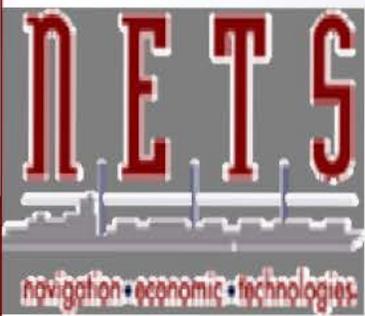


USACE Navigation System Simulation



NaSS

Inland Navigation CoP Workshop

September 19 & 20

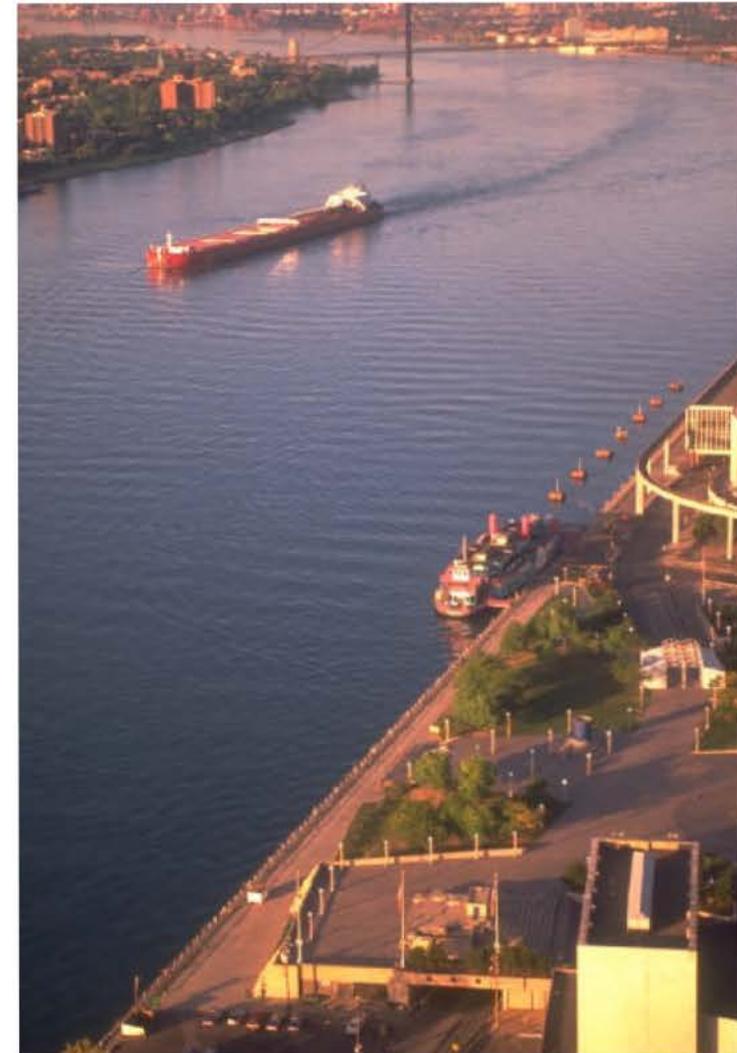
Louisville, Ky

NaSS Vision

- Develop a next-generation simulation model and associated tool suite for inland navigation analysis
 - Data Driven
 - Risk and Uncertainty
- Incorporate the experience gained in previous works
 - Waterway Analysis Model (WAM), NavSym, LCLM, LockSym
- Generate and move vessels through a multi-lock network of waterways with incorporation of scheduled/unscheduled outages and associated shipper response

NaSS PDT

- IWR
 - Mark Lisney, Keith Hofseth
- LRH
 - Buddy Langdon
- University of Maryland
 - Dr. Paul Schonfeld
 - Dr. Shiaaulir Wang
- RMM Technical Services
 - Dr. Richard Males
- CDM



