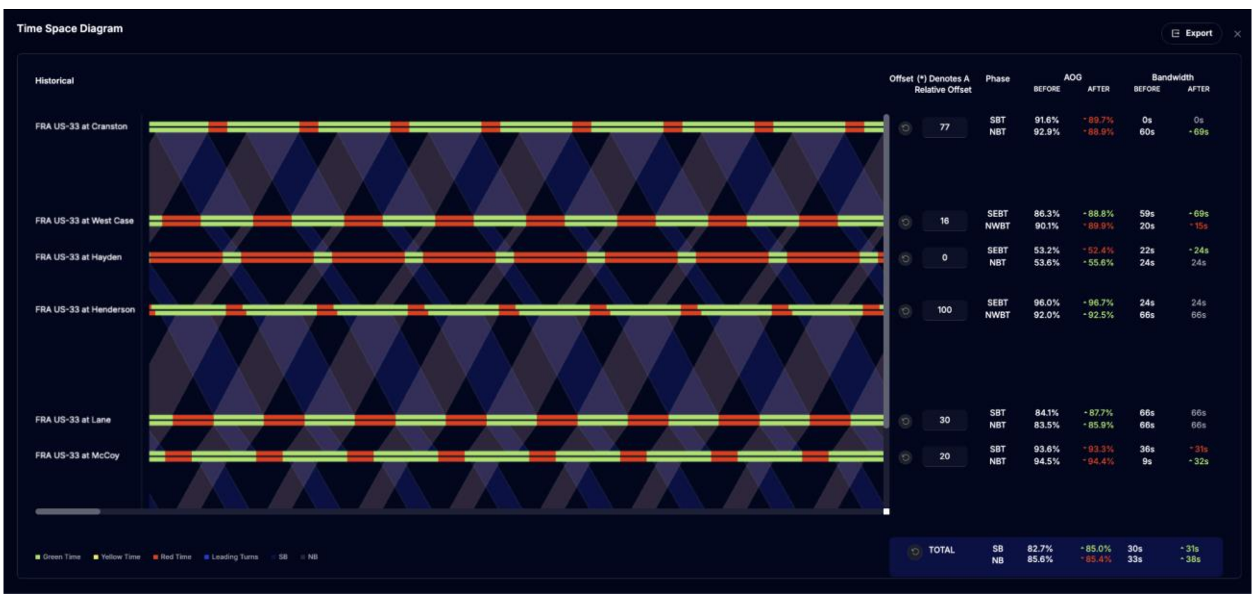
Optimus Timing Optimization Parameters. Optimus supports Offsets, Cycle Lengths, and Phase Splits optimization today. Phase sequences optimization is still in development but is coming soon and should be available in the next 1 - 3 months.



Optimus Reference Time Period Configuration. Use any historical time frame available within Luminus Plus for the training data for Optimus, ensuring that the signal timing plans created are accurate to the time period that needs to be retimed.



Optimus Objectives Configuration. Optimize corridors based on directional bias, target or prevailing speeds, AOG, DZE, etc



Optimus Time Space Diagram. Visualize bandwidths across the corridor using Flow Labs' TSD functionality. Quickly revert back and forth between the old timing plan and the new optimized timing plan to see exactly where Optimus is recommending changes be made

- Existing and Proposed Hardware

1. Explain how you intend to use our existing vehicle detection, your plan for evaluating the detection and setups at various intersections, and discuss any possible plans for upgrades or additions to what is currently installed in the field? Traffic

observation equipment and communication equipment should also be considered while keeping in mind Lexington's desire to move away from traditional floating car runs as we aim to rely more on remote monitoring and "big data," including reliable precise high resolution signal, vehicle, and detector data and video comprised of both live and historical records.

The Project Team, during the preliminary phase of the project, will perform site visits to document and evaluate signal operations, field conditions, and hardware issues that may impact signal timing or data collection, along the corridor. During these site visits we will evaluate and document the current detection implementation at each intersection. For most systems, the detector layout and configuration are done solely for operations. We will review the detection layout and configuration from a data collection and ATSPM perspective.

