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Deployment of a Virtual Operating System for London CSO Management

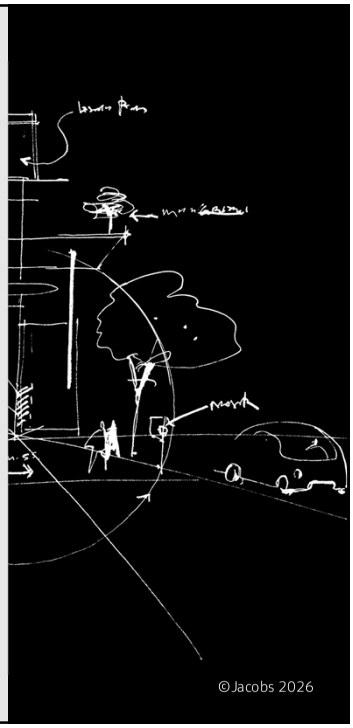
Stephanie McGregor
Virgil Adderley
Amanda Hon
Tyler Nading

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Development of a Virtual Operating System (VOS) for London CSO Management

Agenda

- London Tideway Tunnel (LTT) project overview
- VOS Overview
- Operational benefits and lessons learning during VOS
    1. Development
    2. Deployment
    3. System Acceptance (Future)



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London Tideway Tunnel (LTT) project

- 15-mile-long tunnel with 21 interceptions sites in the heart of London
  - Brought online in February, currently in Storm Testing phase
- Intercepts storm sewage from the Thames Water network
  - 2500 MGal sewage diverted to tunnel to date



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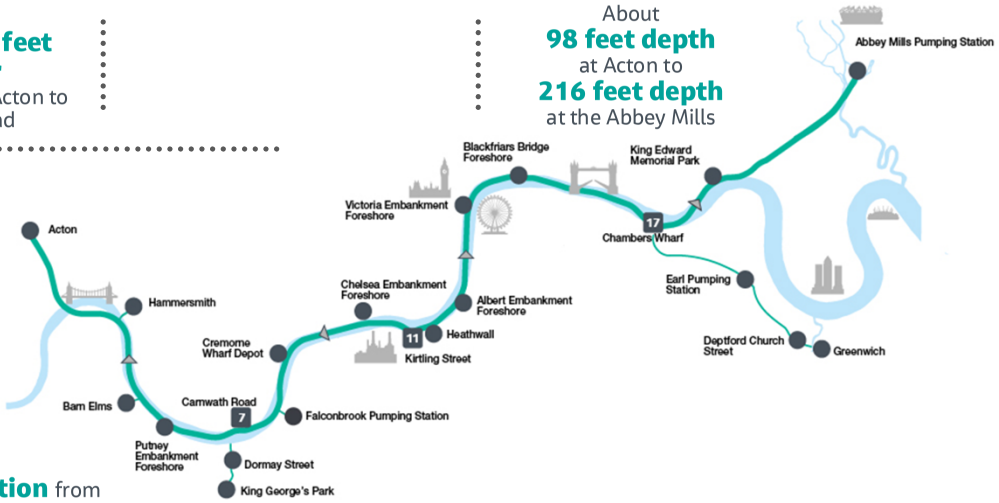
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London Tideway Tunnel (LTT) project

