USACE Navigation System Simulation

NaSS

Inland Navigation CoP Workshop

September 19 & 20

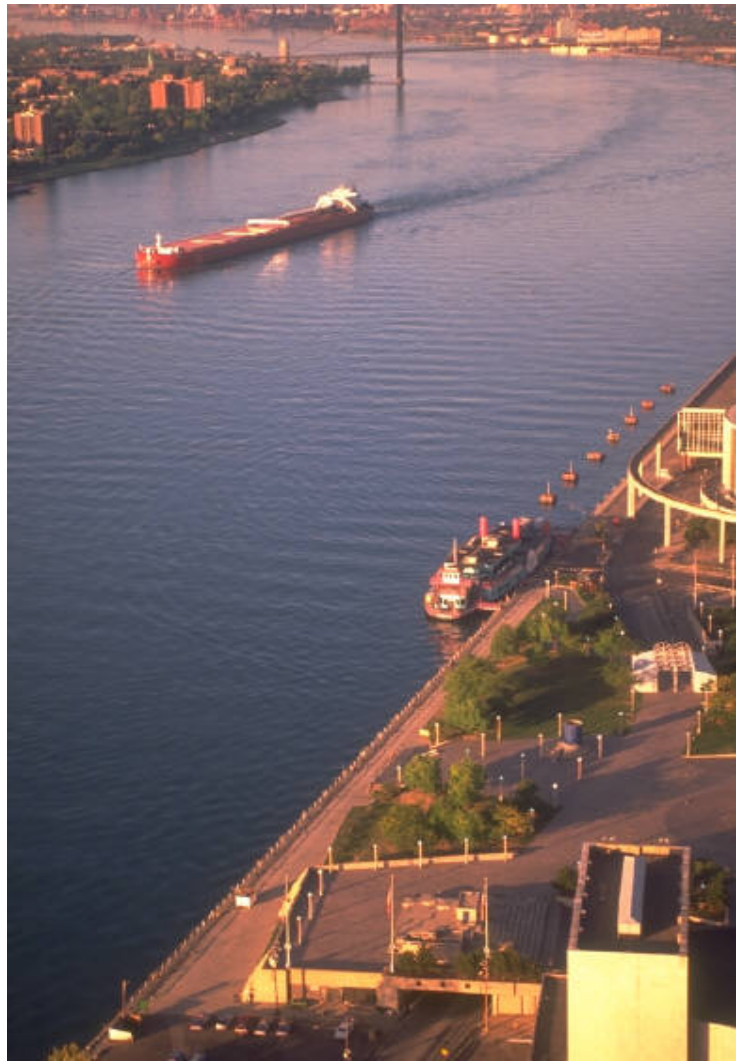
Louisville, Ky

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



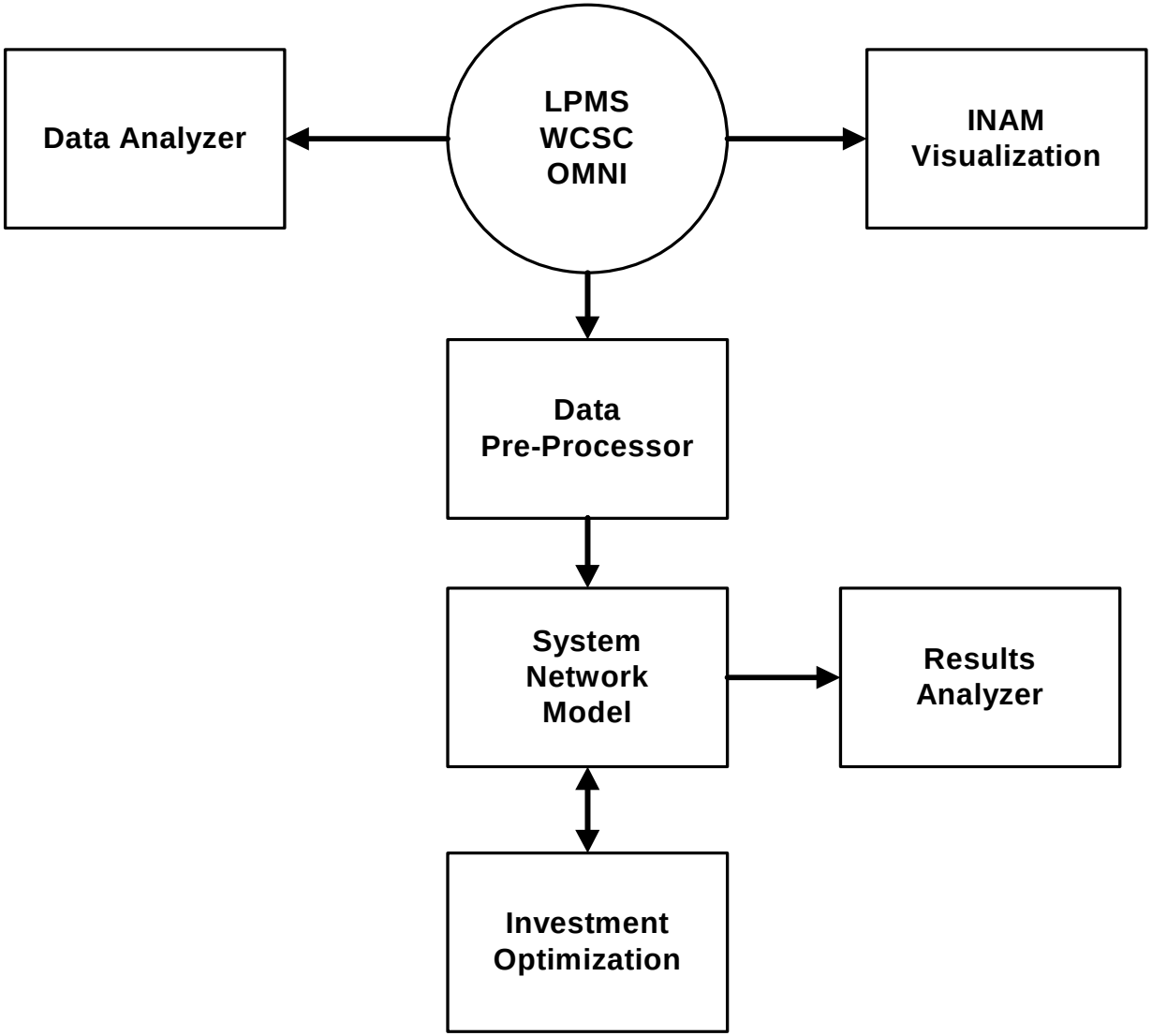
Potential Questions of a System Model