From there, the Team will fully leverage Lexington's existing vehicle detection, traffic observation, and communications infrastructure as part of the Integrated Signal Performance Measures (Luminus Plus) and Optimus deployment. The Flow Labs platform is hardware-agnostic and directly compatible with LFUCG's installed technologies, including 2070L controllers running MaxTime, loop detection, and radar and video detection systems. No new detection or cabinet hardware is required for implementation.

As part of implementation, the Project Team will:

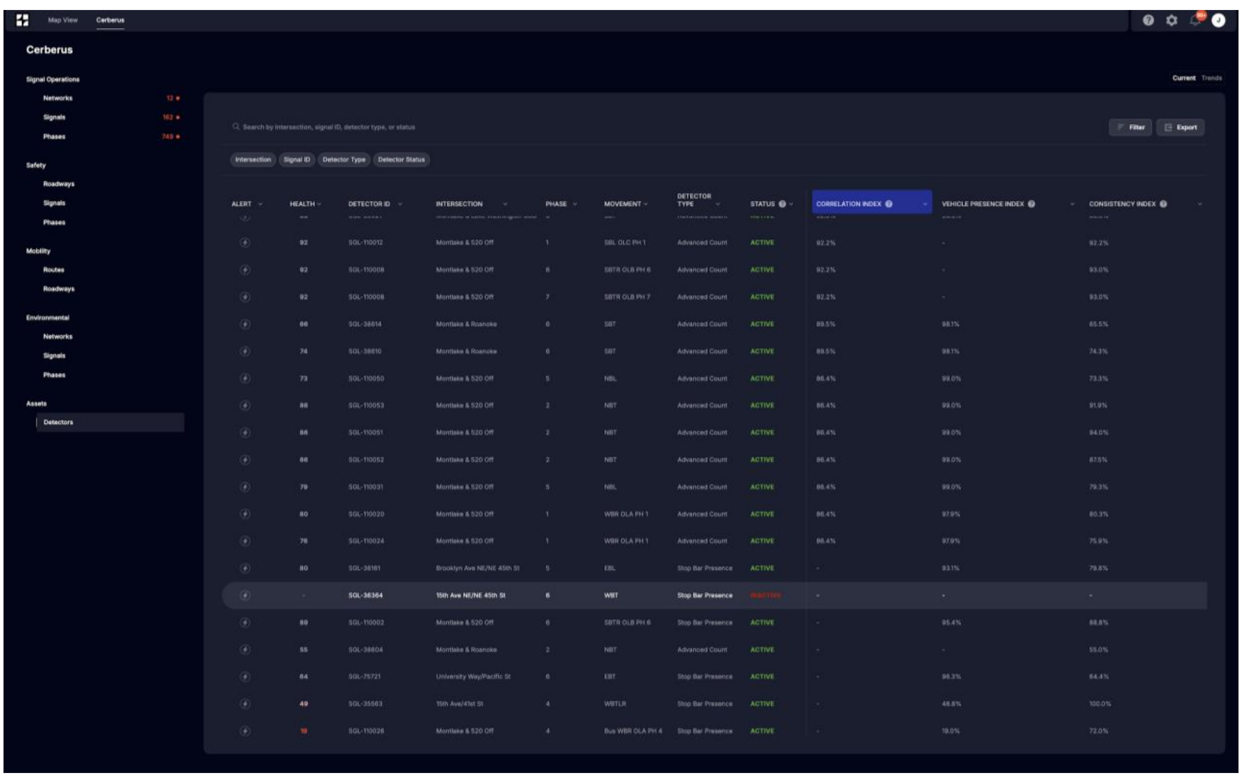
1. **Ingest Existing Detection Data** – The Luminus Plus platform will integrate real-time and historical data directly from controller event logs and detection systems using existing communication channels.
2. **Evaluate Detection Health and Calibration** – Using Flow Labs' detector health analytics, the system will automatically evaluate detection accuracy and consistency using indices such as correlation index, vehicle presence index, and consistency index. This process identifies faulty or miscalibrated detectors by comparing controller data against probe-based vehicle trajectories.
3. **Validate Detector Functionality in the Field** – Any irregularities or inconsistencies identified in software will be flagged for field verification by LFUCG staff or Flow Labs' engineering partners (e.g., WSP). These checks ensure that all active detection zones are performing correctly before optimization begins.
4. **Prioritize Upgrades Where Needed** – During the preliminary field visit, the project team will also provide recommendations for the addition of traffic observation equipment, as needed. The goal for all phases of this project is to migrate the signal performance process away from traditional methods and migrate toward utilizing ATSPM data for signal performance and remote operations evaluations. Remote

