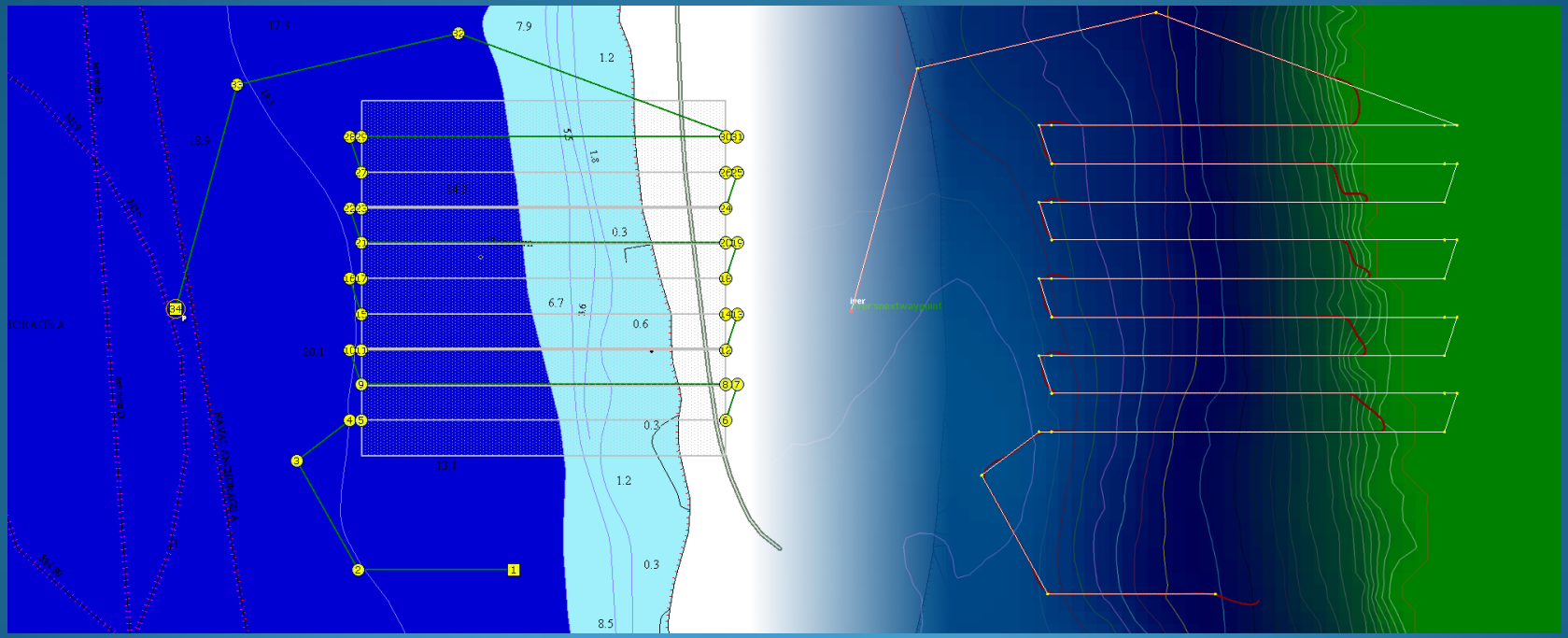
Exploring Hybrid Autonomy on the OceanServer Iver2 AUV



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Overview

- MOOS-IVP Background
- Hybrid autonomy
- Requirements
- Implementation Approach
- Development
- Results

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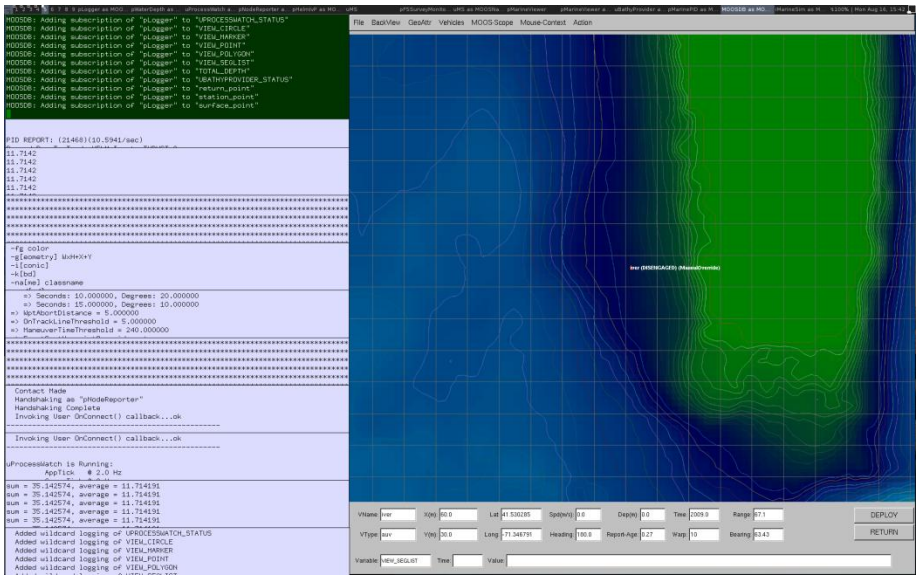
Typical MOOS-IvP Usage

