Physiological Based Adaptive Training

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Operator Performance Laboratory (OPL)[1], Rockwell Collins[2], U.S. Army Research Laboratory (ARL)[3]

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Introduction

- Army training difficulties
  - Changing adversary environment
    - Increasingly competitive, dangerous and cognitively intense
  - Decreasing budgets
  - Mimic one-to-one human tutoring

- Army Learning Concept (ALC)
  - Create adaptive simulation for training
  - Driven by physiological and affectual state as well as performance

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The Problem

- Current virtual training
  - Generally unable to determine trainee's cognitive workload
  - Current training systems are generally not adaptable based on trainee cognitive workload and task performance state

- What is desired for optimal training
  - Automated performance assessment
  - Automated workload and engagement assessment
  - Automated attention assessment (degree of focus)
  - Possibly assessment of affect (joy, confusion, frustration, boredom, surprise and anger)

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Physiological Based Trainee State Module

- Unobtrusive Physiological Classification and Adaptive Training (UPCAT)
  - Combination of GIFT, VBS3 and CATS
  - Advances training according to trainee performance and workload
- Generalized Intelligent Framework for Tutoring (GIFT)
  - Adaptive computer-based tutoring system
- Virtual Battle Space 3 (VBS3)
  - Serves as the simulation platform (can also be replaced with real vehicle)
  - Delivers driving performance into GIFT local tutoring process
- Cognitive Assessment Tool Set (CATS)
  - Delivers workload into GIFT local tutoring process

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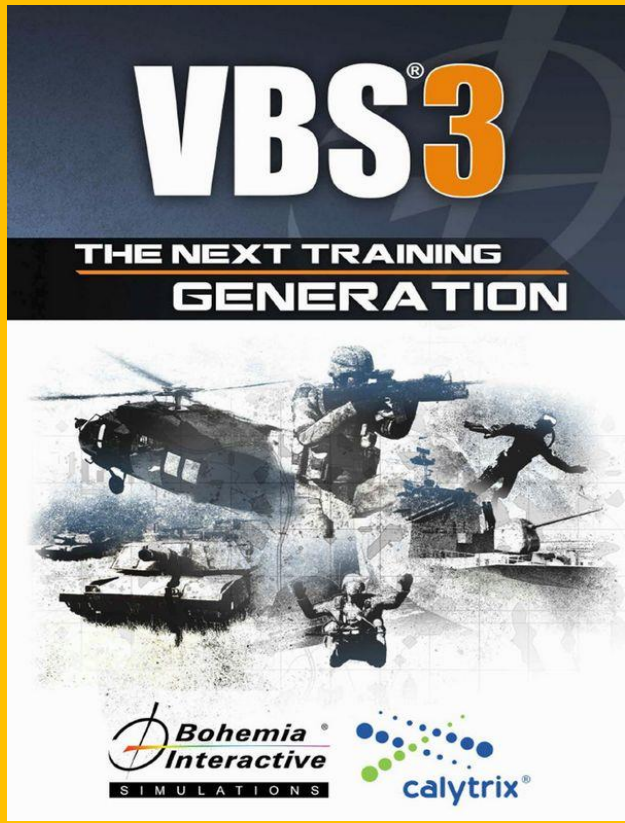
VBS3

- Game-based military simulation
- Flexible simulation training solution
- Open architecture
  - Create a custom range of training scenarios
  - Mass selection of vehicles, weapons, people and objects
- After-action reviews



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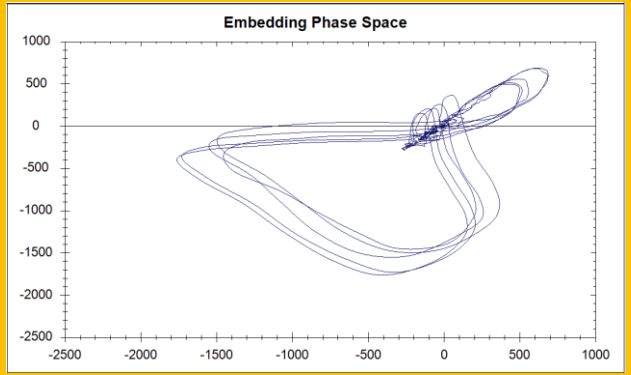
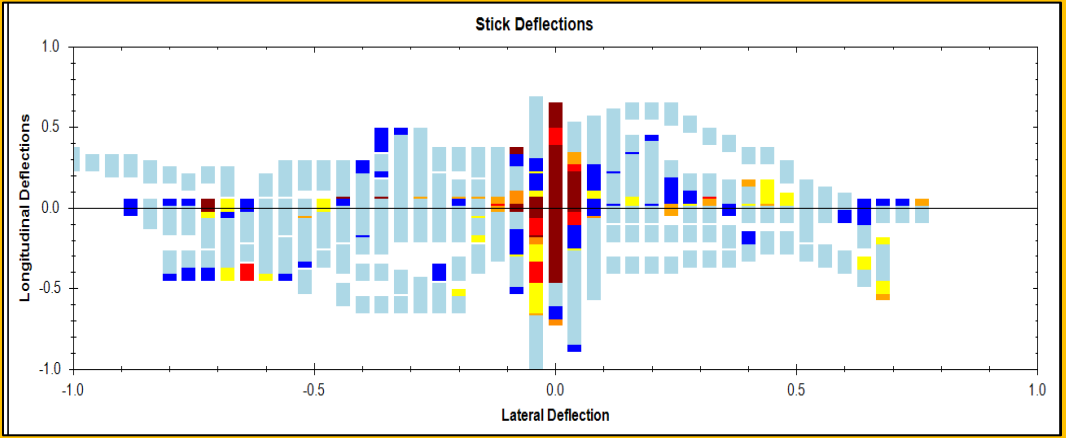
Cognitive Assessment Tool Set (CATS)