4.3 miles, 21 feet diameter
main tunnel from Acton to Carnwath Road

About
98 feet depth
at Acton to
216 feet depth
at the Abbey Mills



21 interception from **18 CSO sites** and **3 new low level** sewer interception

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VOS Development

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VOS Development Objective

Initial Storm Selection	Rational
Small filling storm WW E050380* Typical Year	Tunnel fills to 1/3 but below CTL To calibrate Replica rate of rise / timing Tunnel filling / emptying without any LTT trigger met
15-year 120 min WW	All WW triggers met, including inflow control except nLL1 Chelsea and Greenwich PS. • Confirm inflow sites with sequential penstock closure pre-emptively close one penstock when CTL is exceeded, and remaining penstocks closes when each inflow limit is reached. • Confirm tunnel penstocks closes when LTT OT levels are met. • Confirm bypass priming fills storm tunnel and Tideway PS operates when levels are reached • Confirm western reach tunnel penstocks close when LTT OT levels are met. • Confirm Abbey Mills penstocks closes when LTT OT levels are met. • Confirm reopening of tunnel penstocks and stopping of bypass pumping and emptying of storm tunnel.
25th July 2021 storm EWW	All EWW triggers met, inflow control at Earl PS met. • Confirm inflow sites with sequential penstock closure pre-emptively close one penstock on EWW initiation, and Earl PS closes on inflow limit. • Confirm tunnel penstocks and Abbey Mills penstocks closes and reopens when LTT OT levels are reached. • Confirm bypass priming / Tideway PS operates starts and stops when levels are reached. • Confirm storm tunnel emptying when levels are met. LTT system unavailable when GREPS river penstock needs to open.
12th July 2021 storm WW	Localised storm, partial filling with no Tideway bypass pumping, but with LTT penstock closure, and CTL exceeded. Inflow control at Hammersmith & Ranelagh met. In addition: • Confirm by Tideway bypass priming occurs, but no Tideway PS to river. • Confirm western reach penstocks and Abbey Mills remains open.
Storm Alex (October 2020) EWW	All EWW triggers met except inflow control. A back-to-back storm Lee Tunnel controls calibrated

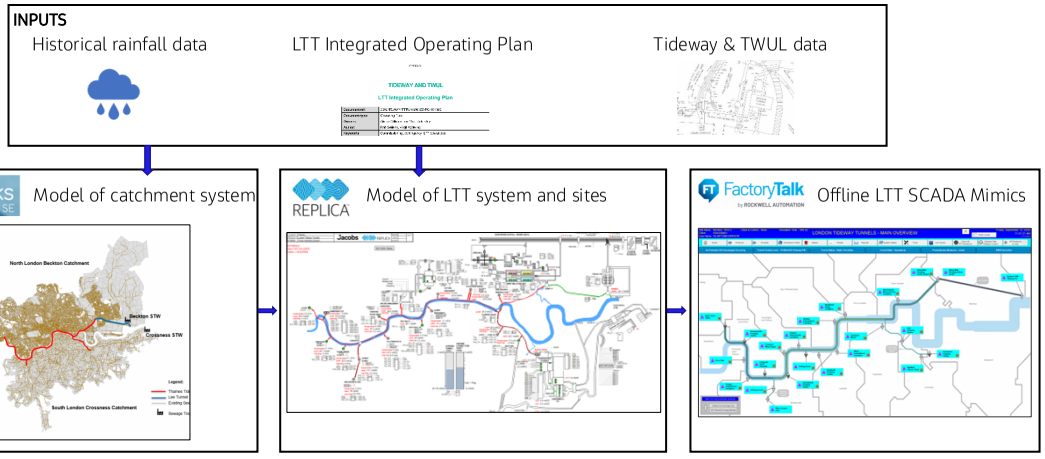
Storm selection to thoroughly test the proposed Operating Techniques

- Develop integrated tool to provide accurate representation of LTT hydraulics and controls
  - Evaluate 10 storm events
  - Evaluate 10 failure scenarios
- Primary end use in Commissioning: **Operator Training**
- Later end use in Acceptance Period: **System Optimization**

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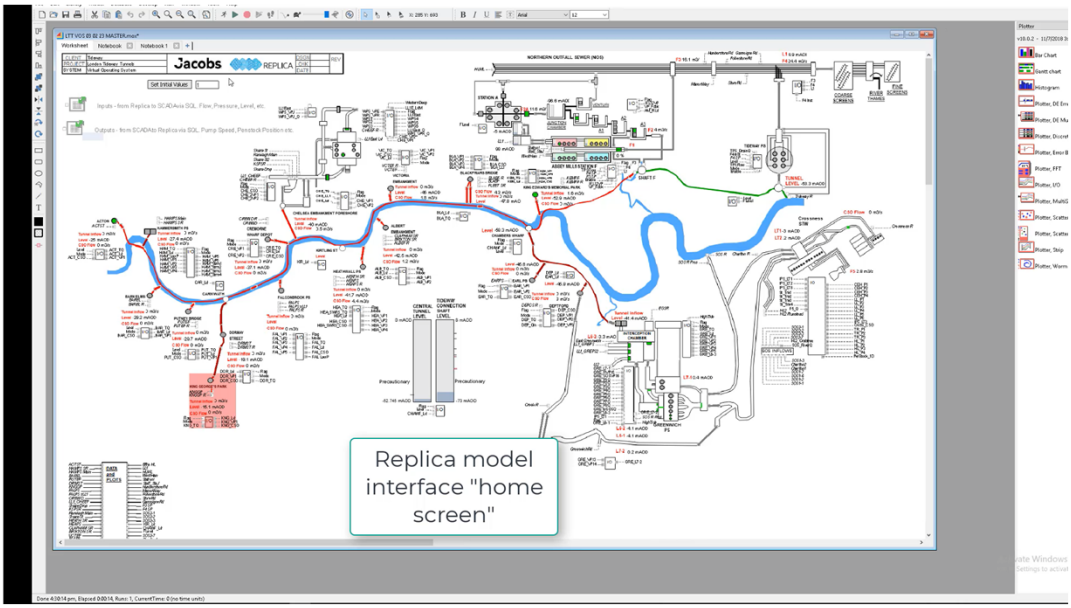
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What is the VOS?