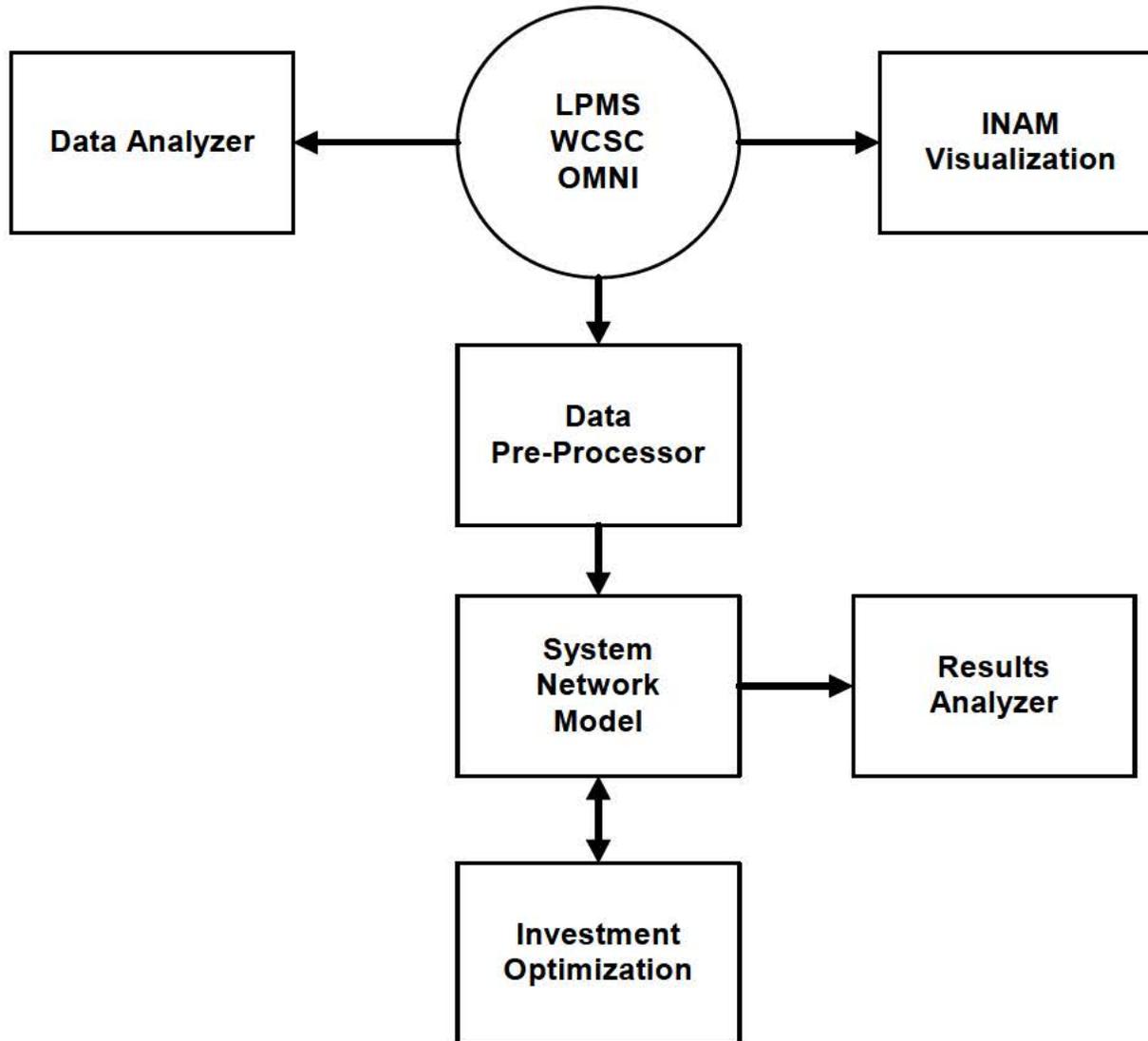
Potential Questions of a System Model

- What is the overall system performance of a waterway network under different operating, demand load and reliability conditions?
- How effective are alternative lockage policies at reducing delays and delay costs?
- How does any single lock improvement project affect delays at other locks?
- What is the proper scheduling and choice of investment decisions on a waterway system?