- Data Visualization
  - Graphs
  - Heat maps
  - *Real-time relative workload*





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Cognitive Assessment Tool Set (CATS)

- CATS
  - Relational database repository of all data
    - Data collected via providers in CATS
      - Vehicle state, environmental state, eye tracking, ECG, ect.
    - Data time stamped at source with global synchronization
    - Communication link between data base and sensors
  - Over a decade of physiological based assessment work
  - For cognitive workload, preferred sensor is electrocardiogram (ECG) waveform
    - Proven workload assessment
    - NeXus 4 Bluetooth to monitor ECG (creator MindMedia)
      - Unobtrusive device for trainee
    - Deterministically nonlinear classifier

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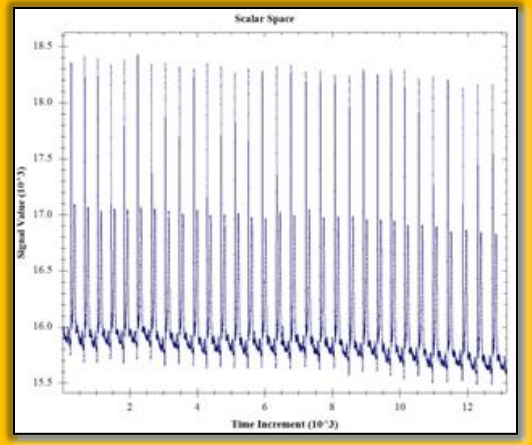
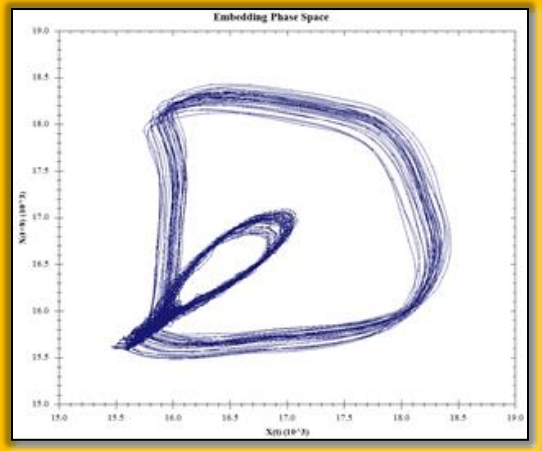
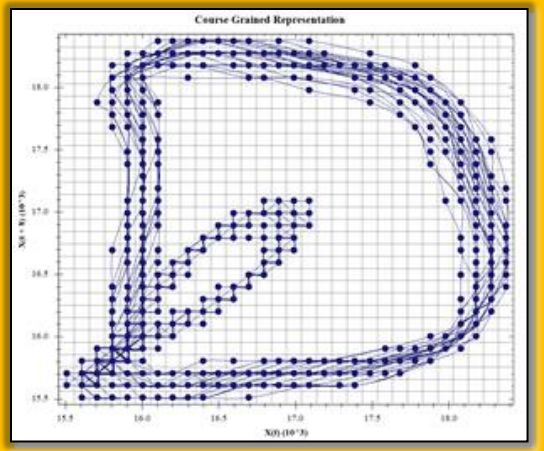
Representation of ECG

- Normal scalar space time series (left)
- Embedding phase space (center)
- Course grained representation of phase space (right)
  - Numerical array to represent quantitative signature
  - Chaotic Physiological Classifier method (CPC)