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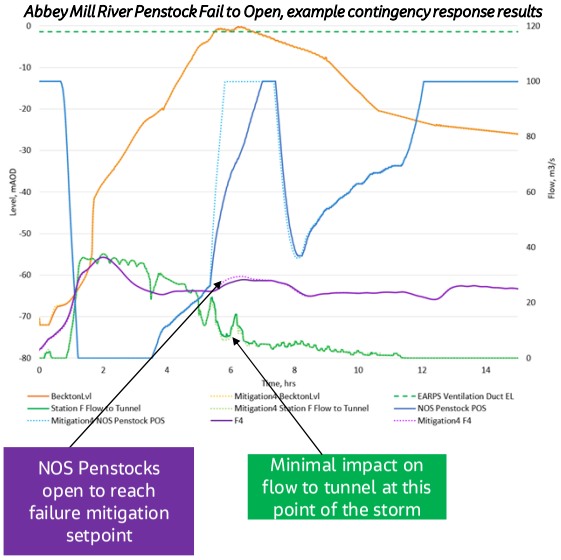
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VOS Development Benefits

- Provided confidence in the LTT operational strategy performance during a variety of storm events
- Demonstrated overall system operation similar to ICM, but is more visible and hands on for Operators
- Provided critical information and simulation of the complex Greenwich control strategy
  - "We've got some really useful results that have allowed us to test and refine the PLC software and avoid significant issues on site."
- Evaluated emergency contingency responses and mitigations for failure scenarios raised in the Systemwide HazOp
  - Provided insight into the effectiveness of the proposed failure mitigation strategies

Abbey Mill River Penstock Fail to Open, example contingency response results



NOS Penstocks open to reach failure mitigation setpoint

Minimal impact on flow to tunnel at this point of the storm

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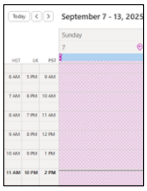
VOS Development Lessons Learned

- Tideway team input throughout the model development was key to success
  - Close coordination between ICM and Replica teams
  - Go/No-Go reviews at key break points in the model development
  - Time zone coordination

Agenda

1. Schedule and Project Background – 10 min
2. Model Verification Summary – 30 min
3. Greenwich/Crossness Controls Analysis – 15 min
4. System Integration Framework – 20 min
5. Financials – 10 min
6. Phase 3 Summary – 10 min
7. Next Steps – 10 min

Sample agenda from a Go/No-Go review



Adding multiple time zones to Outlook's calendar helped with time zone coordination

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VOS Deployment

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VOS Deployment Objectives



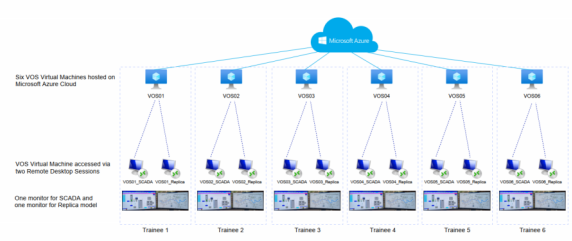
- Provide operator training to forty people
- Provide on-site access to the VOS throughout the commissioning period
- Support self-learning and LTT system simulations by Operations and Commissioning staff

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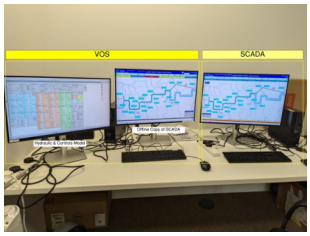
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VOS Deployment