NaSS Components

- NaSS Schema
- DAPP – Data Analyzer Pre-Processor
- System Network Model
- Detailed Lock Model
- Investment Optimization Model
- Agent-Based prototype of shipper response
- Visualization Capability

NaSS Architecture

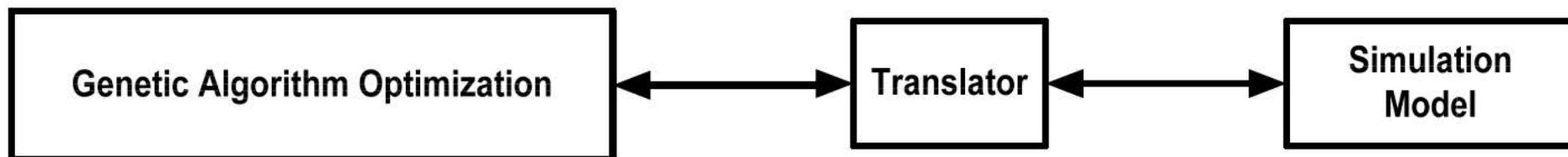


Investment Optimization Model

- Optimization of system performance on alternative investment plans
 - Project choice
 - Project scheduling
- Investment Types
 - O&M Investments that can change reliability
 - Project investments that can change reliability and project capacity (new chambers, larger chambers, etc..)
- Combination of optimization and simulation
 - Genetic Algorithm (GA) optimization search
 - Simulation model evaluates “fitness” of given plan

Simulation Combined with Optimization

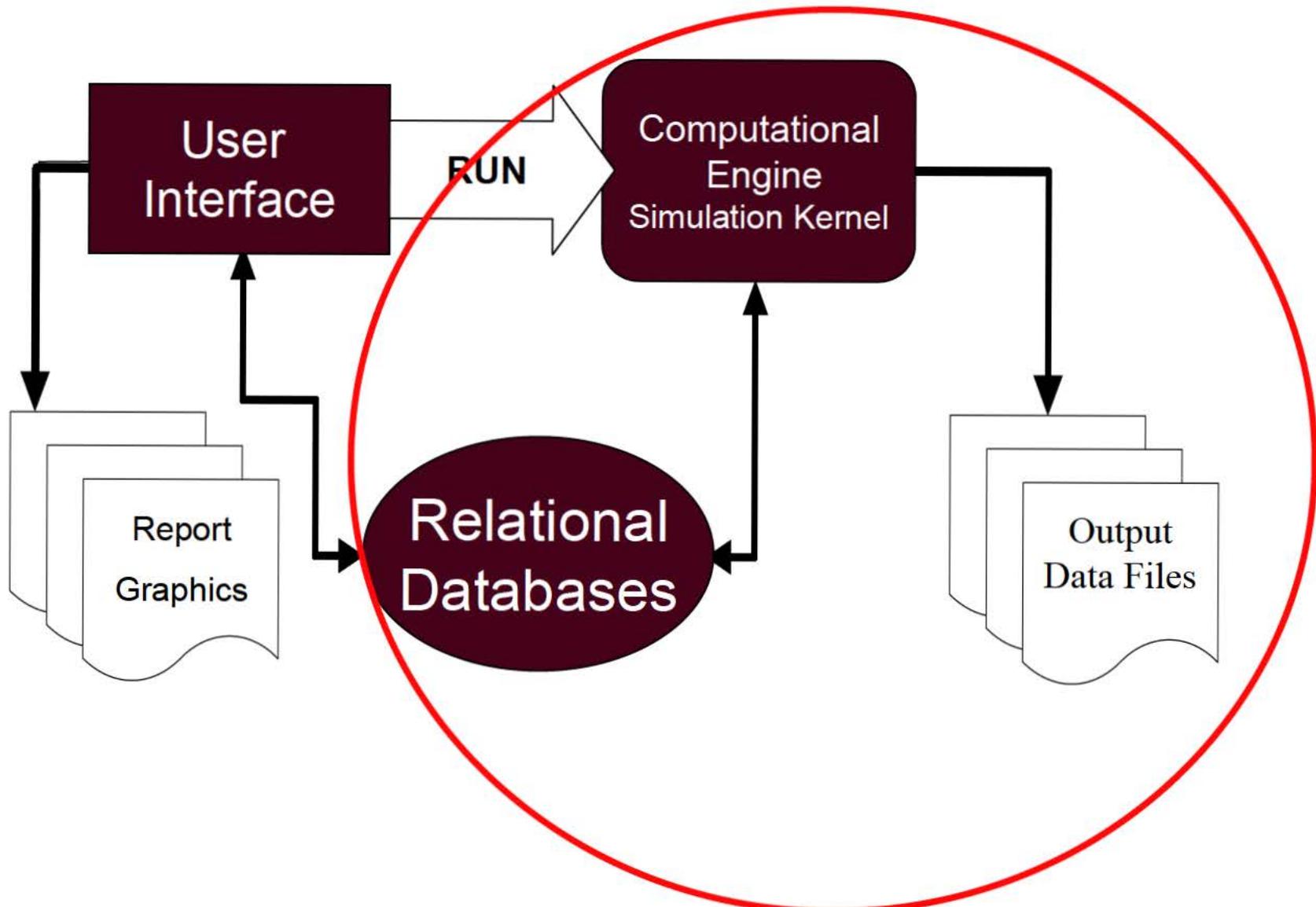
- Develop 1st generation chromosomes (solutions) randomly
- Evaluate fitness of each through simulation model
- Select best solutions for genetic refinement
- Modify “fittest” chromosomes to develop 2nd generation
- *Process continues until termination rule is true*
 - Max number of iterations or evaluated solutions
 - Search results unchanged for n generations
 - Search results improved by less than $x\%$ over previous n generations