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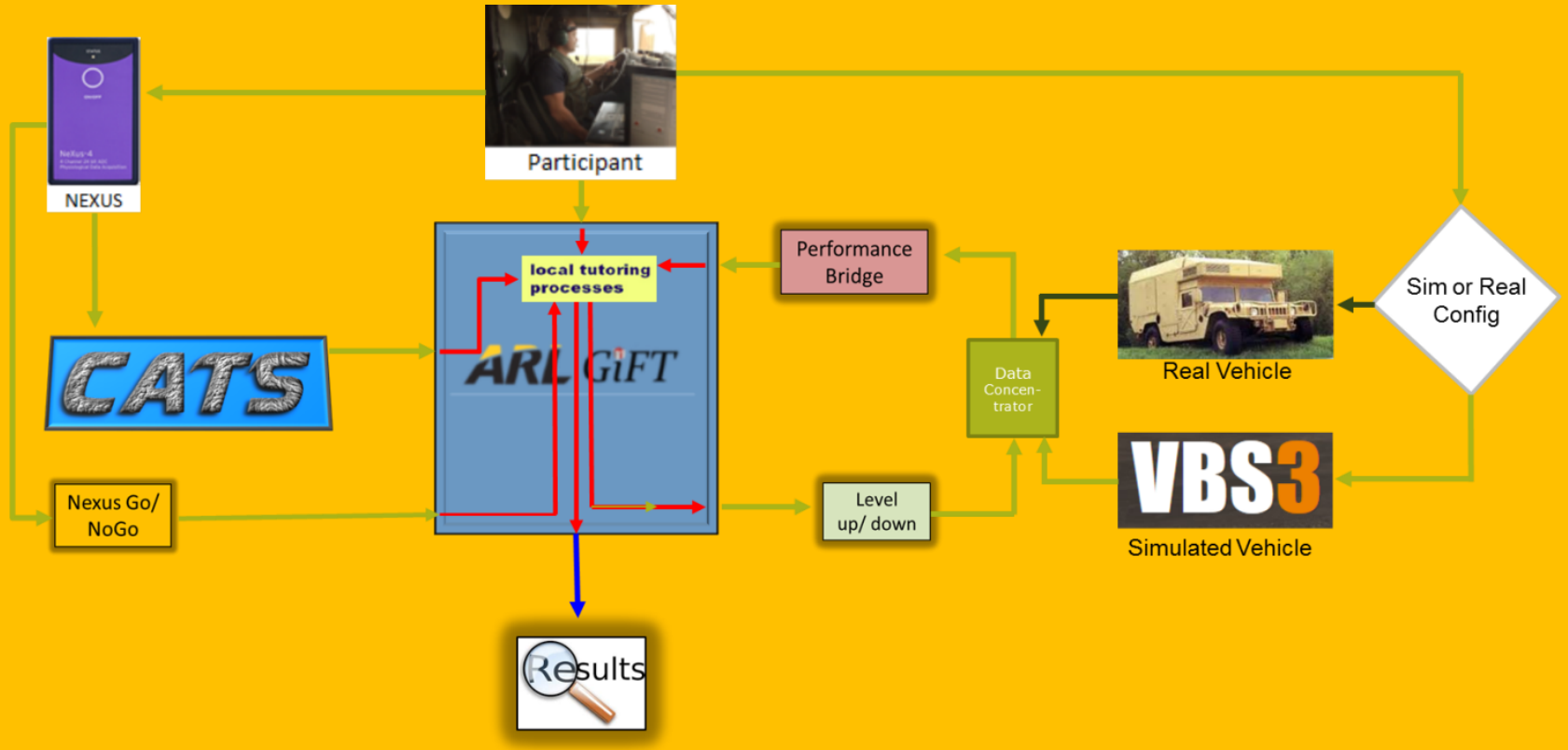
UPCAT System Architecture



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GIFT Process in UPCAT

- Steps performed by GIFT
  - Workload classification filter
  - VBS3 scoring filter and condition
  - Surveys per scenario and scoring condition
  - Real time difficulty changing interface (VBS3 script commands)
  - Combine the workload and VBS3 filters into a Domain Module to transition scenarios
  - Transmit information via Learner Module into a Pedagogical Module for trainee feedback
  - Create a Domain Knowledge File (DKF) author Triggers for rules of performance

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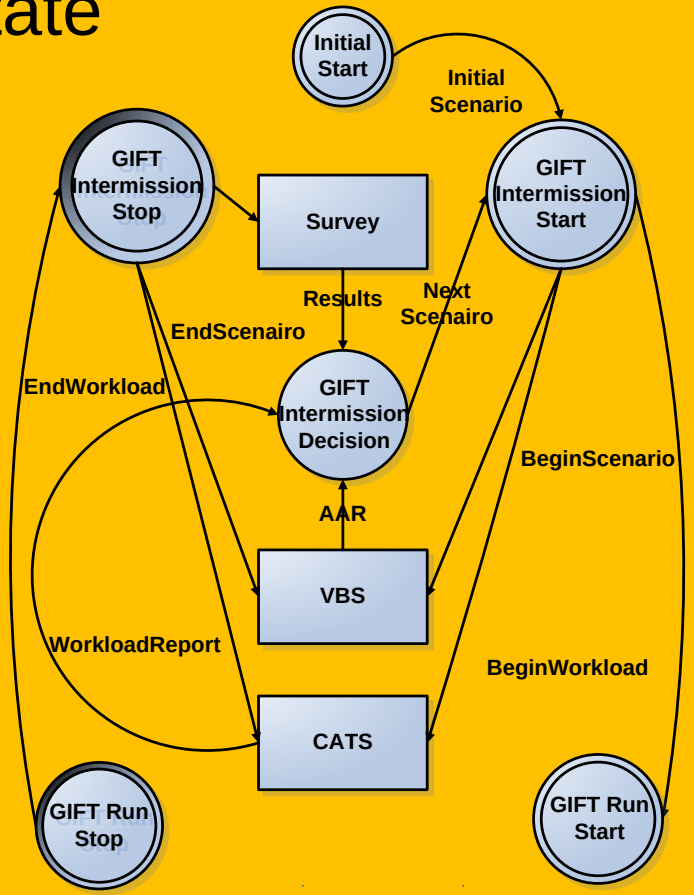
Intermission State

- Transitions between scenarios
  - Analyzes results of previous scenario
  - Adaptive to scenario as whole unit
    - Increase or decrease of difficulty
    - Move on or redo scenario



