Interfacing ACT-R and the X-Plane Flight Simulator

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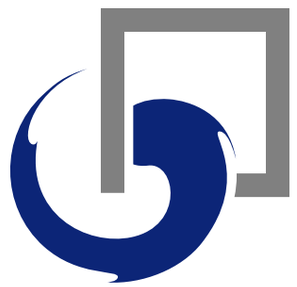
Overview

- The research problem
- The environment
- Our solutions
- Open issues

Research Problem

- Surface traffic management is a critical concern for NextGen
  - Goal: optimize timing and route for each plane
  - Too computationally difficult for human controllers
  - Exacerbated by increasing amount of surface traffic
- FAA and NASA developing algorithms to calculate optimal routes
- HITL experiments with ground controllers
  - Require many participants to act as “pilots” to ensure simulation fidelity
- Large-scale computer simulations
  - No dynamic models of human pilots
  - Simulated pilots react in zero time, perfectly predictably



The Environment

- Taxiing a 737 from gate to takeoff
- Unique opportunity to validate ACT-R model against not subjects in simulations, but actual operational data
  - Compare with extensive data taken from real operations at DFW airport (SODAA data)
- How to use these extensive data?
- Environment plays a huge role in shaping behavior
  - Aircraft physics
  - Location of signs and routes
  - Other agents: aircraft, ground controllers, surface traffic
- How to hook ACT-R up to this rich and complex environment?

X-Plane

- Commercially available and affordable medium-fidelity ("award winning" too, I'm sure) flight simulation environment
- Has plugin architecture; we use two plugins:
  - Load and run SODAA data, reproducing a slice of real time at DFW airport
    - Can "take out" one real aircraft, replace with plane driven by ACT-R
  - Communicate with Lisp environment
    - Location and state of ownship controlled by ACT-R
    - Locations, orientations, and some properties of all other aircraft
    - The **big** limitation: cannot "see" out the window!

LAN LIGHT
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NAV LIGHT
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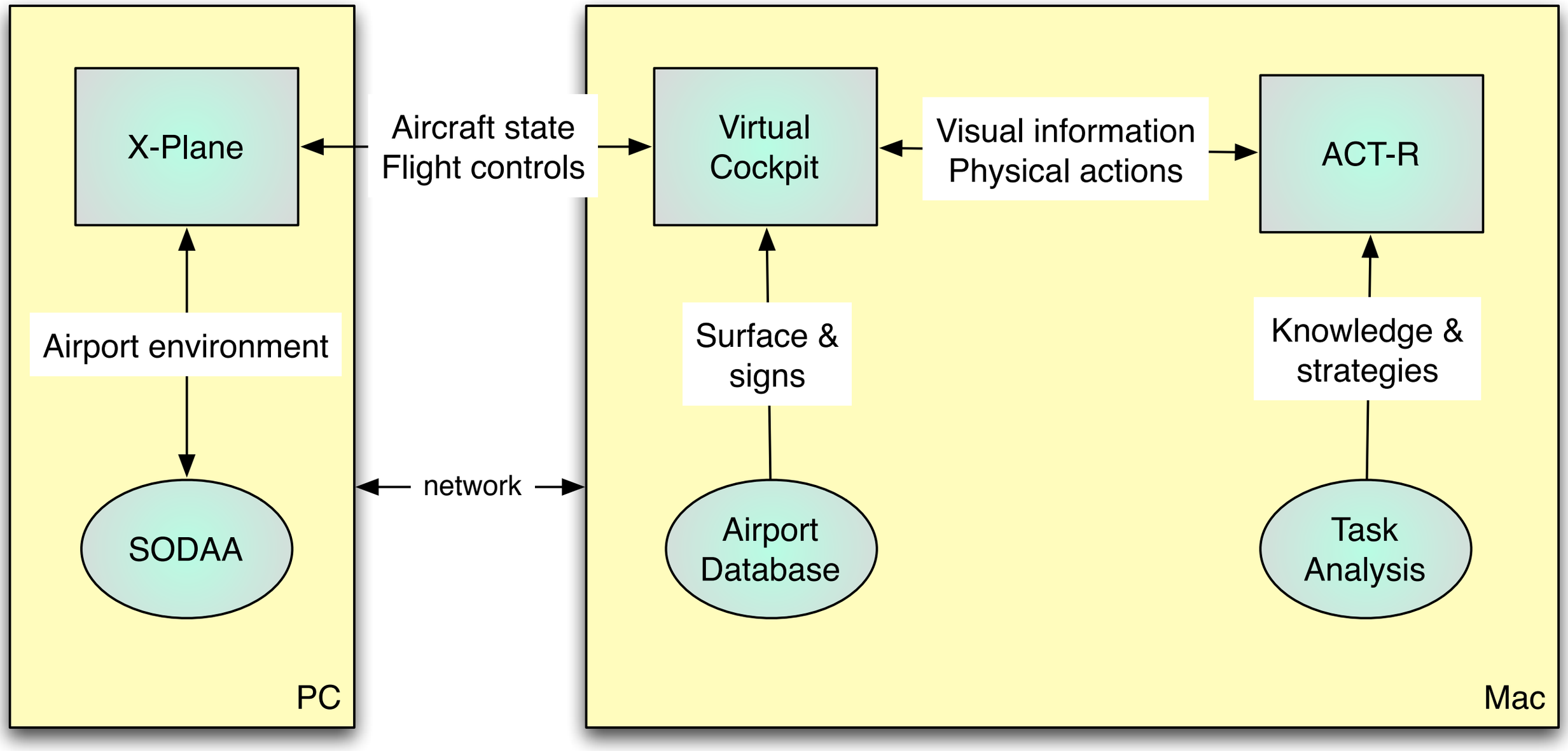
Our Solution