BasinSym Overview

- Simulation of waterway system activities to determine transportation costs under a variety of conditions
- Discrete-Event Monte Carlo simulation
- Generation and movement of tows through the locks and reaches of a system-wide waterway network

Architecture

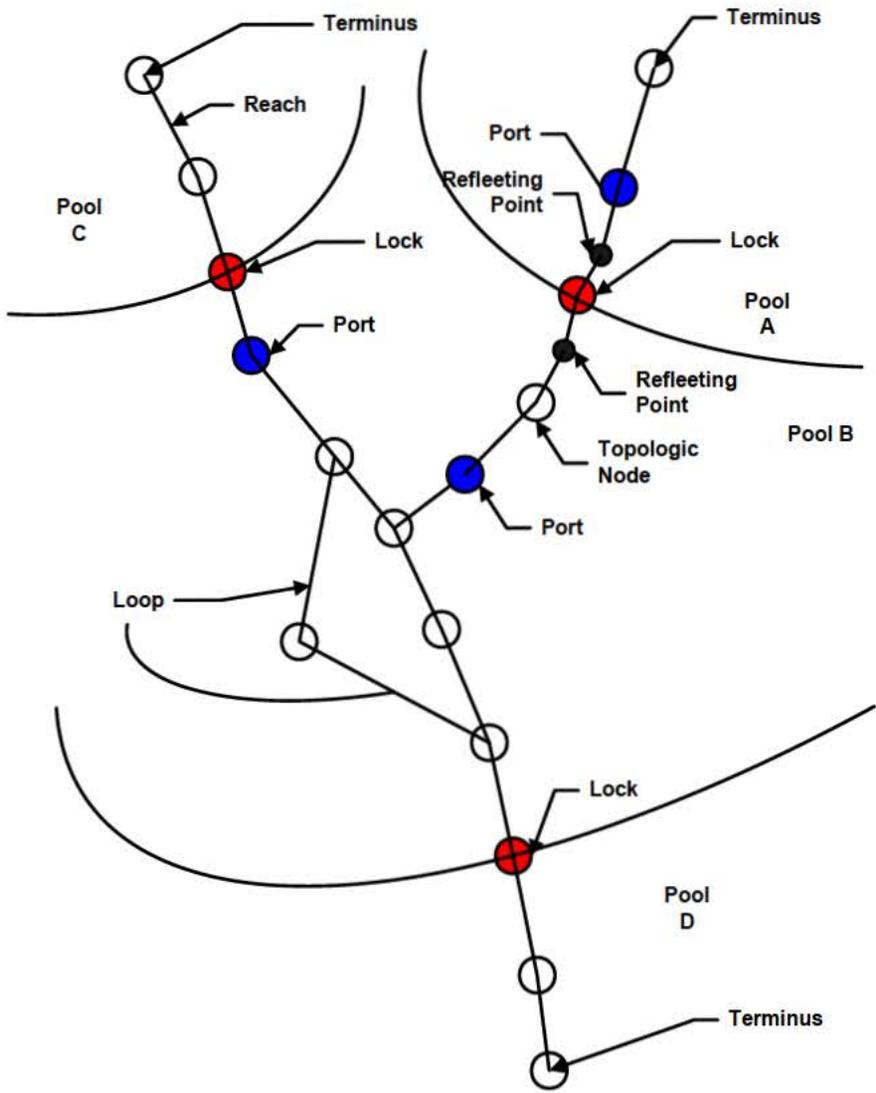


BasinSym Network

- Navigation network
 - Linked Node Network of waterways / locks
 - Nodes
 - ID, name, latitude, longitude
 - Type – Dock, Topographic, Terminus
 - Collection of “Equipment”
 - In Use
 - » On Movement (cargo ops)
 - » Awaiting Movement
 - Available
 - Reaches
 - Normal / Lock