observation tools will only add benefit to the process for evaluations current and updated timings plans. Should the evaluation identify degraded or missing detection coverage, the Project Team will provide a ranked list of recommended upgrades or adjustments, focusing first on intersections with high delay or coordination sensitivity. These recommendations will be optional and based on cost-benefit justification, not as a deployment requirement.

The Project Team fully supports Lexington's goal to move away from traditional floating car runs toward a "big data" approach. By integrating controller event data, probe vehicle data, and detection feeds, the Luminus Plus platform provides continuous, visibility into signal and corridor performance—without field-based travel runs.

- **Probe-Based Vehicle Data** supplements detection to create a near-complete record of vehicle trajectories and intersection behavior, even where detection is limited.
- **High-Resolution Controller and Detector Data** provide precise signal actuation records for validation and long-term trend analysis.

Together, these data sources form a self-sustaining ecosystem of automated performance measurement and validation—enabling LFUCG to monitor, evaluate, and optimize signal performance remotely, accurately, and continuously.



Flow Labs Detection Monitoring - Flow Labs provides a dashboard showing Detector ID, Detector Type, Detector Status (Active/Inactive), Correlation Index, Vehicle Presence Index, Consistency Index, and more to support Detector Health Monitoring.

2. Discuss how detection data and even current signal timing data from external detection devices will be used (i.e. from other detection products, or from other intersections not slated for retiming with this project with live and historical data is available for use).

Luminus Plus is built to integrate and analyze data from any detection or controller source, regardless of manufacturer or deployment location. All available live and historical detection data, including that from intersections not currently slated for retiming—will be utilized to establish a network-wide operational baseline. This enables Lexington to evaluate how upstream and downstream intersections influence corridor performance, even beyond the defined project limits.

Detection and signal timing data from external devices will be automatically ingested through controller event logs or API integrations. These data feeds are then used to validate the accuracy of probe-derived measures and enhance timing analysis precision (and vice versa).