The "Virtual Cockpit"

- A software object in between ACT-R and X-Plane
  - An ACT-R "device"
- Gets information from X-Plane
  - Location and state of aircraft, detailed info about ownship
- Renders visual world for ACT-R to see
  - Constructs instrument panel based on X-Plane values
  - Renders out-the-window view
    - Driven by database describing taxiways, signage, etc.
    - Combined with location information from X-Plane
- Relays commands given by ACT-R to X-Plane
  - Throttle, brake, and yoke adjustments

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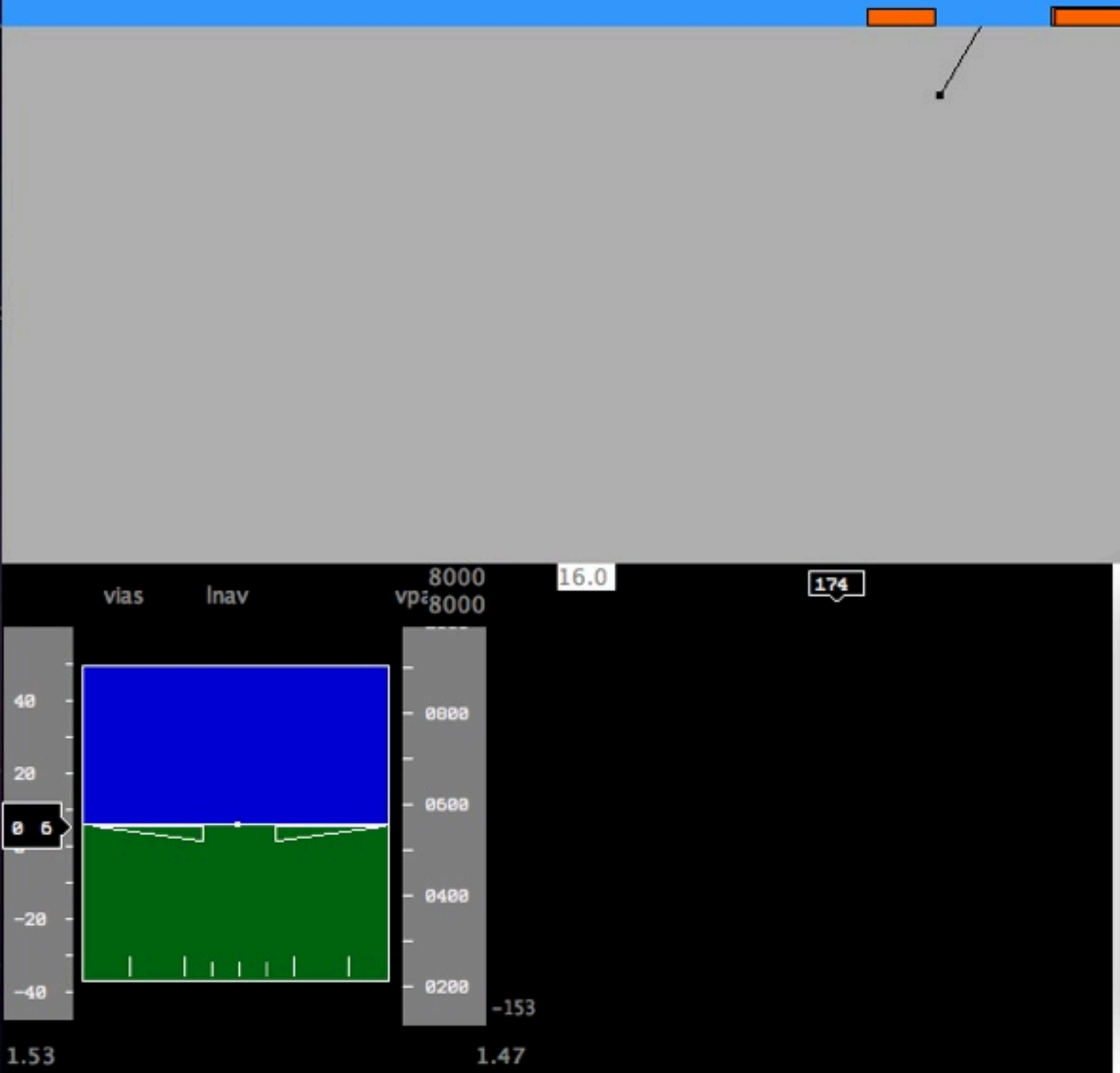
3X-TREAM Virtual Cockpit