- Very capable platform for vehicle control
  - MOOS Suite
    - Core IPC and program control
  - IvP Modules
    - Advanced autonomy capabilities
  - Portable between various AUVs
  - Extremely configurable and customizable
    - Great for developers!
- “Backseat Driver” approach
  - Leverage vehicle-specific manual control facilities

“Back Seat Driver” Workflow

1. Determine LL origin
2. Configure .moos file
3. Configure .bhv file
4. Simulate mission
5. Deploy to vehicle



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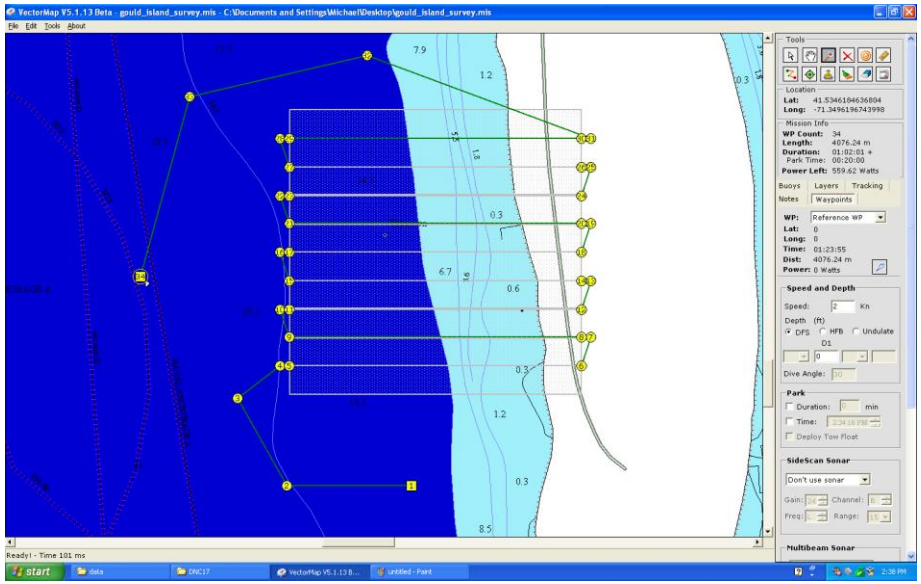
“Front Seat Driver” Workflow

- Vehicle-specific workflow
- IVER2
  1. Open VectorMap
  2. Import geo-referenced map
  3. Plan mission waypoints
  4. Configure sensors
  5. Deploy to vehicle



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Hybrid Autonomy

- Utilize front seat and back seat computers
- Vehicle control swaps as needed
- Front seat typically in control of vehicle
- Back seat monitoring for engagement conditions
  1. Back seat requests vehicle control from front seat driver
  2. Vehicle maneuvers under back seat control
  3. Back seat relinquishes control and resumes monitoring

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Hybrid Autonomy

- Short term advantages
  - Rapid planning capability provided by vendor
  - Mission-specific advanced configurability of MOOS-IvP
- Disadvantages
  - Scope of applicable behaviors
  - Potential portability issues (varying FS<->BS interface)

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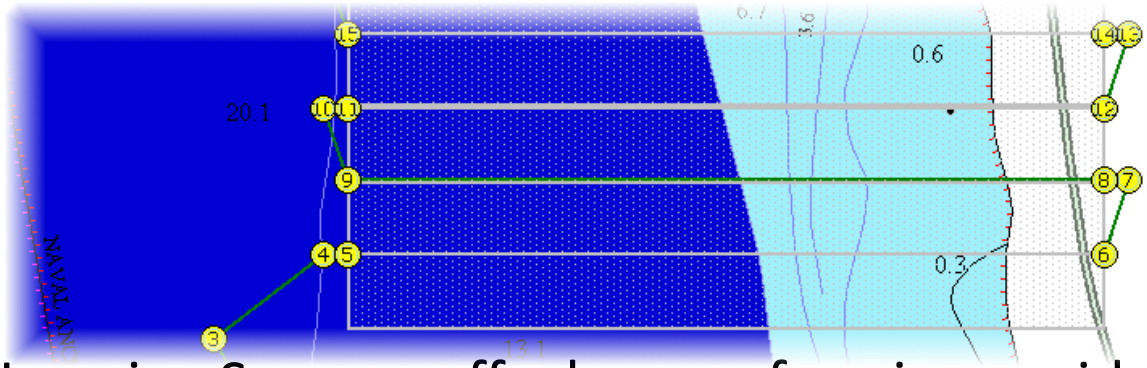
Requirements

- AUV end-users purchasing vehicles from vendor
  - Familiar with manufacturer-supplied vehicle control capabilities and mission planning software
    - “Front Seat Driver” (VectorMap + UVC in Iver2)
- By default, sensors controlled via front seat computer
  - Sensor activation-deactivation determined by waypoint
- End users also want enhanced capabilities
  - May or may not match up with vendor development goals
- How can we enhance the existing capabilities of the vehicle when the code is owned by the manufacturer?