 - Maximum tow speed
 - Characteristics
 - Length, width, depth, current, cross-sectional area
 - User specified pools with re-fleeting

BasinSym Network Representation

System Network Representation



Vessel Classification

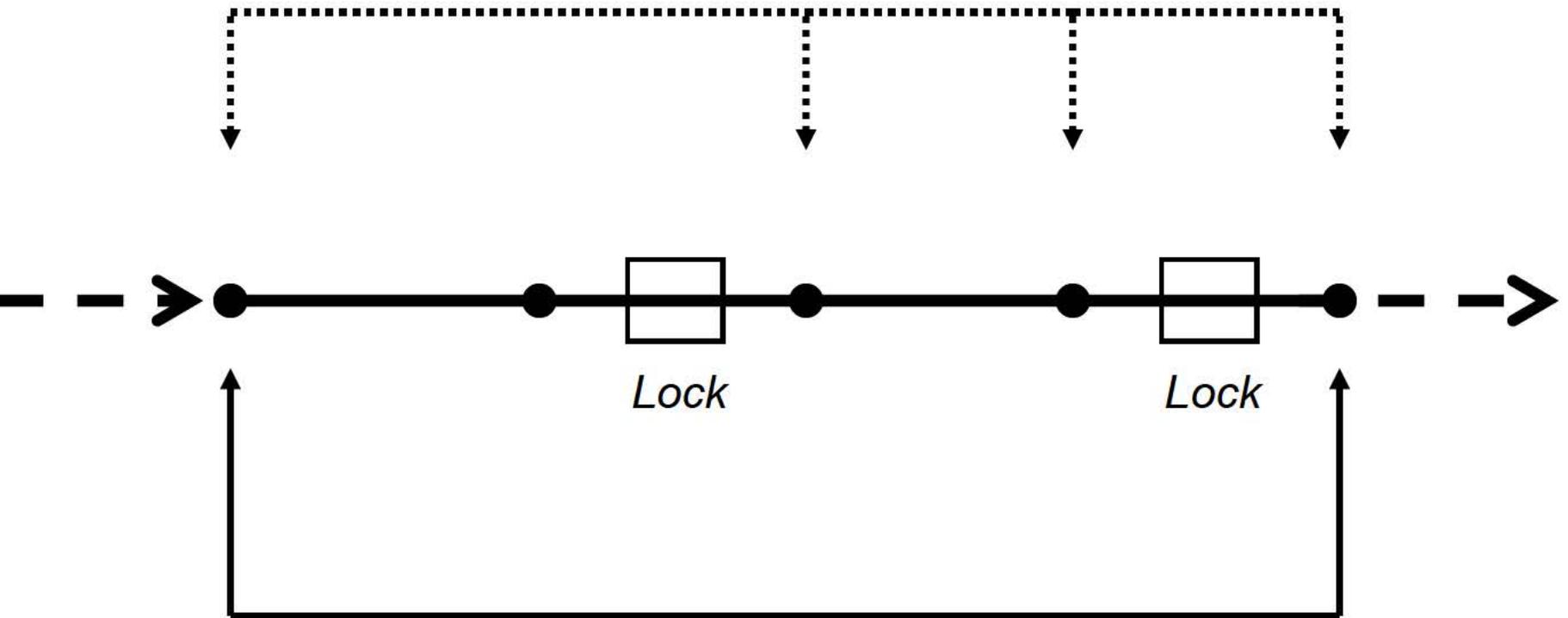
- Powered vessel fleet – a list of unique power vessels available for use in simulation
- Barge class / sub-class hierarchy
 - Class: Hopper | Sub-Class: Jumbo
- Vessel Attributes
 - Default vessel attributes
 - Horsepower (if a powered class)
 - LOA, Beam, Draft, Capacity
 - Commodities carried
 - Cost to operate staffed and moored