Listener

```
   147.335   PROCEDURAL            PRODUCTION-FIRED SCTX-NEXT-GOAL
   147.335   PROCEDURAL            MOD-BUFFER-CHUNK GOAL
   147.335   PROCEDURAL            CONFLICT-RESOLUTION
   147.335   PROCEDURAL            PRODUCTION-SELECTED POP-START
   147.335   PROCEDURAL            BUFFER-READ-ACTION GOAL
   147.335   PROCEDURAL            QUERY-BUFFER-ACTION RETRIEVAL
   147.385   PROCEDURAL            PRODUCTION-FIRED POP-START
   147.385   PROCEDURAL            MOD-BUFFER-CHUNK GOAL
   147.385   PROCEDURAL            MODULE-REQUEST RETRIEVAL
   147.385   PROCEDURAL            CLEAR-BUFFER RETRIEVAL
   147.385   DECLARATIVE           START-RETRIEVAL
   147.385   PROCEDURAL            CONFLICT-RESOLUTION
   147.500   NONE                  UPDATEVC
147.50, 147.91, -0.41
   147.500   VISION                SET-BUFFER-CHUNK VISUAL-LOCATION VISU
   148.000   NONE                  UPDATEVC
```

CL-USER Busy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3X-TREAM Virtual Cockpit

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1.47

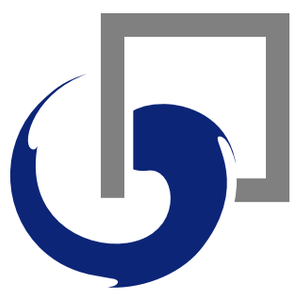
Listener

```
60.670   VISION       Find-location
60.670   VISION       FIND-LOC-FAILURE
60.670   PROCEDURAL   CONFLICT-RESOLUTION
60.670   PROCEDURAL   PRODUCTION-SELECTED FIND-FAILURE-VISLOC
60.670   PROCEDURAL   BUFFER-READ-ACTION GOAL
60.670   PROCEDURAL   QUERY-BUFFER-ACTION VISUAL-LOCATION
60.720   PROCEDURAL   PRODUCTION-FIRED FIND-FAILURE-VISLOC
60.720   PROCEDURAL   MOD-BUFFER-CHUNK GOAL
60.720   PROCEDURAL   CONFLICT-RESOLUTION
60.720   PROCEDURAL   PRODUCTION-SELECTED SEARCH-FOR-RED-SIGN
60.720   PROCEDURAL   BUFFER-READ-ACTION GOAL
60.770   PROCEDURAL   PRODUCTION-FIRED SEARCH-FOR-RED-SIGN
60.770   PROCEDURAL   MOD-BUFFER-CHUNK GOAL
60.770   PROCEDURAL   MODULE-REQUEST VISUAL-LOCATION
60.770   PROCEDURAL   CLEAR-BUFFER VISUAL-LOCATION
```