- 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

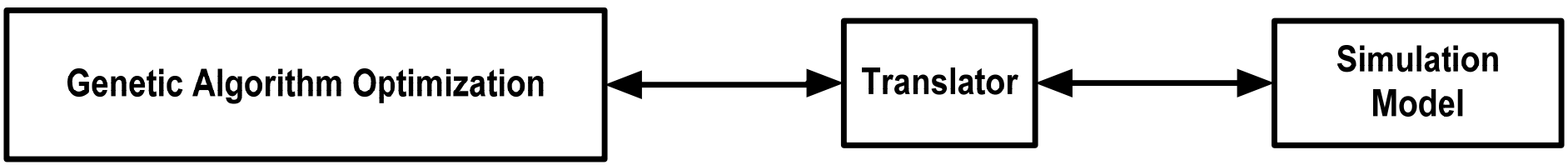


Investment Optimization Model

- 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

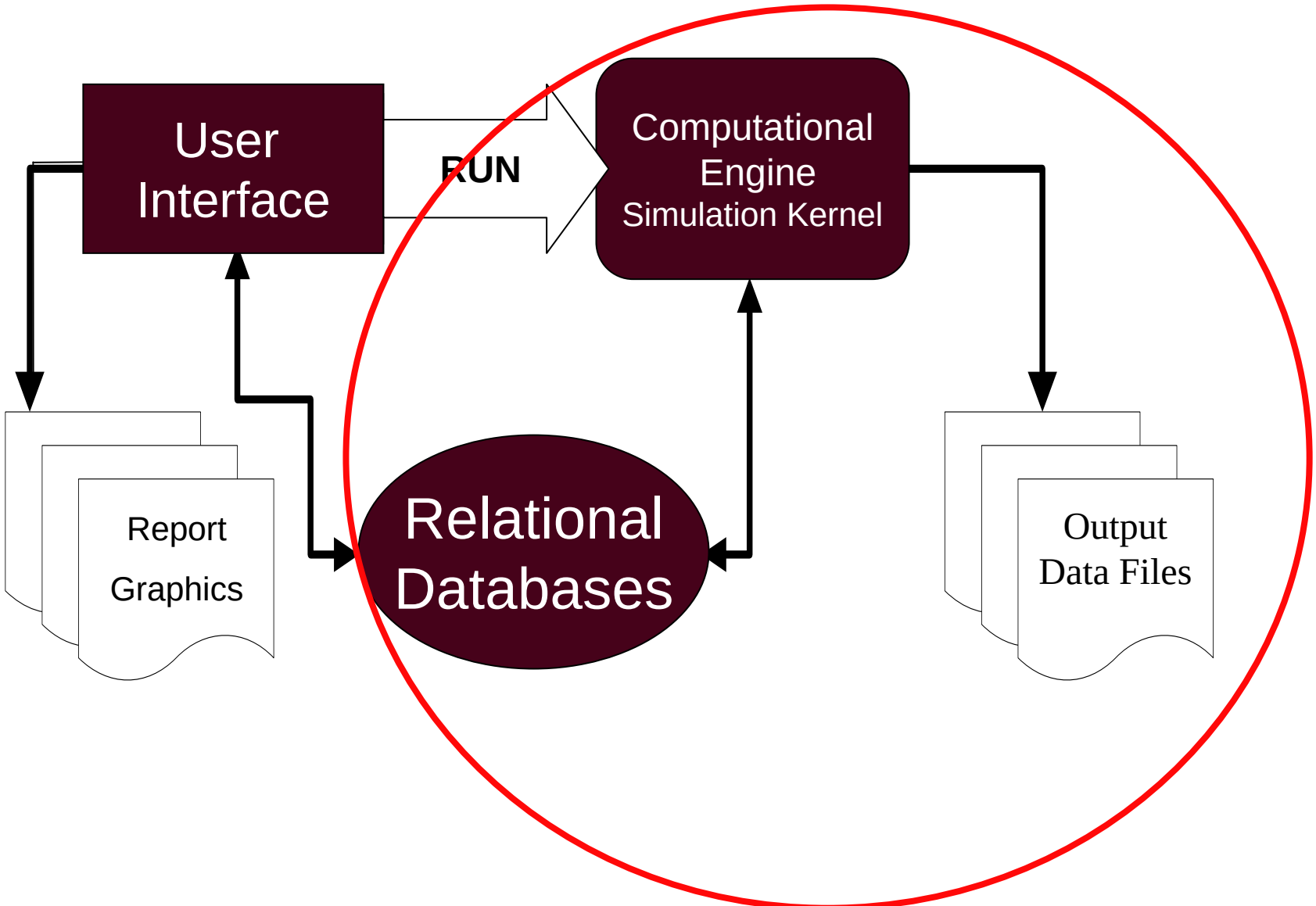
- Develop 1st generation chromosomes (solutions) randomly
- Evaluate fitness of each through simulation model
- Select best solutions for genetic refinement
- Modify "fittest" chromosomes to develop 2nd generation
- *Process continues until termination rule is true*
  - Max number of iterations or evaluated 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