Azure VMs used for training sessions



VOS walk up workstation, next to live SCADA

- Cloud hosted virtual machines to allow trainees to 'drive' the VOS during training sessions
- Physical workstation configured in London for long term access
  - Reliance on local support for updates

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VOS Deployment Benefits



Video recorded during one of the training sessions

- Provided realistic operational training to LTT Operators
  - Provided comfort and familiarity with SCADA graphics while operating the VOS
  - Provided experience of controlling the LTT system across a wide range of storms before the system became live
  - Provided insight into extreme and failure event scenarios and the effectiveness of mitigations and response actions
  - Ability for users to watch and interact with their own model during training to solidify learning
    - Avoided undesirable training hardware cost through the temporary use of virtual machines
- Enabled Commissioning Team to simulate storms and rehearse storm testing actions in the control room with coordinated field rehearsals.

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VOS Deployment Lessons Learned



Amanda Hon (ICM, Tideway) and Stephanie McGregor (VOS PM, Jacobs) with the Thames River and Putney Bridge interception site in the background

- Do not underestimate the time needed for coordination for hardware procurement, IT and cyber security
- So many things can be accomplished remotely, but sometimes travel expenses are well worth it

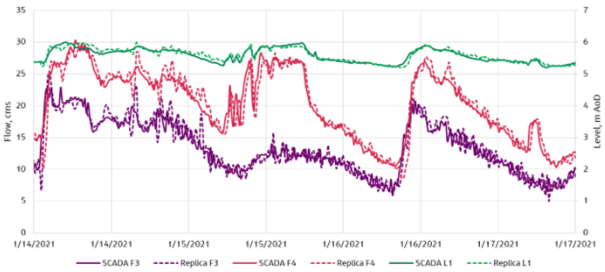
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System Acceptance

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System Acceptance (Soon)

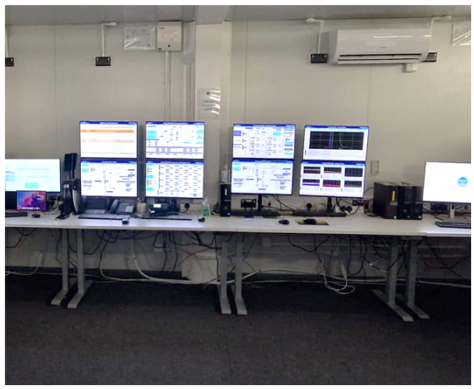


Calibration results from the Lee Tunnel portion of the model. The team is awaiting rainfall and storm data to perform the VOS calibration.

- Calibrate the VOS to LTT historical data collected during commissioning to provide confidence in future VOS storm predictions and the overall LTT system operations

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System Acceptance Objective



Tideway control room located at the Beckton Sewage Treatment Works.

- Support System Optimization, including modifications to:
  - Tunnel setpoints,
  - Tideway pump station setpoints,
  - Control of interfaces (weirs, pump stations, etc.) with TWUL local sewer network
- Train operators on optimized system
- Confirm LTT system can be operated by TWUL successfully to manage CSOs across a range of storms

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Thank you!

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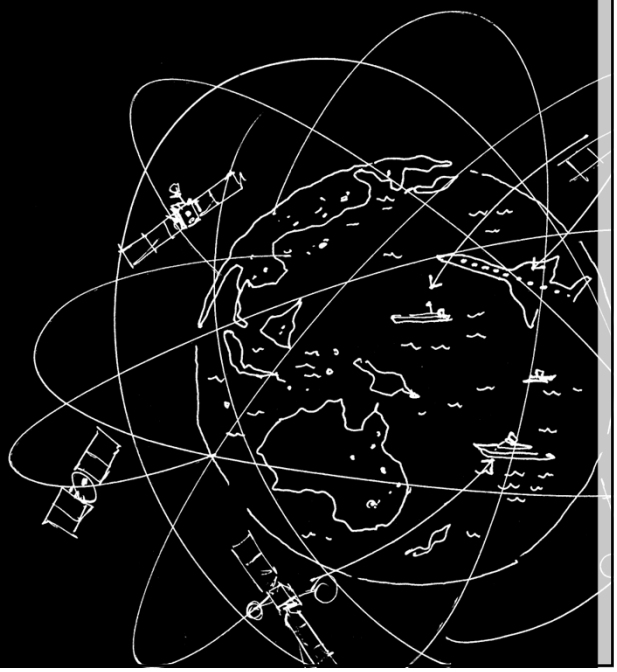
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