Requirements

- Our particular requirements:
  - Retain front seat mission planning capability
  - Safely execute ladder survey in shallow water
    - Vehicle turns to avoid dangerously shallow areas



  - Imaging Sensors off when performing avoidance maneuvers
    - Preserve vendor's existing CONOPS for sensor performance
    - Simplify processing of data for end user

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Implementation Approach

- Vendor Mission Planner (VectorMap)
  - Parse resulting mission for ladder survey waypoints
- MOOS Process – pFSSurveyMonitor
  - Monitor vehicle depth and altitude, i.e. total water depth
  - On total depth threshold violation, back seat takes control
    - Communicates with IvP Helm running waypoint behavior
    - Issues new set of backseat waypoints to drive to next track line
    - Updates front seat waypoint
      - Vehicle inherits waypoint's properties (e.g. sensors *disabled*)
      - Back Seat Driver still in control
  - Vehicle abandons current track line and maneuvers towards next survey leg

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Implementation Approach

- Continue to monitor total water depth and perform additional maneuvers if necessary
- When total water depth deemed safe:
  - Ensure vehicle is on next track line before relinquishing control to front seat
  - Update front seat waypoint to next valid waypoint
    - Vehicle inherits waypoint's properties (e.g. sensors *enabled*)

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Development Background

- Front Seat Mission Parser
  - Generates CSV output with mission waypoints
  - Indicates ladder survey number and whether waypoint is survey leg or turnaround leg
  - Parser must be updated if mission file format changes
- Simulation Environment
  - Front seat simulator – BHV_FrontSeatWaypoint
    - Modified BHV_Waypoint from MOOS-IvP
    - Reads preprocessed front seat mission file and generates corresponding waypoints
    - Reacts to waypoint update requests as the front seat computer does

Development Background

- Issues Encountered
  - IvPBehavior::getBufferCurrTime(…) was not returning correct time of last buffer update
    - Fixed in HEAD (r2483)
  - UTM v. LocalGrid Coordinate System
    - CMOOSGeodesy::LatLong2LocalGrid(…) or LatLong2LocalUTM(…)
    - Lots of issues getting map background to line up to waypoints when using LocalUTM
    - Vehicle local x/y coordinate system is a local 2d grid
    - Ultimately could only make LocalGrid work
  - pMarineViewer / libtiff issues
    - Backgrounds must be square!
    - Pixel count must be a power of 2