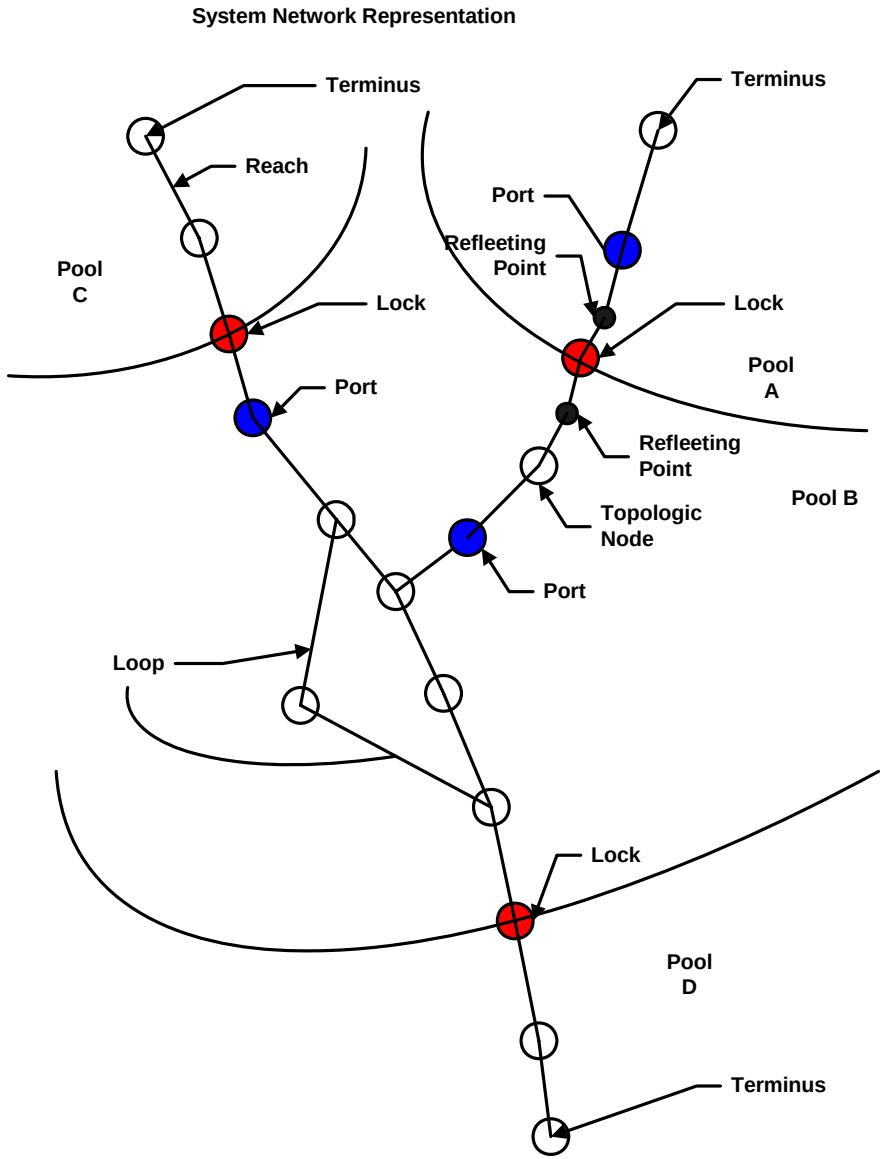
Architecture



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



Vessel Classification

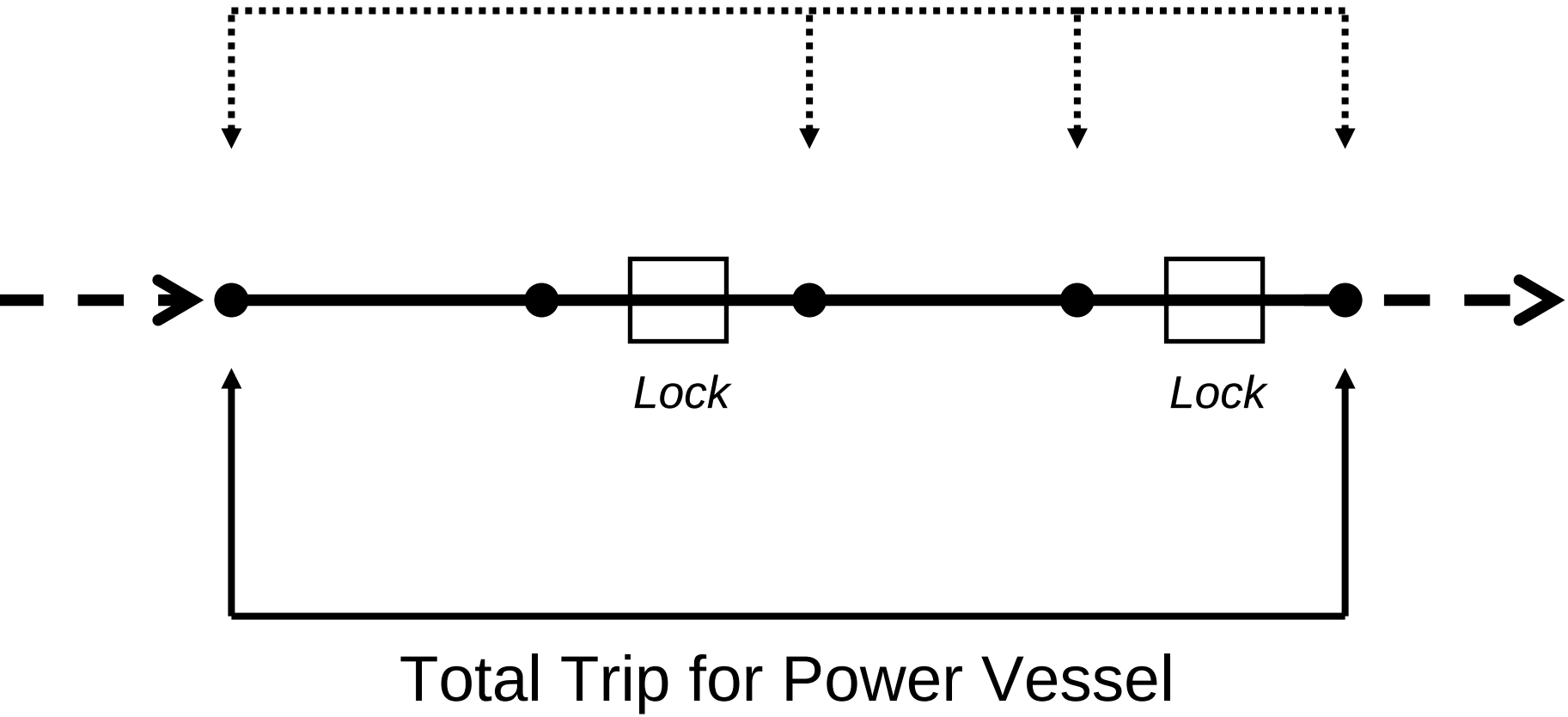
- Powered vessel fleet – a list of unique power vessels available for use in simulation
- Barge class / sub-class hierarchy
  - Class: Hopper | Sub-Class: Jumbo
- Vessel Attributes
  - Default vessel attributes
    - Horsepower (if a powered class)
    - LOA, Beam, Draft, Capacity
    - Commodities carried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