Shipment List

- Direct shipment list
 - Trips: A powered vessel movement
 - Date/time of trip start
 - Origin and ultimate destination
 - Visits: Nodes along a trip at which transactions occur
 - Node ID to visit
 - Order within trip
 - Transactions: Changes to the tow
 - Power vessel changes
 - Barge additions or removals
 - Cargo loads or unloads

Composite Trips

Barge Transactions



Total Trip for Power Vessel

Routing

- Optimal routes are found using the A-Star technique of artificial intelligence graph searches
- Cost based routing with time as the metric
- Congestion reflective cost modification
- Network changes over time such as lock closures trigger route regeneration

Transit Rules

- Rule system that governs tow traffic within a reach
- Rules employed
 - No passing
 - No overtaking
 - No meeting
 - Exclusive reach usage
 - Minimum inter-tow distance
- Rule outcomes
 - No conflict – tow may proceed without limitations
 - Tow is delayed by a period of time
 - Tow may proceed but with speed limitations

Lock Representation I

- Simplified and detailed versions of locks
- Choose from 3 levels of simplified locks, a detailed lock model or any combination within the modeled basin
- Multiple levels of simplification
 - *Level 1*
 - Tow based locking
 - Upbound and downbound tow processing time distributions
 - Upbound and downbound non-tow processing time distributions
 - Chamber turnback processing distribution for filling and emptying
 - Constant Value For Additional Lockage Time per Vessel in Chamber
 - *Level 2*
 - Implements cut based locking
 - Capabilities and data requirements – same as level 1 but implemented at the cut level

Lock Representation II

- Currently under development
 - *Level 3* - Cut based locking with vessel interactions
 - Detailed Lock Model
 - Internal lock geometry
 - Micro-level chamber components
 - Micro-level lockage processing

Outages

- Scheduled outages
 - Chamber based
 - Date/time and duration specified
- Unscheduled (in development)
 - Component based Markhov chain failure state system
 - Age and Cycle based failure
 - Repair/Rehab based on failure state
 - Cost to repair
 - Fixed or stochastic failure duration

Incorporating Uncertainty

- Tow Reconfiguration
- Commodity Transfer Operations
- Vessel Speed in Reach
- Lockage Processing
- Component Based Reliability
 - Probability of Failure
 - Duration of Outage
- User selectable distribution types
 - Uniform, normal, triangular
- User definable functions
 - Cumulative distributions

Simulation User Interface

- User Specified duration, iterations, seed
- Optional variable-speed animation
- Start, Stop, Resume functions
- Reach and Node identification labels
- User selected .csv output files
- Geospatial element placing
- Basic geospatial data layers with pan/zoom
- Dynamic internet based layers (MS TerraServer)
 - Aerial photography
 - Topo maps
- Tow query capability