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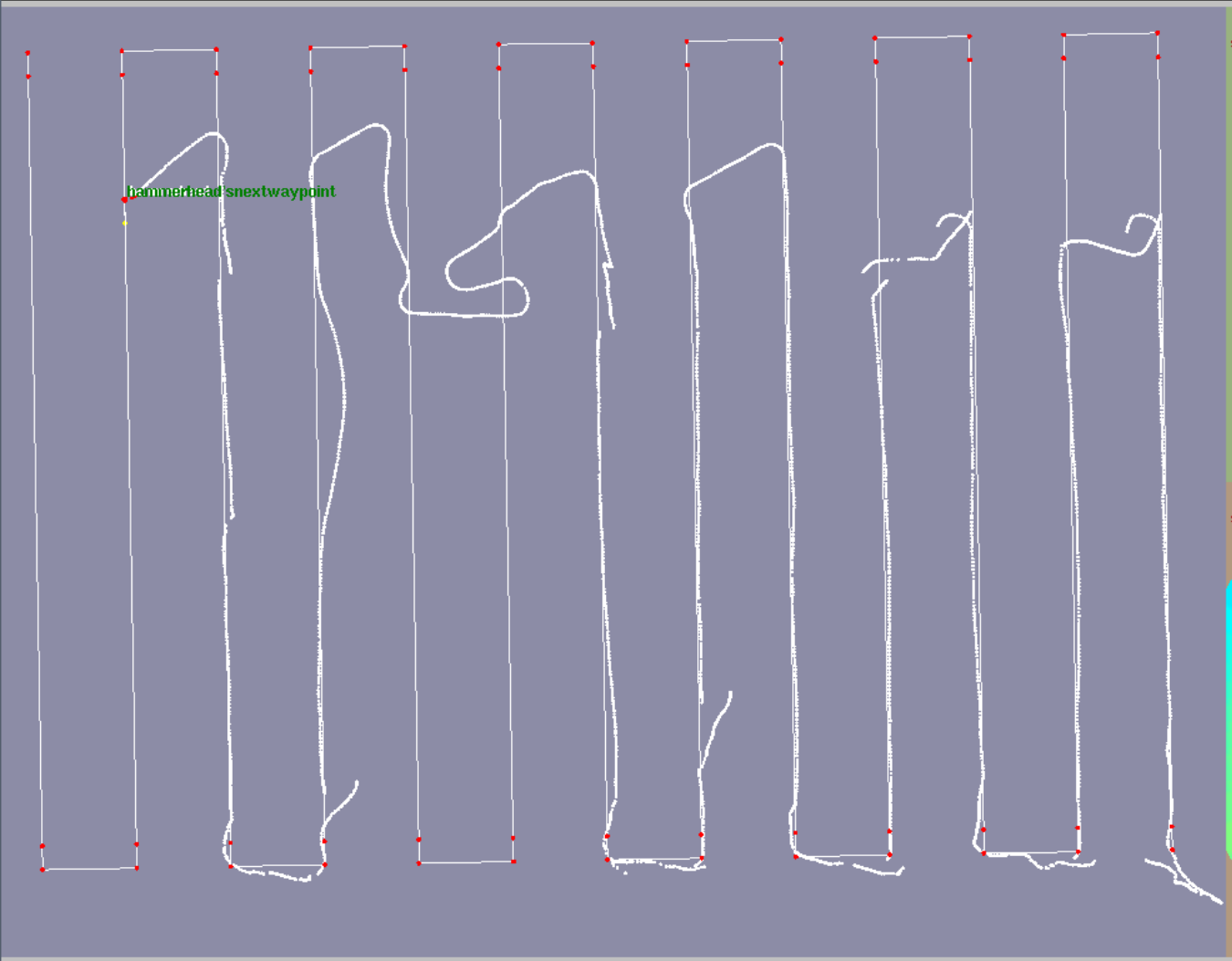
Results

- Early testing - Florida Keys
  - Shallow water
  - 2.5m depth at 300m from shore
  - Uneven bathymetry (“pools” where vehicle can get stuck)

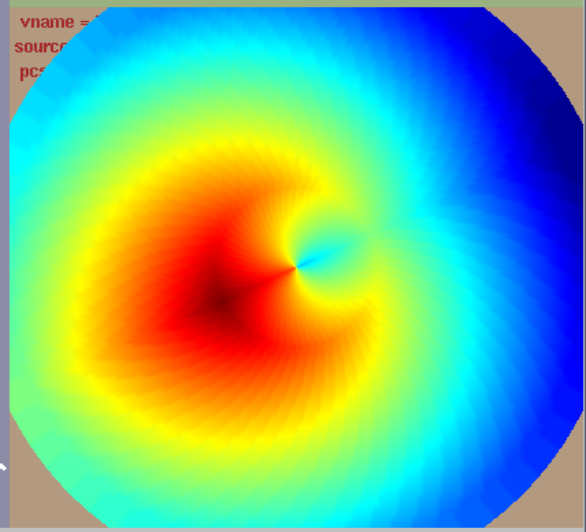
File BackView GeoAttr Vehicles Replay LogPlots(L) LogPlots(R) HelmPlots IPFPlots(Top) IPFPlots(Bot)



vname = hammerhead (11328)
source = deploy_depth
pcs = 3

No Function on Helm Iteration #11328

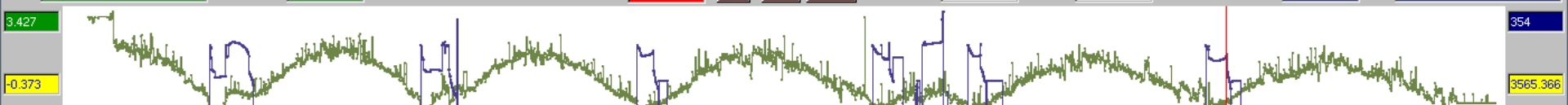
vname =
source
pcs



Vehicle:	11328-hamm	Mode:	none	Decision:	course=246.0, depth=1.0, speed=1.0		
Active:	waypt_depthavoidance, deploy_depth						
Running:	none						
Idle:	waypt_return						
Complete:	none						