CL-USER Busy

Issues

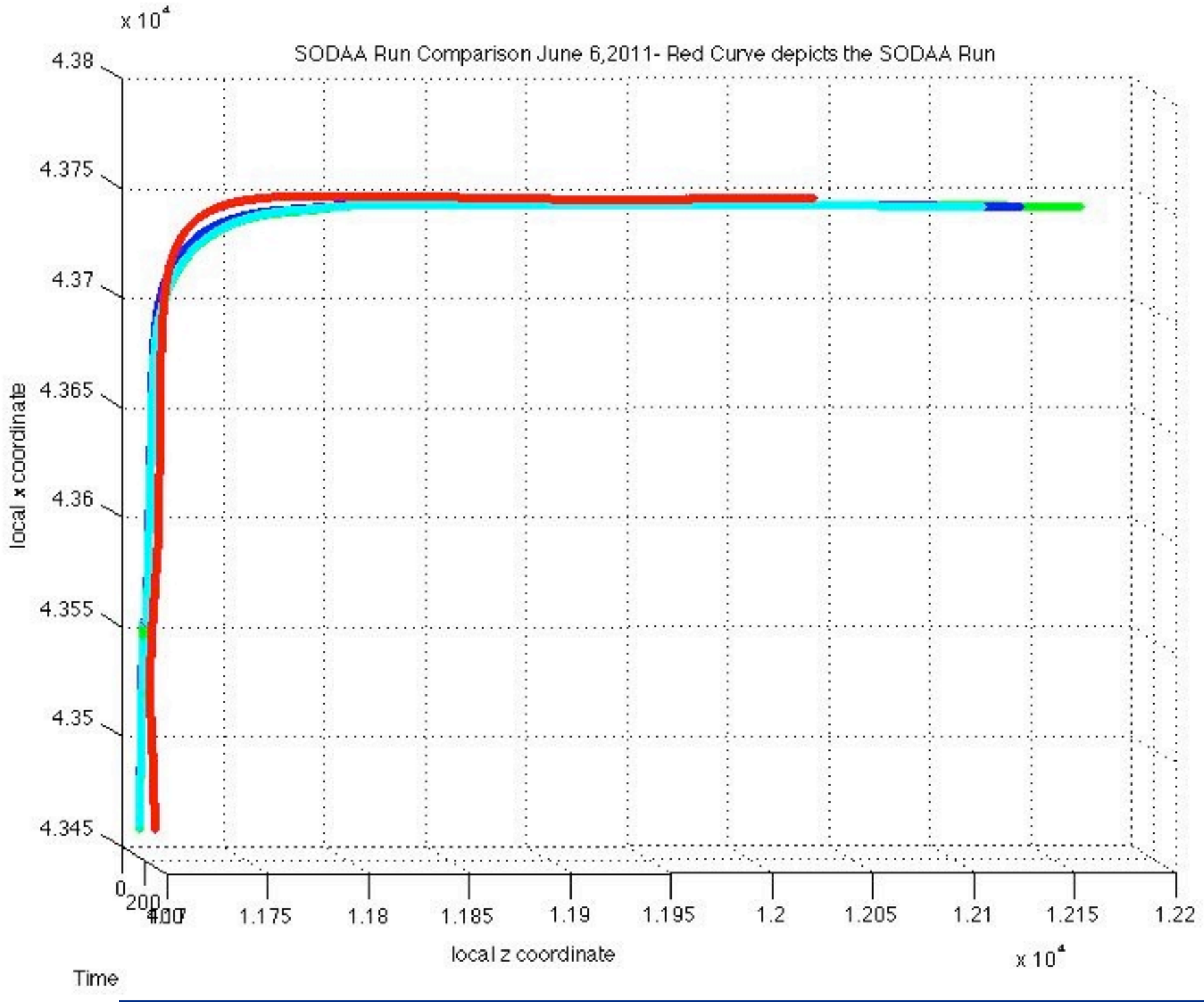
- Mostly, it “works” pretty well
  - That leaves rather a lot of room for improvement
- Two biggest problems are labor and time
- Labor
  - Mapping out sections of the airport taxi surface is labor-intensive
    - Not just taxiways and signs, but locations of intersections and other visual markers that are needed by the model
  - Not a lot of shortcuts here