Simulation User Interface

BasinSym

Duration: 720 Iterations: 1

Start Stop Resume

Pan Zoom

Animation Speed: 0.01

CSV Log
 Event Log
 Animation

External Imagery

None
 Topo Maps
 Aerial Photo

Node Labels

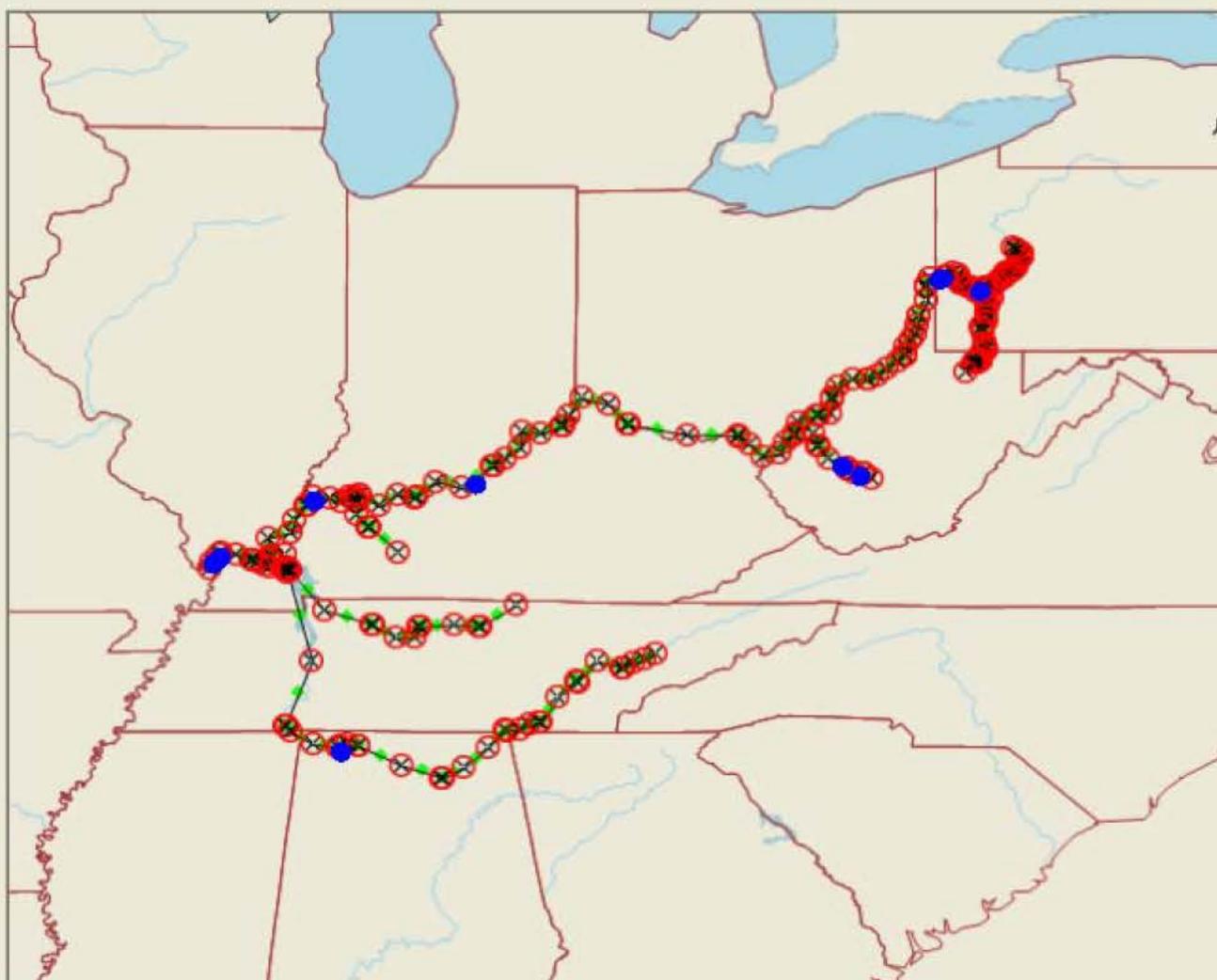
None
 Short Label
 Long Label

Reach Labels

None
 Short Label
 Long Label

Time: 3.37

Version 1.0.0.0

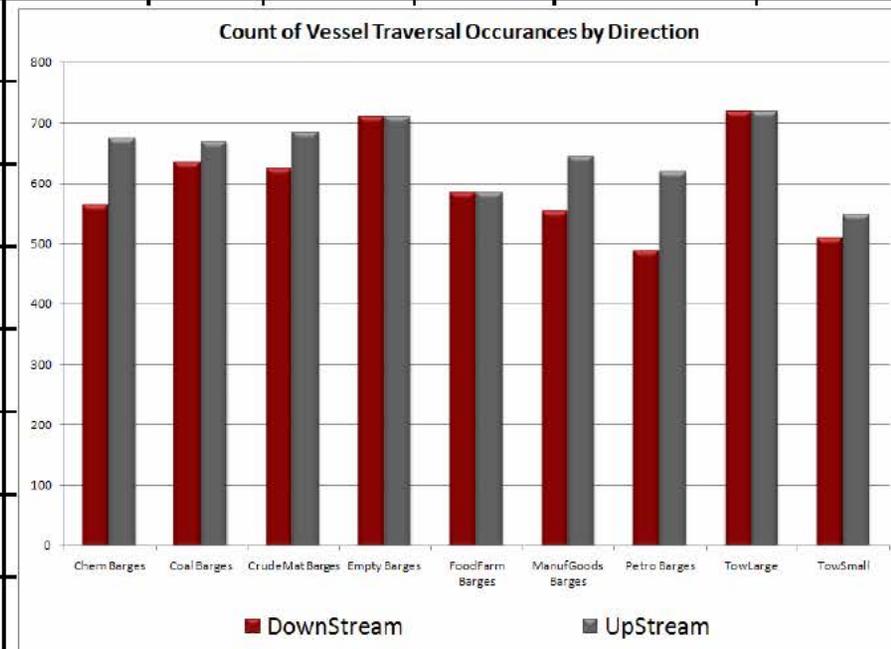


The map displays a network of nodes and reaches. Nodes are represented by red circles with a cross, and reaches are represented by green lines connecting the nodes. The route starts from the bottom left and moves generally towards the top right, with a complex branching structure on the right side. The map background shows state boundaries and major water bodies.

Outputs

- Detailed Event Log
- Summary Output Statistics
 - By Vessel Class
 - Time in Reach
 - Time in Lock
 - Processing and Queuing Time
 - Time in System

Iteration	Reach ID	UpStream DownStream	Vessel Class ID	Vessel Class	Total Traversal Time	Vessel Traversal Occurances	Total Cost to Traverse
1	120	UpStream	2	TowLarge	1364.275201	191	27285.50402
1	120	UpStream	12	CrudeMat Barges	4961.334303	688	0



Vessel Class ID	Vessel Class	Total Queue Time	Total Processing Time	Vessel Lockage Occurances	Cost in Queue	Cost During Processing
2	TowLarge	0.685759095	61.39270921	201	13.71518189	1227.854184
12	CrudeMat Barges	0.062047275	172.2487239	627	0	0