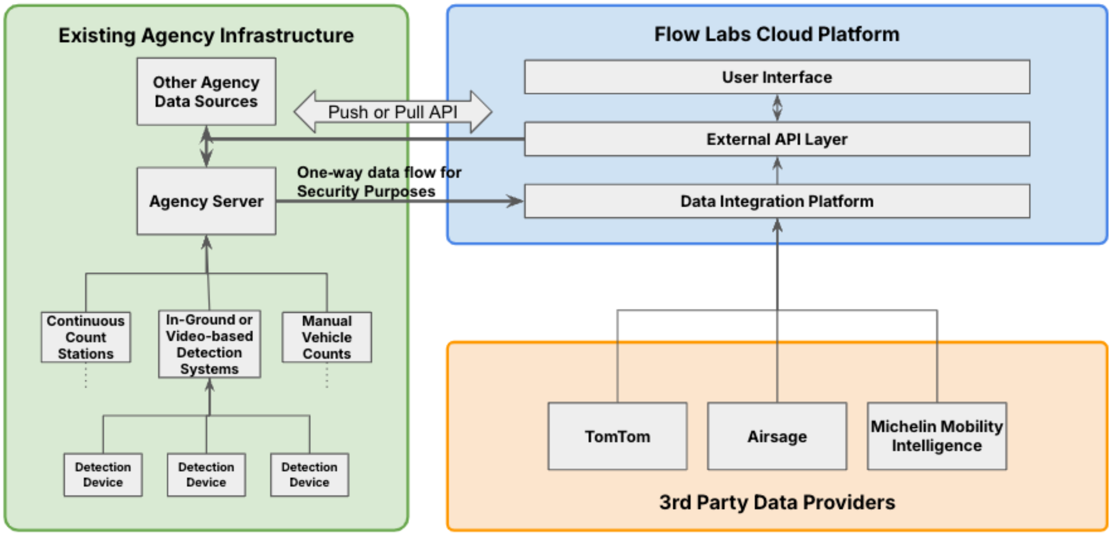
Existing signal timing data, including cycle lengths, splits, offsets, and coordination parameters—will be imported directly from MaxTime controllers via NTCIP-compatible exports or historical plan libraries (or via Engineer-manual entry into the Optimus Configuration Wizard). Flow Labs' analytics engine combines these with real-world traffic behavior observed through probe trajectories, producing a unified dataset for performance benchmarking and retiming support.

Even for intersections outside the immediate scope of optimization, the system leverages their datasets to:

- Quantify boundary effects and corridor progression continuity.
- Identify and ensure side street minimum delay tolerances; and
- Establish performance trends across the broader Lexington network, not just those signals that are being optimized.

This integrated approach ensures that all available detection and signal timing data—whether local or external, are fully utilized to support accurate, data-driven signal performance analysis and optimization across the entire LFUCG system.

ARCHITECTURE 1: EXTERNAL API



Potential Data Integration Architecture. The Flow platform is completely flexible for MoDOT's needs for data integration for both first party data flowing into Flow Labs and Flow Labs traffic data flowing to the City's data infrastructure. Flow Labs can meet any security requirements for data flows as specified by the City and can ingest API data, VM polling, or another requested integration method.

- Signal Timing and Traffic Flow Solution

1. We are expecting lane closures due to upcoming utility construction projects that may not allow for much notice. How will your signal timing solution address this type of situation and how quickly do you expect to be able to have a solution installed and active on the street?

The Project Team's signal timing solution is designed to rapidly adapt to changing roadway conditions such as temporary lane closures, detours, or construction impacts, without requiring field data collection or manual modeling.

When lane closures occur, **Luminus Plus** immediately detects operational changes—such as increased delay, reduced arrivals on green, or degraded progression—through its continuous, real-time monitoring of controller and probe vehicle data. Once identified, these impacts are flagged automatically within the platform's Cerberus monitoring dashboard, allowing engineers to confirm the extent and location of the disruption within minutes.

From there, Engineers can use **Optimus** to generate updated timing plans within a few minutes based on the latest field data, optimizing splits, cycle lengths, and offsets to mitigate congestion near the affected area. Because the platform requires no new hardware installation or field calibration, these updated plans can typically be reviewed, validated, and exported for deployment within hours/days of detection—ensuring minimal disruption to corridor performance. There are also no limitations to the number of timing plans generated by Optimus, so LFUCG can optimize individual sections of the corridor (depending on work zone impact), create different timing plans for different times of day, etc. as needed.

This rapid, data-driven workflow allows LFUCG to maintain efficient signal operations throughout construction events, quickly adjust as traffic patterns shift, and restore normal coordination once lanes reopen—all without reliance on floating car runs or manual retiming studies.

2. Tates Creek Road is over-capacity by quite a bit during the AM And PM rush hours. Is your initial timing solution and adjustment plan based on traffic counts or traffic demands? Can you give us some details on how your signal timing strategies might differ between over-saturated periods verses periods when there is excess capacity? Also, it is critical that we prevent any ramp traffic from backing up onto New Circle Road where we have high speed conditions. Please briefly speak to how you might address this.