Time

- X-Plane runs only in real time
- ACT-R generally has no problem keeping up with this
  - Even running RMCL on an Intel machine
- Biggest problem is indeterminism (and lag) in communication between Lisp and X-Plane
  - Sometimes, requests come back very quickly
  - Other times, it can take X-Plane/the network hundreds of milliseconds to return with a state update
  - Doing a full redraw and PROC-DISPLAY isn't terribly fast, either
- We handle this by periodically launching another Lisp process to ask for an update
  - That process updates when ready, so ACT-R doesn't wait

So, How's It Working?



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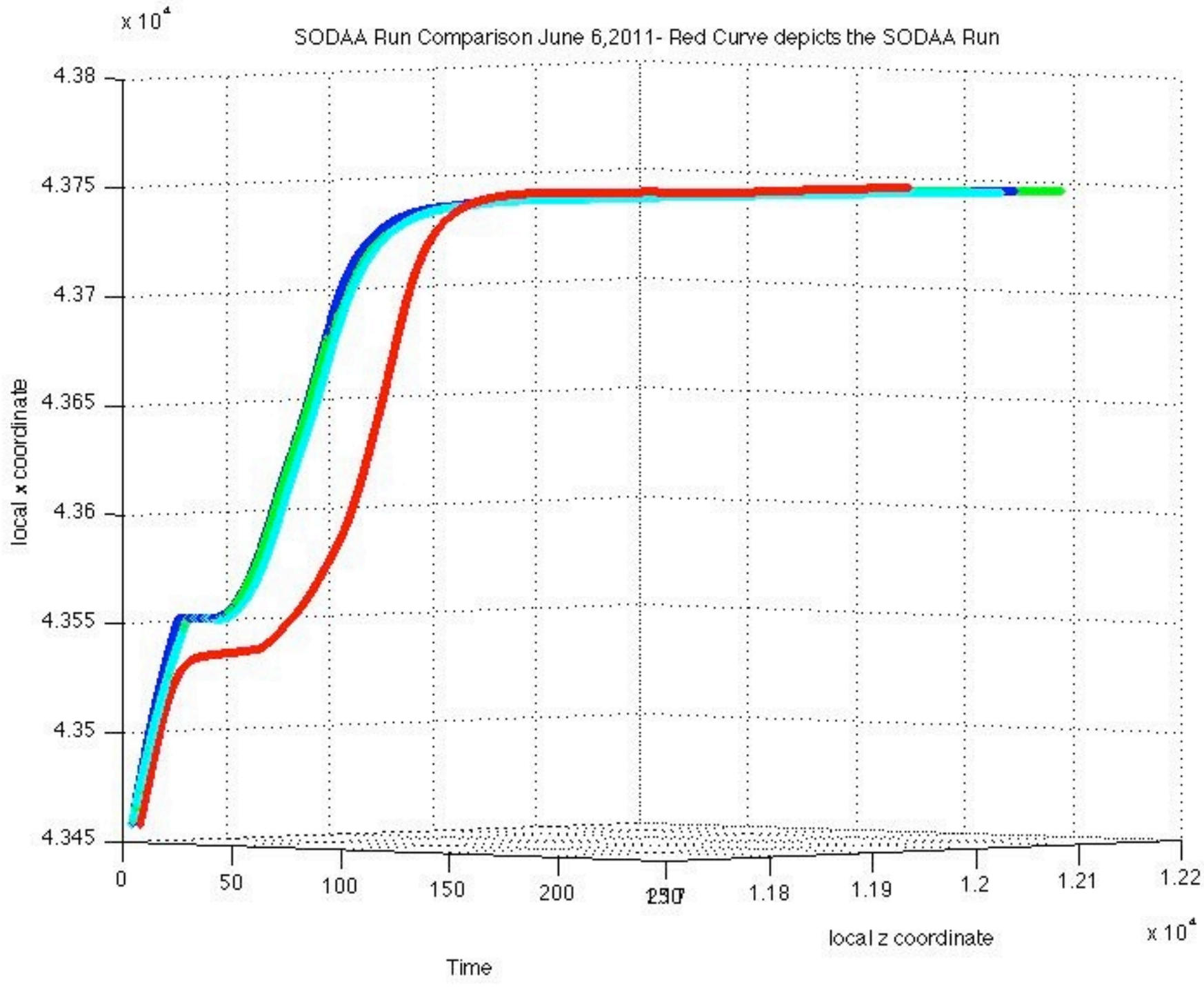