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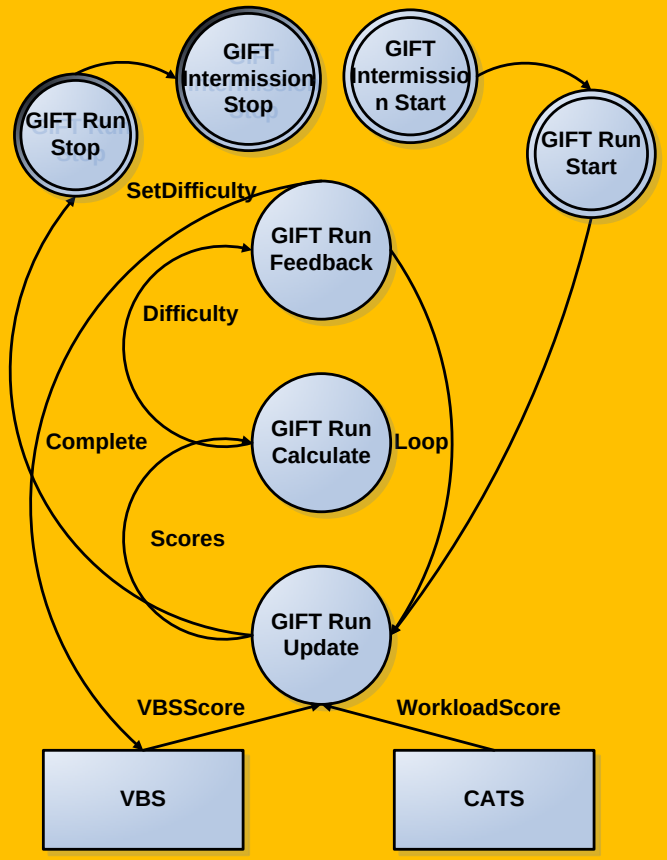
Run State

- Current scenario in real time
  - Activated when driving
  - Adjusts current scenario difficulty
  - Small dynamic changes
    - Modulates workload and performance to ideal state



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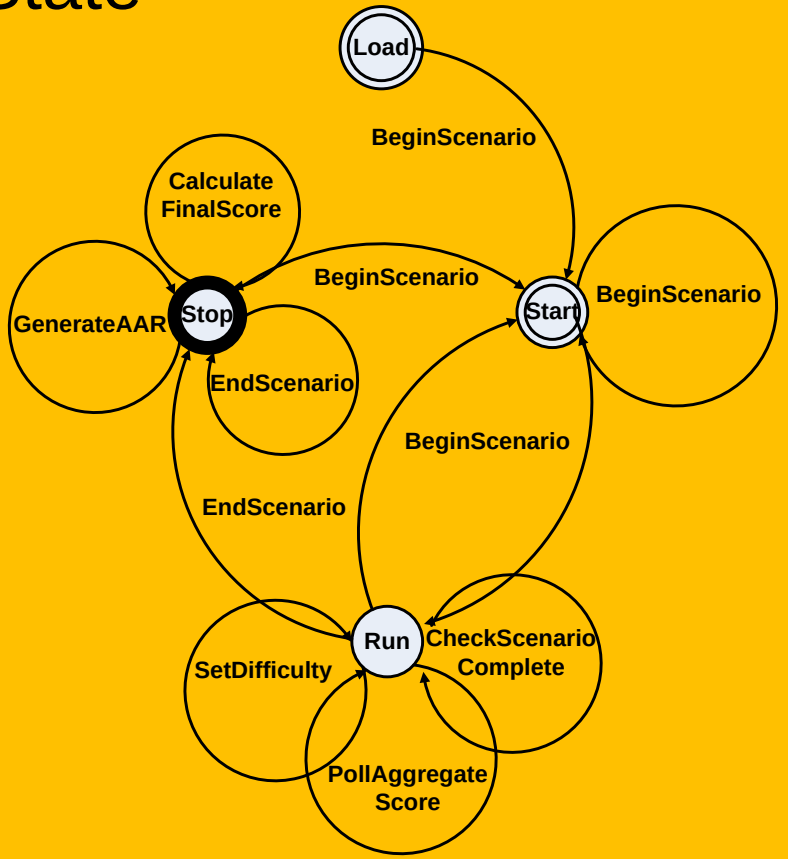
Script State

- Inside of VBS3
  - Performs changes in scenarios and difficulty levels
  - Reacts to the other GIFT stages



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UPCAT Concept of Operations (CONOPS)

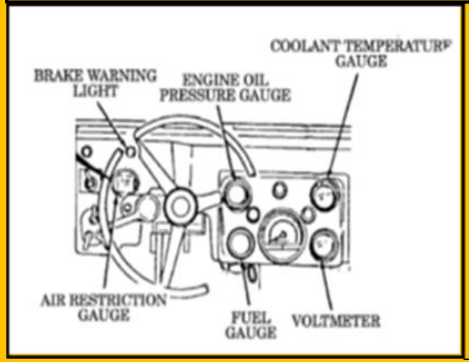
Computer based training (CBT) begins

- Start of training will begin with GIFT tutorials on hooking up devices and vehicle familiarization with administered quiz