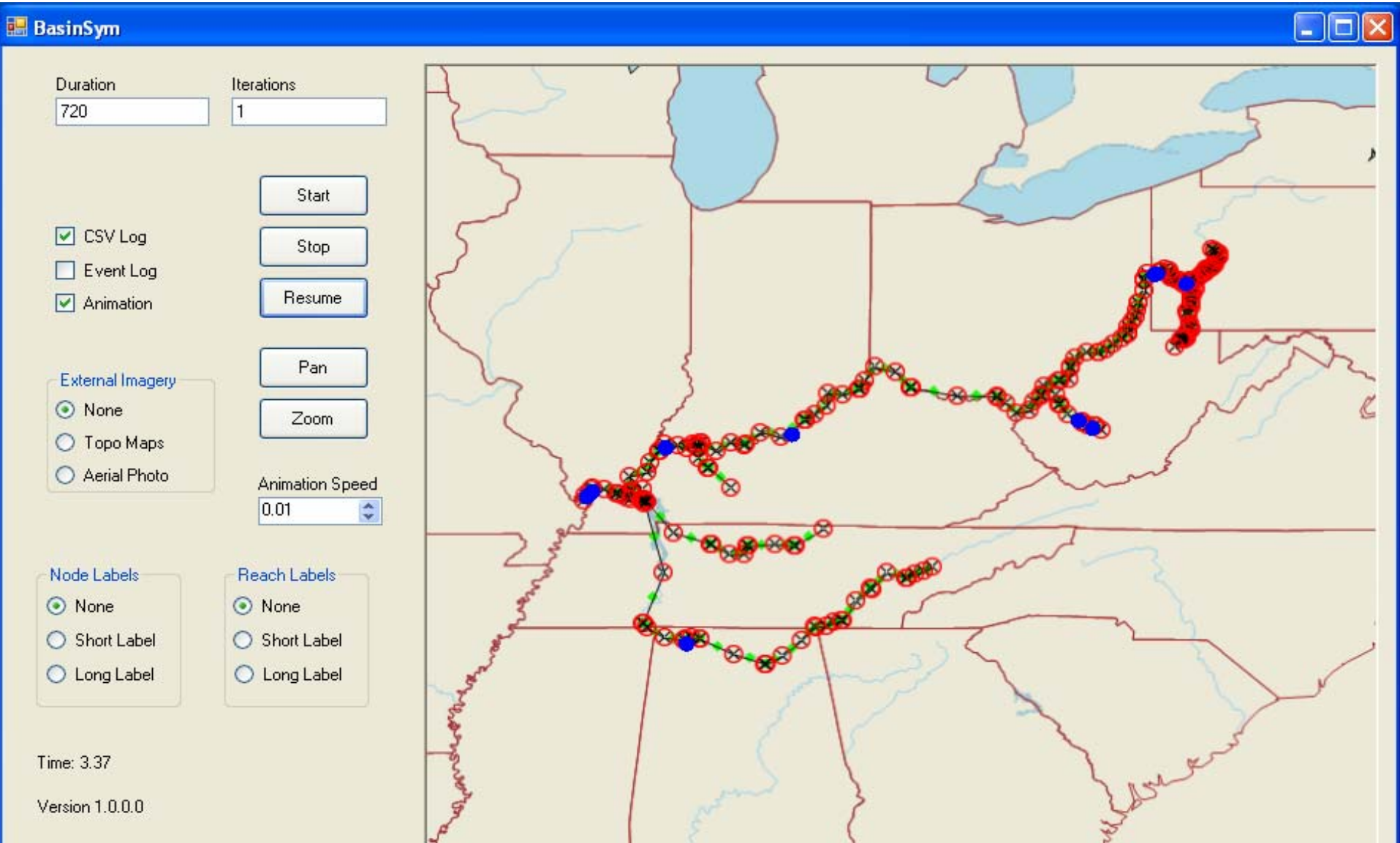
- Tow Reconfiguration
- Commodity Transfer Operations
- Vessel Speed in Reach
- Lockage Processing
- Component Based Reliability
  - Probability of Failure
  - Duration of Outage

- 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

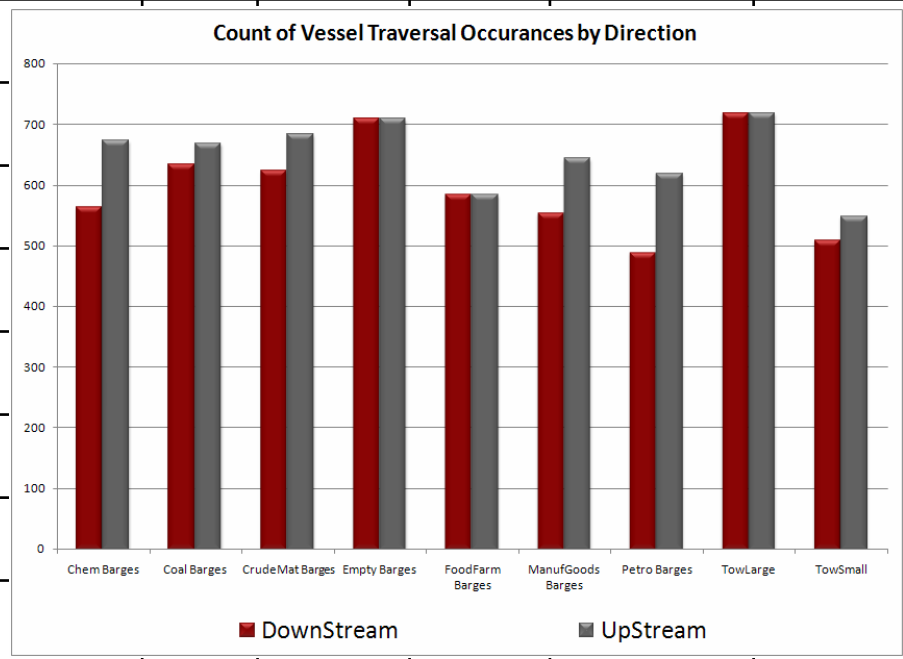
Simulation User Interface



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
1	120						
1	120						
1	120						
1	211						
1	211						
1	147						
1	147						
1	147						