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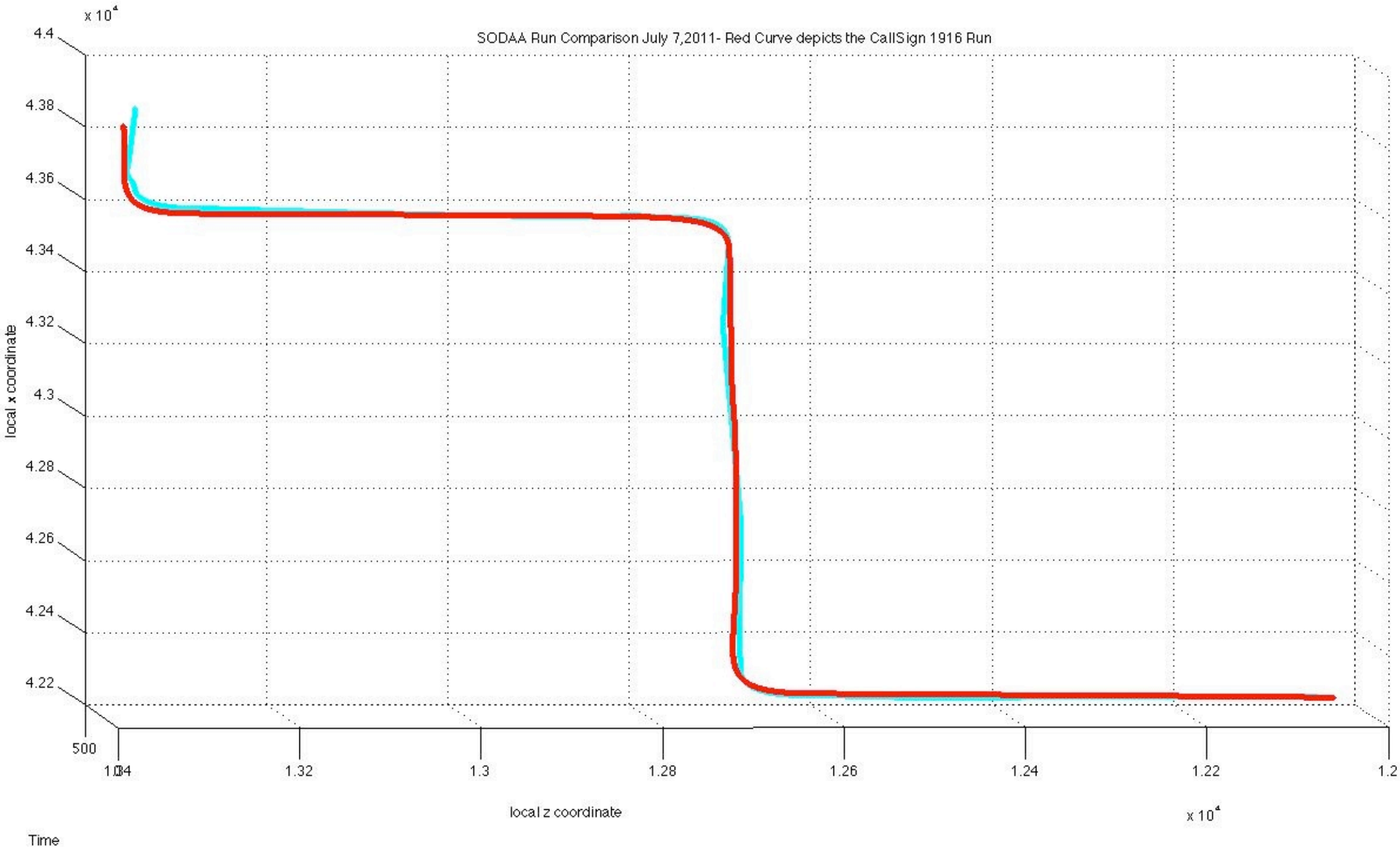