Applying UPCAT sensors

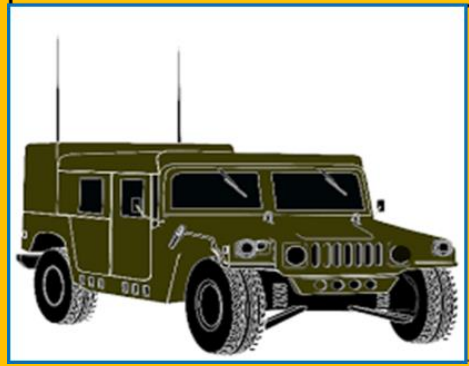
- Tray available
- Short bullet point of application
- Video of set up
- Confirmation test
  - Successful
  - Unsuccessful (Troubleshoot)

Vehicle familiarization review



- Review material only pertinent to vehicle and training
- Multiple PPT slides

Vehicle Familiarization



- This will start the vehicle familiarization
- Review, quiz, score
- Pass/ Fail calculated in GIFT

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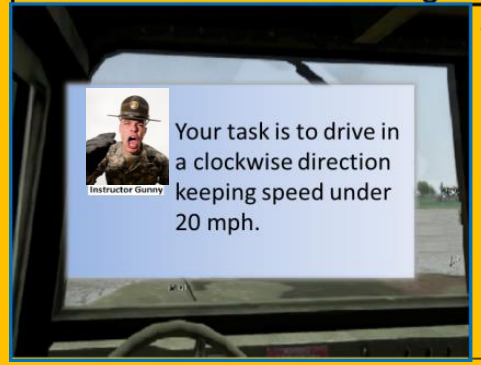
UPCAT Concept of Operations (CONOPS)

Baseline driving Mission 1

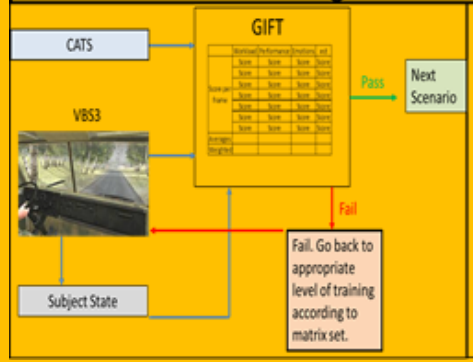


- Screen pops up with instructions

Baseline driving Mission 1 (continued)

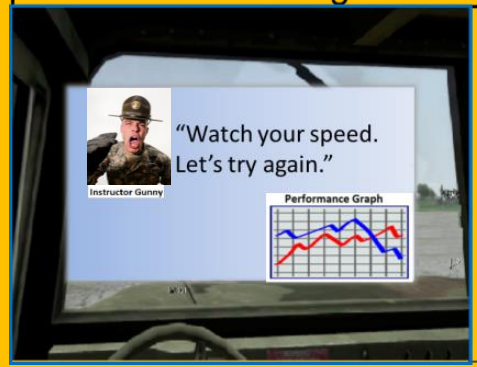
- Drive clockwise
- Under 20 mph
- Until baseline is satisfactory
- Metrics scored in UPCAT
  - Workload
  - Collision
  - Speed

Baseline driving Mission 1(continued)



- Overall performance calculated in GIFT
  - Workload (CATS)
  - Driving Performance (VBS3)
  - Subject State

Baseline driving Mission 1(continued)



- If not satisfactory
  - Point out fault
  - State it
  - Loop till satisfactory completion

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UPCAT Concept of Operations (CONOPS)

- **Level 1**: Baseline
- **Level 2**: Parking lot with obstacles placed to drive around.
- **Level 3**: Driving on an open, mostly straight highway in a foreign country with appropriate visuals and a simple navigational assignment.
- **Level 4**: Addition of curves and reasonable up and down grades.
- **Level 5**: Addition of urban areas.
- **Level 6**: Addition of roadway threats to avoid, requiring severe braking and swerving.
- **Level 7**: Addition of off-road, straight up and down grade.
- **Level 8**: Addition of off-road, along grade (slant), left and right.
- **Level 9**: Addition of driving at nighttime and in degraded visibility conditions.
- **Level 10**: Addition of IED detection and avoidance.
- **Level 11**: Addition of ambush event with backup retreat.
- **Level 12**: Capstone driving event that is assembled from all the parts that the trainee did not do well on.

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Conclusions and Recommendations

- GIFT architecture facilitates the integration VBS3 and CATS effectively
- CATS
  - Operational workload and performance assessment system
  - Used by OPL in real-world driving and flight contexts for a number of years.
  - Proven to assess the performance of fighter pilots in jet aircraft or in flight simulators.
  - Workload assessment capability integrated in the GIFT framework using a Direct Link Library (DLL) methodology.