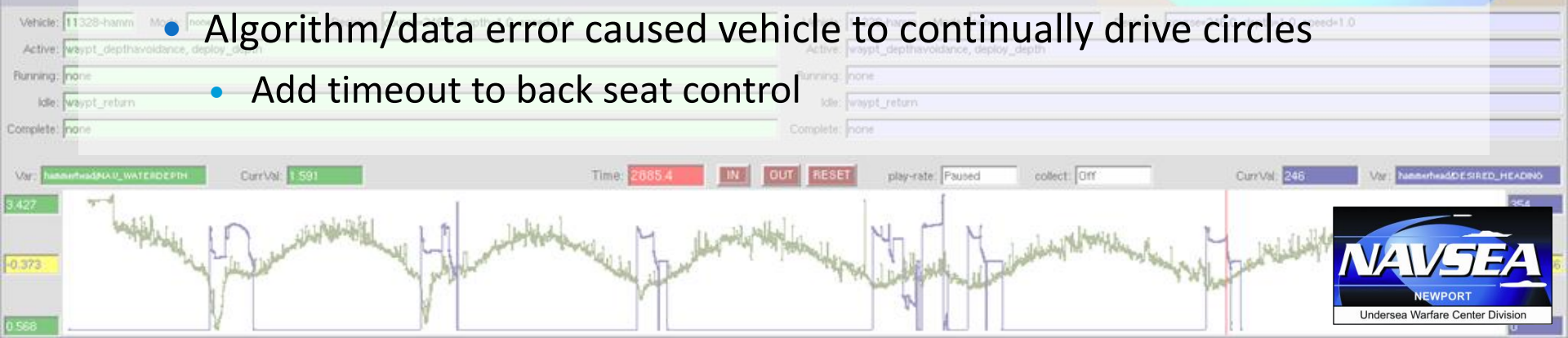
Vehicle:	11328-hamm	Mode:	none	Decision:	course=246.0, depth=1.0, speed=1.0		
Active:	waypt_depthavoidance, deploy_depth						
Running:	none						
Idle:	waypt_return						
Complete:	none						

Var: hammerhead/NAV_WATERDEPTH CurrVal: 1.591 Time: 2885.4 IN OUT RESET play-rate: Paused collect: Off CurrVal: 246 Var: hammerhead/DESIRED_HEADING



Results

- Issues
  - YSI sensor reports 999 feet when bottom lock lost
    - Detect this and don't post incorrect value
  - Vehicle often turns back towards shore during maneuver
    - Offset perpendicular track line intersection by fixed amt (10m)
  - Vehicle prematurely capturing waypoint
    - Set BHV_Waypoint nm_radius=0
  - Vehicle violates threshold again after reaching next trackline
    - Disable maneuvering on outbound legs
  - Algorithm/data error caused vehicle to continually drive circles
    - Add timeout to back seat control



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Results

- Follow-on testing – Mackerel Cove, Jamestown, RI
  - Implemented changes resulting from Florida testing
  - Cleaner bathymetry in test area