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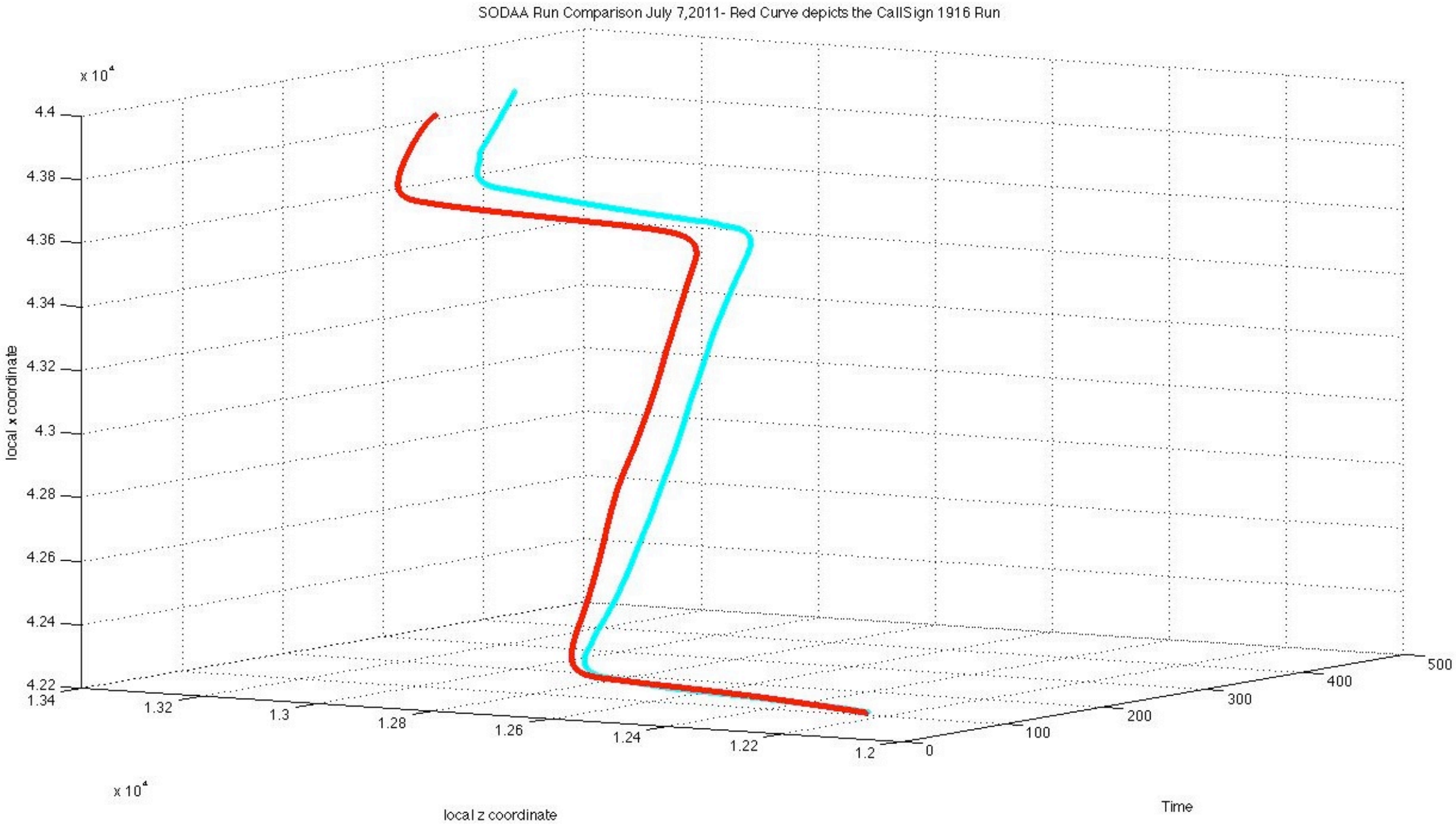

Questions?