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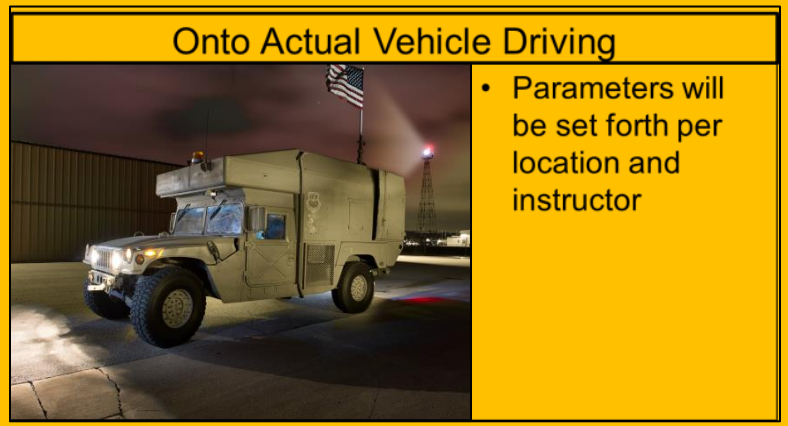
Conclusions and Recommendations

- Year 2
  - Refine the UPCAT feasibility demonstrator
  - Test and evaluate the UPCAT
  - N=12 participants undergoing training on HMMWV
  - Full-mission training evolution as described in the CONOPS



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Conclusions and Recommendations

- Research questions that Year 2 experiment will seek to answer
  - Is the UPCAT workload assessment accurate enough?
  - Is adaptive training more effective than its non-adaptive counterpart?
  - Is the base program UPCAT/GIFT system acceptable for actual training in an Army context?

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Acknowledgements

- ARL
  - Dr. Robert A. Sottilare
  - Dr. Jason D. Moss
  - Dr. Keith Brawner

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Unobtrusive Physiological and Adaptive Training (UPCAT) “DEMO”

Thomas Schnell[1], Cory J. Reuter[1], Ezekiel D. Gunnink[1], Bradley M. Parker[1], Carlton H. Richey[1], Jaclyn A. Hoke[2], Jason D. Moss[3]

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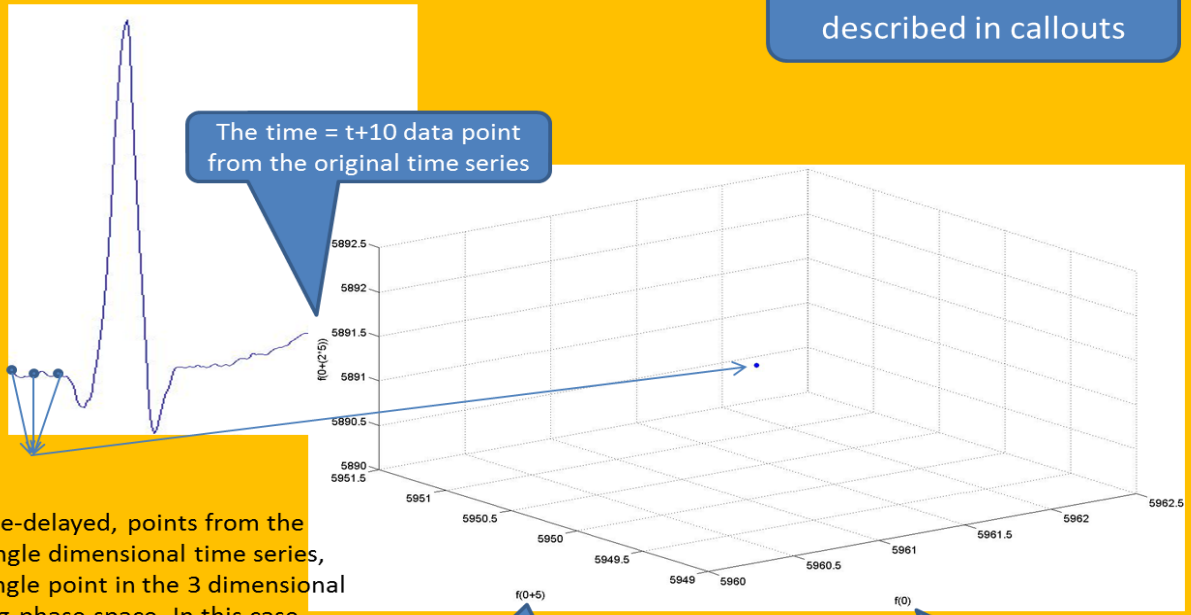
UPCAT SIMULATOR DEMO

Discrete Deterministic Nonlinear Workload Assessment in CATS

Note Axis labels described in callouts



Three, time-delayed, points from the original single dimensional time series, forms a single point in the 3 dimensional embedding phase space. In this case f(t=0+ (0*5)), f(t=0+(1*5)), f(t=0+(2*5)) from the time series forms f(t=0) in the embedding phase space