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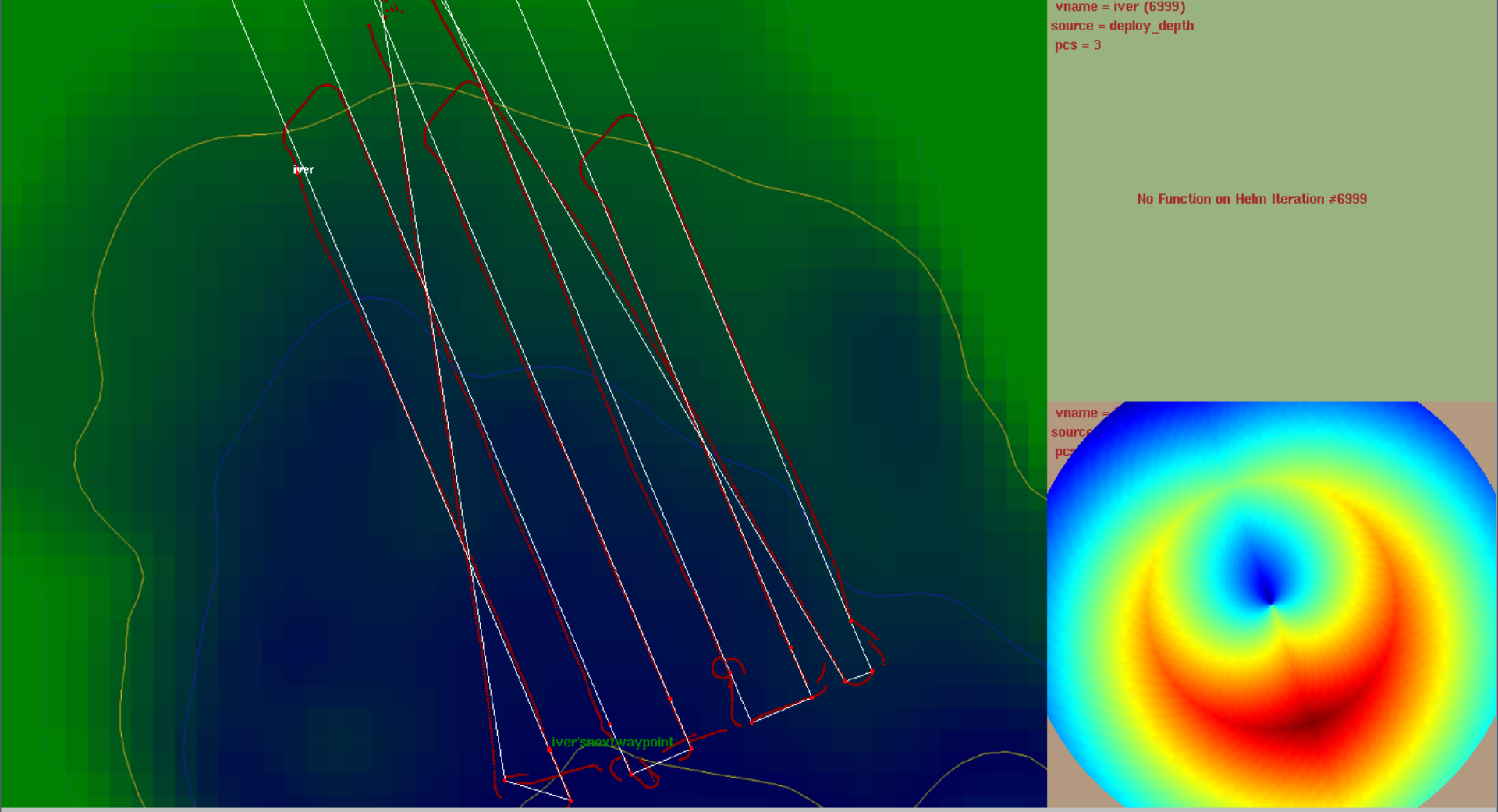
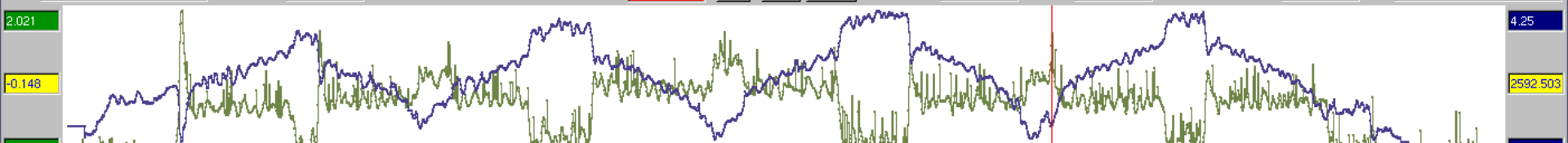


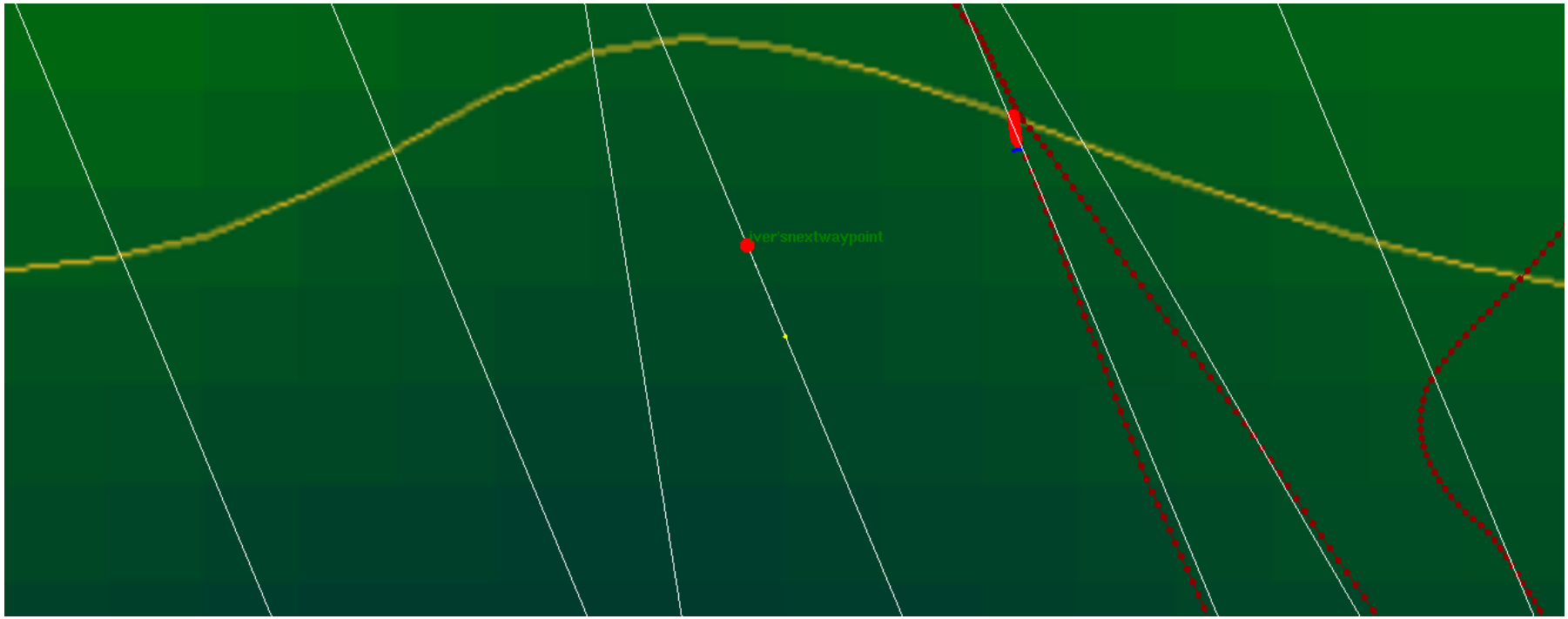
Vehicle:	6999-iver	Mode:	none	Decision:	course=157.0, depth=1.0, speed=1.0		
Active:	waypt_survey, deploy_depth, waypt_depthavoidance, deploy_depthavoidance_depth						
Running:	none						
Idle:	waypt_return						
Complete:	none						