The initial timing plans and ongoing adjustments are based on real-world traffic demand, not static turning movement counts. Using high-penetration probe vehicle data combined with controller and detector data from **Luminus Plus**, the system continuously measures actual flow, delay, arrivals on green, and queue length at every intersection along Tates Creek Road. This ensures that optimization decisions are grounded in live, verified demand conditions rather than limited count samples and deterministic modeling.

During over-saturated peak periods, Engineers can use **Optimus** to prioritize minimizing delay and queue spillback by balancing splits and offsets to maximize throughput along the dominant direction while preserving critical side-street access. When excess capacity exists during off-peak hours, Engineers can use Optimus to reduce cycle lengths and reallocate green time to improve progression and minimize unnecessary delay. This demand-responsive approach ensures efficient operation under both congested and free-flowing conditions, without manual plan switching or reprogramming.

To prevent ramp queue spillback onto New Circle Road, the platform continuously monitors upstream queue lengths and approach delay through ISPMs' real-time and historical probe data. The great part of Flow Labs integrated probe data approach is that we are not limited by the placement of the advanced detector. Luminus Plus can alert LFUCG of where the back of the queue exists regardless of how far back it is. During TODs where congestion typically backs up toward the ramp, Optimus can generate timing plans that increase ramp exit green time, adjust offsets, or rebalance coordination along the corridor to protect the freeway merge zone.

In summary, Flow Labs' timing strategies are demand-driven, data-validated, and safety-conscious, designed to maintain mobility during oversaturated peaks while protecting critical ramp operations through proactive, real-time signal control.

3. How will you address tying in the project signals with adjacent signals to the project relative to timing and traffic flow? For instance, one concern might be sending platoons into stopped conditions or into the dilemma zone at the next downstream signal outside of the project area.

The Project Team will coordinate project signals with adjacent intersections by treating upstream/downstream nodes as boundary conditions in both **Luminus Plus** (diagnostics) and **Optimus** (plan generation). We import the existing MaxTime timings (cycle, splits, offsets) for adjacent signals when available and use probe-validated corridor metrics (arrivals on green, approach delay, queue length, stops) to model how platoons traverse beyond the project limits. This lets us optimize within the project while respecting fixed offsets or TOD plans at neighboring signals.

To avoid sending platoons into stopped conditions or into the dilemma zone downstream, Optimus uses corridor objectives and constraints that:

- **Target arrival windows on green** at the next signal by adjusting offsets/bandwidth, and lock offsets where an adjacent signal must remain unchanged.
- **Guard against spillback** by monitoring downstream blockage and queue length at the upstream intersection boundary. Implement timing plans to prioritize AOG to reduce the likelihood of downstream blockage and spill back. Optimus allows the Engineer to prioritize AOG vs Bandwidth to ensure progression needs are met.
- **Reduce late-green arrivals** (which elevate dilemma-zone exposure) by shifting progression earlier within the green window and balancing left-turn service, without altering safety timings. Optimus allows the Engineer to prioritize DZE reduction to ensure late-green arrivals are limited as much as possible.

Operationally, the workflow is: (1) the Project Team will diagnose boundary performance in ISPMs, (2) the Engineer generates a corridor timing plan that includes the boundary intersections as constraints and prioritizes AOG, Bandwidth, or DZE reduction as needed, (3) the Engineer reviews in the time–space diagram to confirm downstream arrivals stay in green bands, and (4) export timing plan for controller upload. Post-deployment, ISPMs continuously verifies AOG, delay, queues, and boundary health so we can quickly re-tune if construction, incidents, or demand shifts change downstream conditions.

4. What advanced signal timing features, if any, might you explore for this arterial beyond cycle lengths, splits, sequences, and offsets?

During the initial site evaluation and preliminary timing implementation, the project team will evaluate the operation of each intersection. This will include timing parameters that have a direct impact on the responsiveness of the intersection, including passage times, detection delays, phase sequence, and volume density if applicable. The RFP indicated all clearance intervals and pedestrian timings have already been evaluated and updated. If we find issues with current operations, we will document the localized issue and provide recommendations to improve operational efficiency.