The time = t+5 data point from the original time series

The original data point from the time series for time t=0

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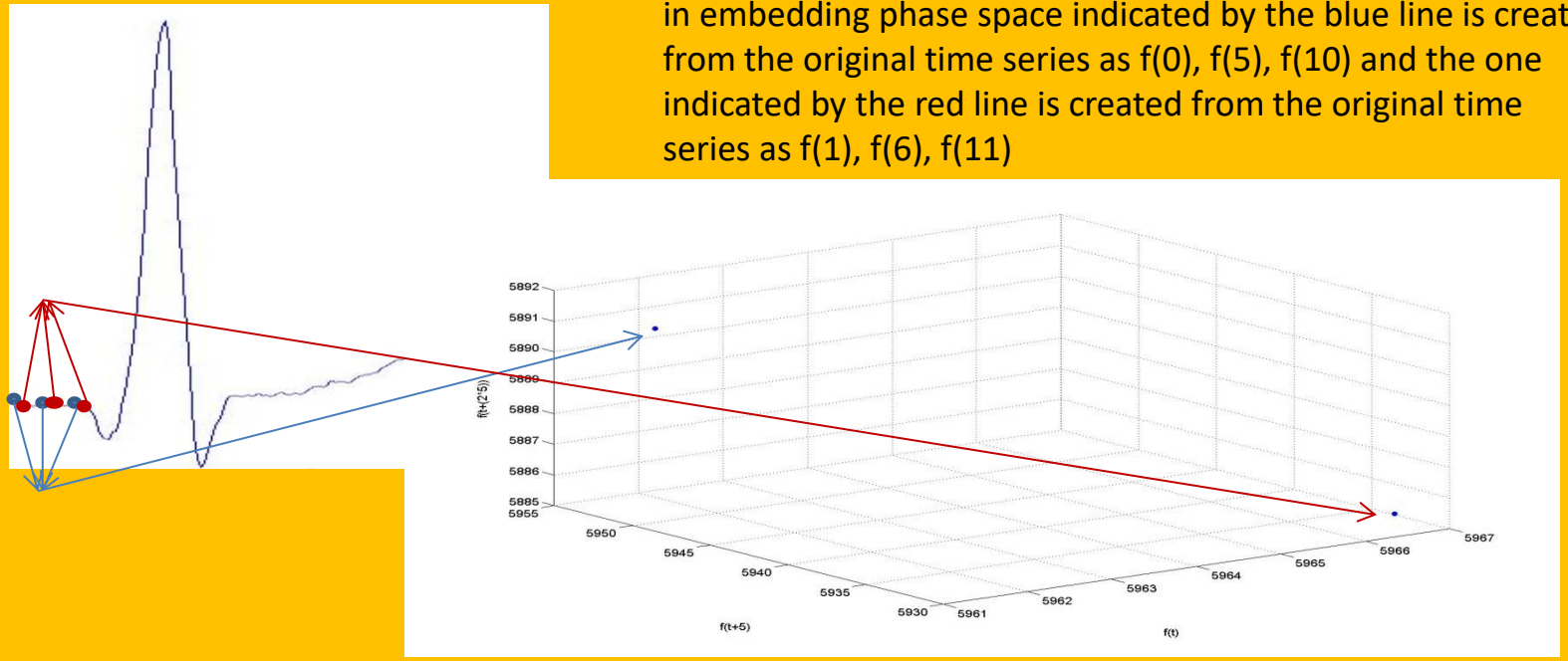
Discrete Deterministic Nonlinear Workload Assessment in CATS

Embedding Phase Space is constructed from repeated applications of the time-delay transform. In this case the point in embedding phase space indicated by the blue line is created from the original time series as f(0), f(5), f(10) and the one indicated by the red line is created from the original time series as f(1), f(6), f(11)



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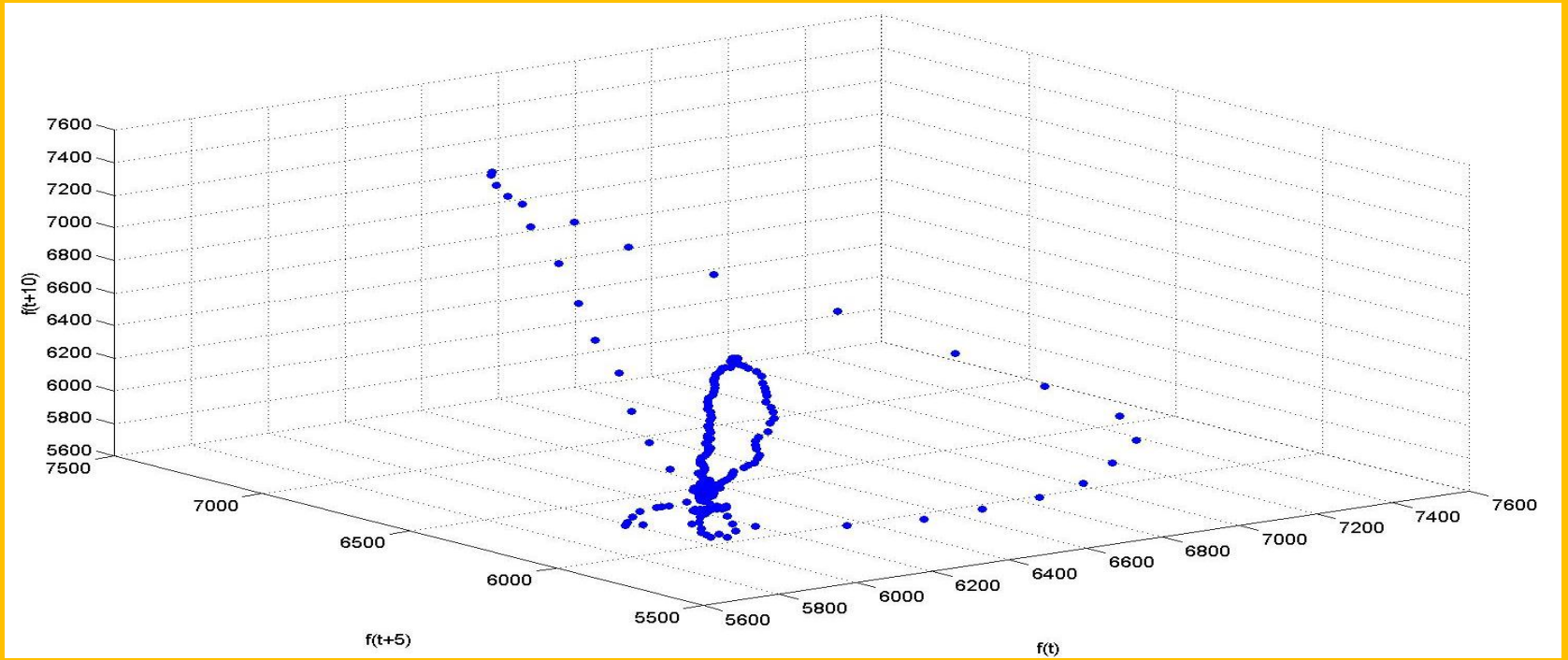
Discrete Deterministic Nonlinear Workload Assessment in CATS