9	ManufGoods Barges	0.12409455	45.5997114	219	0	0
1	TowSmall	0	5.149695447	3	0	51.49695447
6	Empty Barges	8.365727006	256.8466633	694	0	0

Current Status

- Prototype development
 - NaSS database schema developed
 - DAPP – working prototype developed
 - BasinSym (system network model) prototype developed
 - SimOPT – simulation combined with optimization for large scale investment planning
 - Agent-Based prototype of shipper response
 - Inland Navigation Animation Module (INAM) prototyped

Next Steps

- Component-based reliability
- Integration of basic Detailed Lock Model
- Generation of trips (statistically and demand-driven)
- Incorporation of long-term shipper response (mode choice)
- User Interface
- Integration of GA optimization model

BasinSym Preview

BasinSym [Window Title Bar]

Duration: 720 Iterations: 1

[Start] [Stop] [Pause]

CSV Log
 Event Log
 Animation

External Imagery:
 None
 Topo Maps
 Aerial Photo

Animation Speed: 0.01

Node Labels:
 None
 Short Label
 Long Label

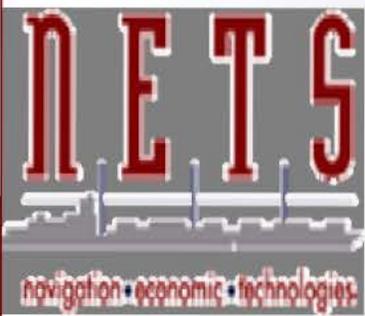
Reach Labels:
 None
 Short Label
 Long Label

Status
 Version

[Pan] [Zoom]

The main 3D view displays an aerial perspective of a river system. A large lock and dam structure is visible in the foreground, with a barge and several barges in the water. The surrounding area includes green fields, a road, and a city skyline in the distance under a clear sky.

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