Vehicle:	6999-iver	Mode:	none	Decision:	course=157.0, depth=1.0, speed=1.0		
Active:	waypt_survey, deploy_depth, waypt_depthavoidance, deploy_depthavoidance_depth						
Running:	none						
Idle:	waypt_return						
Complete:	none						

Var: iver/NAV_DEPTH CurrVal: 1.286 Time: 1780.4 IN OUT RESET play-rate: Paused collect: Off CurrVal: 0.94 Var: iver/NAV_ALTITUDE



Vehicle Maneuver Process



- DEPTHAVOIDANCE_STATUS
  - Throttling speed to 1.030000
  - Depth threshold violation (1.990028). Turning to 247.031809
- DEPTHAVOIDANCE_NEWPTS
  - speed=1.03#points=-97.5163,611.648:-93.6141,602.441

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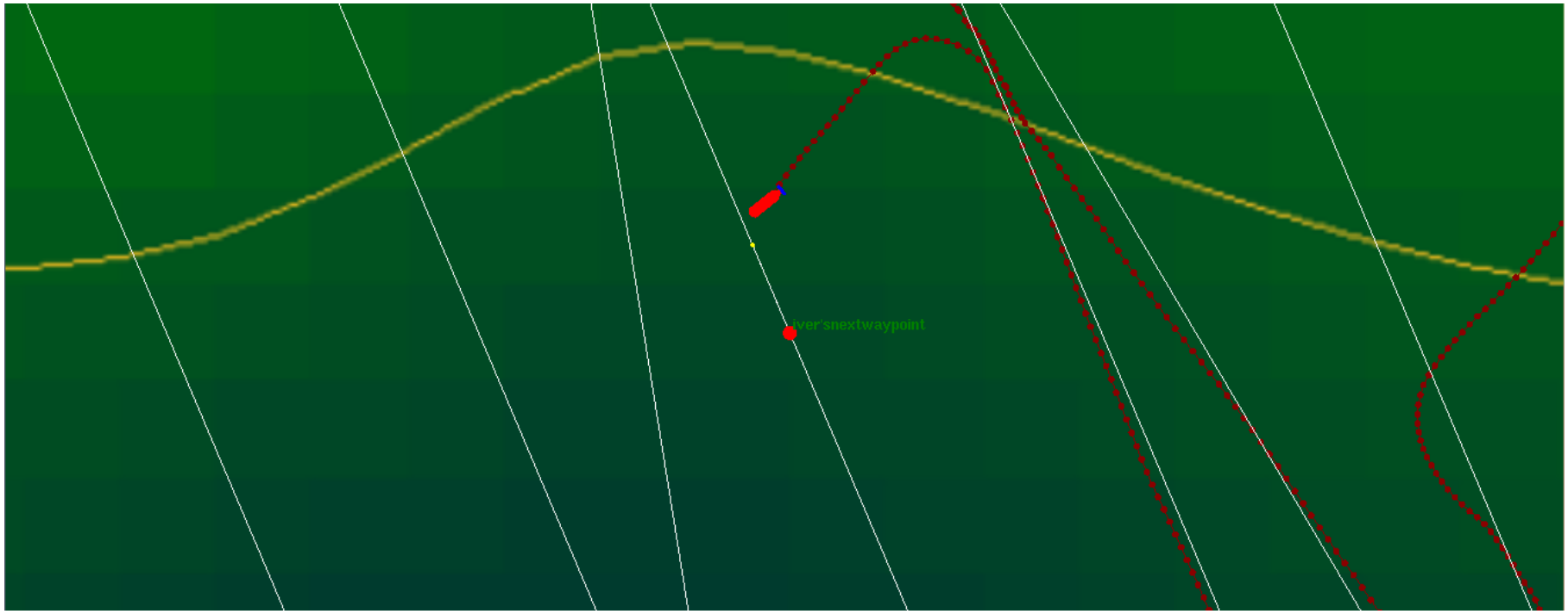
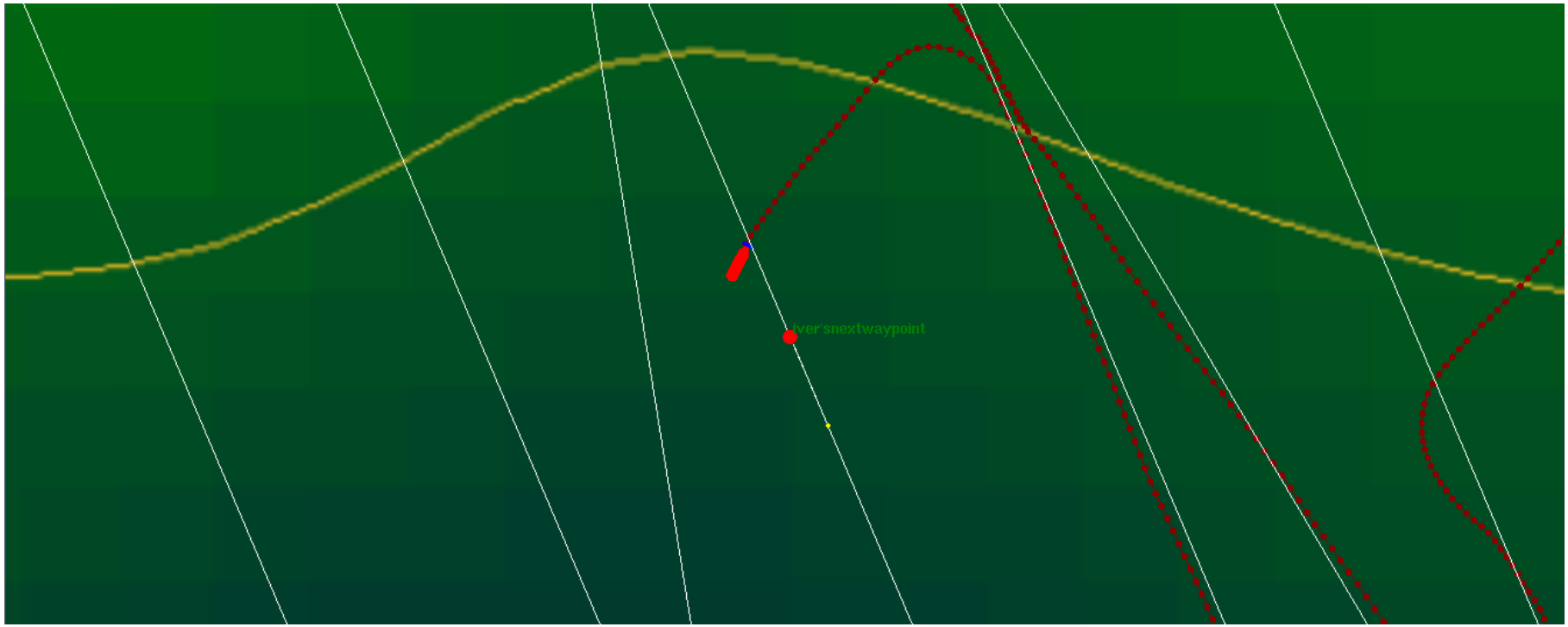
Vehicle Maneuver Process



- BHV_WAYPOINT captures first waypoint

Vehicle Maneuver Process



- DEPTHAVOIDANCE_STATUS
  - Outside depth thresholds (total depth: 2.645208, threshold: 2.490028). Maneuvering to perpendicular intersection with next track line (offset 10.000000m)
- DEPTHAVOIDANCE_NEWPTS
  - points=-93.826,602.941:-89.9238,593.734

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Vehicle Maneuver Process

- BHV_WAYPOINT captures first waypoint (again)

Vehicle Maneuver Process

- BHV_WAYPOINT captures final waypoint
- DEPTHAVOIDANCE_STATUS
  - Reached destination. Driving until clear of 2.490028 meters.

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Vehicle Maneuver Process

- BHV_WAYPOINT captures final waypoint
- DEPTHAVOIDANCE_NEWPTS
  - points=12.657,351.695

Vehicle Maneuver Process

- DEPTHAVOIDANCE_STATUS
  - Depth limit cleared (total depth: 2.466905, threshold: 2.378046). Disengaging behavior. Updating front seat waypoint to 25
- FS_NEW_WPT
  - 25

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Thanks!

Questions/Comments?

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