To this end, here are some smart, beyond-the-basics features we'd consider for this arterial—each used selectively, with engineer-set guardrails and subject to LFUCG policy and controller capability:

- **Progression speed tuning & dynamic bandwidth shaping:** Optimize target cruise speeds and green bands by direction/time period to reduce late-green arrivals and smooth platoons between nodes.
- **Event-/season-aware TOD variants:** Suggest alternate plans for school peaks, special events, or work zones (same base timings, different offset/split emphases)..
- **Dilemma-zone risk mitigation:** Shift arrivals earlier within the green, limit late-green terminations, and refine force-off windows to reduce high-speed yellow entries at downstream approaches.
- **Reliability-focused plans:** Create "incident" variants with slightly shorter cycles and more balanced splits to dampen volatility and stabilize queues.
- **Emissions-aware tiebreakers:** When multiple plans are operationally equivalent, select the one with fewer stops/idle time to cut fuel use and emissions.

- Traffic Data

1. How much traffic observation data is needed or collected before timing changes are recommended and/or activated?

The beauty of Luminus Plus is that probe data can be provided up to 2 years historically (one year standard), so the only traffic observation data (ground truth data) required is for TMC calibration purposes. Ideally this ground truth data is provided from the corridor in the last year, but new data can be collected whenever is convenient, assuming no other calibration data is available.

2. How do you account for events like horse racing at Keeneland, University of Kentucky football games, or even traffic incidents like a stalled vehicle blocking a lane when you suggest or activate timing improvements?

The Project Team handles special events and incidents with a real-time monitoring approach through **Luminus Plus** and a pre-built event timing "playbook" that is data-driven, engineer-controlled, and fast to deploy via **Optimus**:

- **Detect & flag:** Luminus Plus continuously monitors real-time probe data and controller events to surface unusual patterns—e.g., surging demand near Keeneland, pre/post-game flows for UK football, or incident signatures like sudden queue growth and degraded arrivals-on-green.
- **Prebuilt event "playbooks":** Engineers, using Optimus, can configure time-bound TOD variants for known events (directional progression, targeted splits, adjusted offsets, shorter/longer cycles as appropriate) using historical reference data from previous events. This ensures that the signal timing "playbook" for the special events is based in the historical real-world observed data, ensuring the highest correlation between timing plan and road user experience

3. Discuss how you might identify, locate, and make improvements for bottlenecks within project limits.

Flow Labs identifies, locates, and resolves bottlenecks through a data-driven, multi-layered diagnostic and optimization process combining real-time analytics from **Luminus Plus** with rapid optimization capabilities in **Optimus**.

1. **Identification** – Using continuous & real-time probe vehicle and controller event data, Luminus Plus automatically detects potential bottlenecks by monitoring metrics such as approach delay, queue length, arrivals on red, and split failures. When thresholds are exceeded, the Cerberus monitoring dashboard flags these intersections or movements for review and notifies the Engineer responsible.
2. **Localization** – Engineers can visualize bottleneck locations using map-based and time-space diagrams. ISPMs trace the source of congestion by correlating real-time performance across adjacent intersections. This corridor-level + intersection-level visibility ensures that the true cause (not just the symptom) of delay is identified and isolated.
3. **Improvement and Verification** – Once bottlenecks are identified, Engineers can use Optimus to generate targeted timing recommendations to relieve congestion. Engineers can fine-tune these recommendations and preview their expected

performance improvements—such as reduced delay or improved arrivals on green—before deployment. Following implementation, ISPMs automatically generate before-and-after reports validating the improvements and confirming that the bottleneck has been resolved.

Through this continuous feedback loop—detect, diagnose, optimize, and verify—Flow Labs ensures bottlenecks within the project limits are accurately identified and efficiently mitigated, with measurable, data-backed performance gains.