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

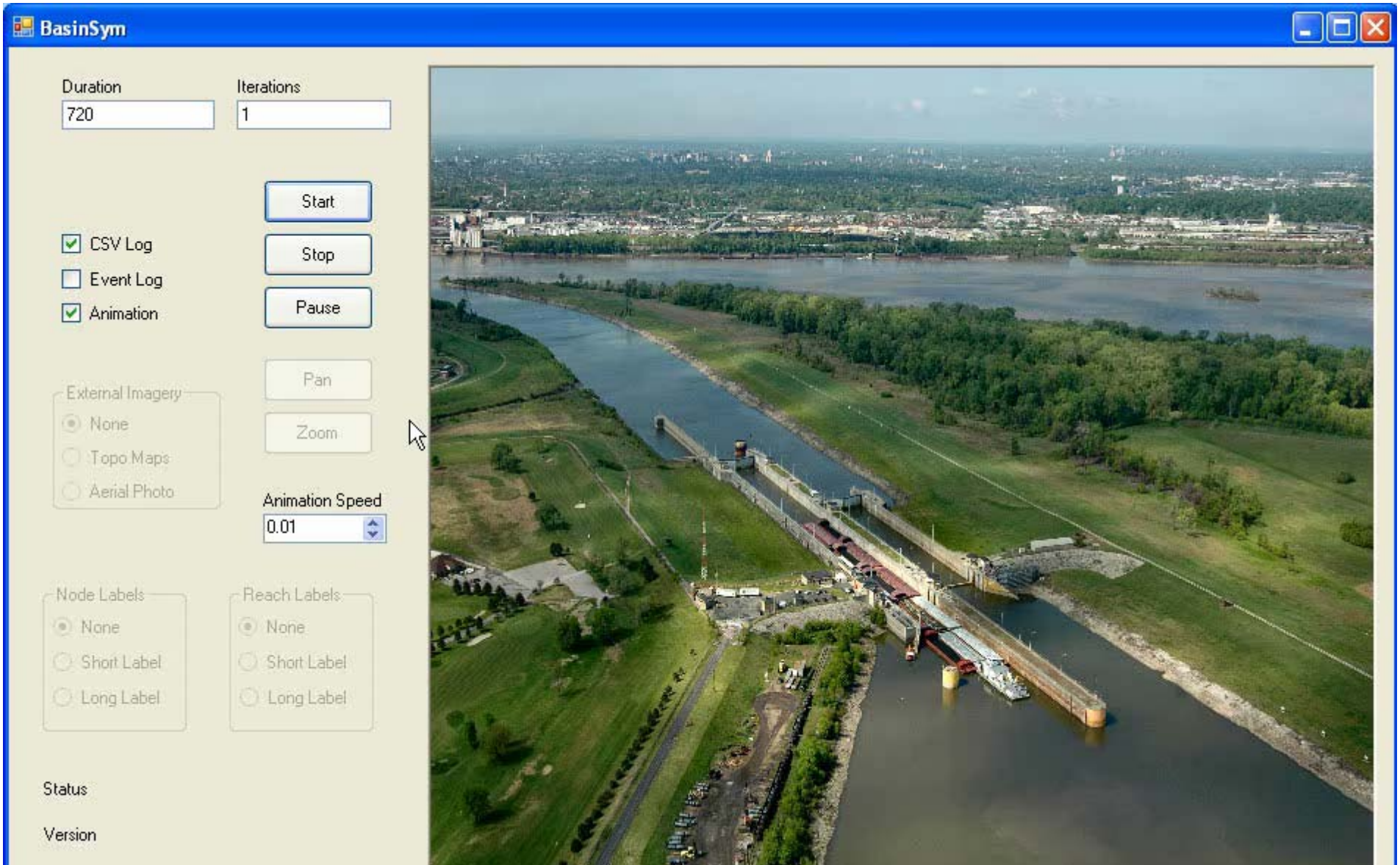
Current Status

- 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



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