Performing the repeated transformation to embedding phase space 300 times produces a plot as shown below



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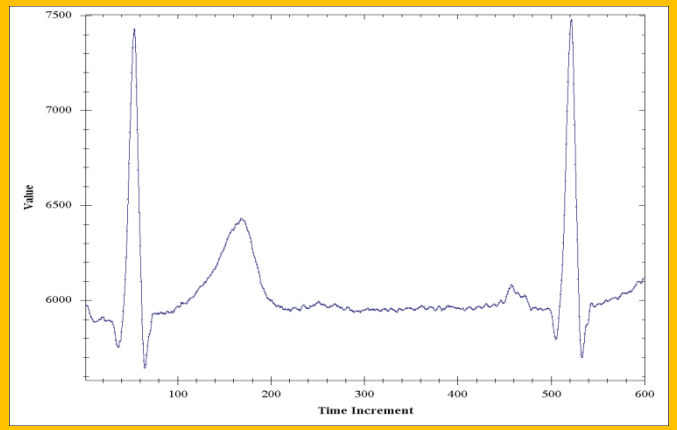
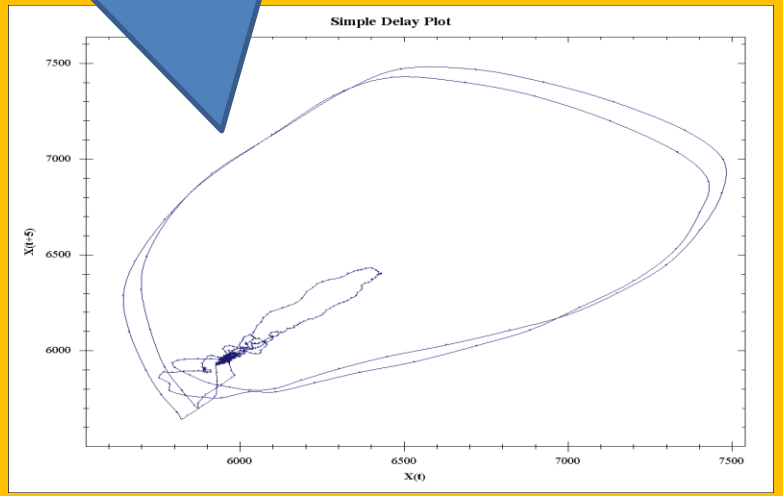
Discrete Deterministic Nonlinear Workload Assessment in CATS

When viewed two dimensionally with the points connected the following ECG signal is transformed into Embedding Phase Space



Note that the 2D view here represents a birds eye view (looking down) of the embedding phase space



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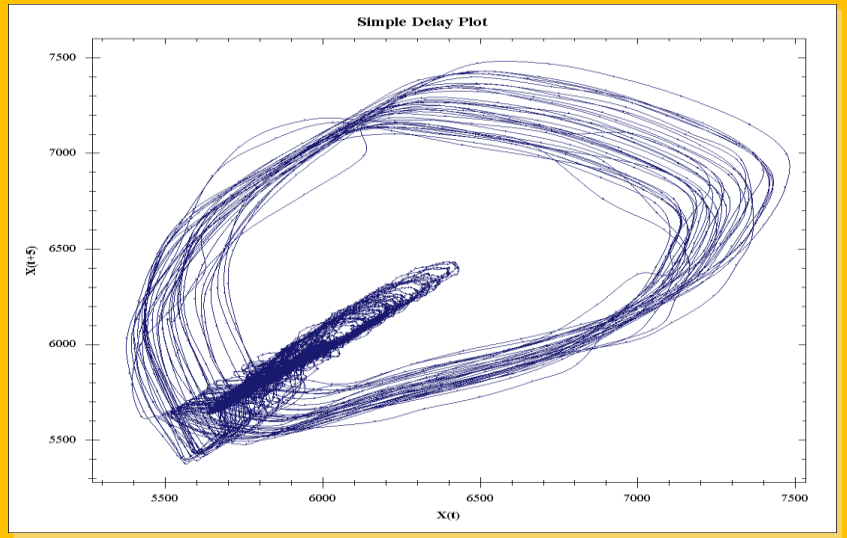
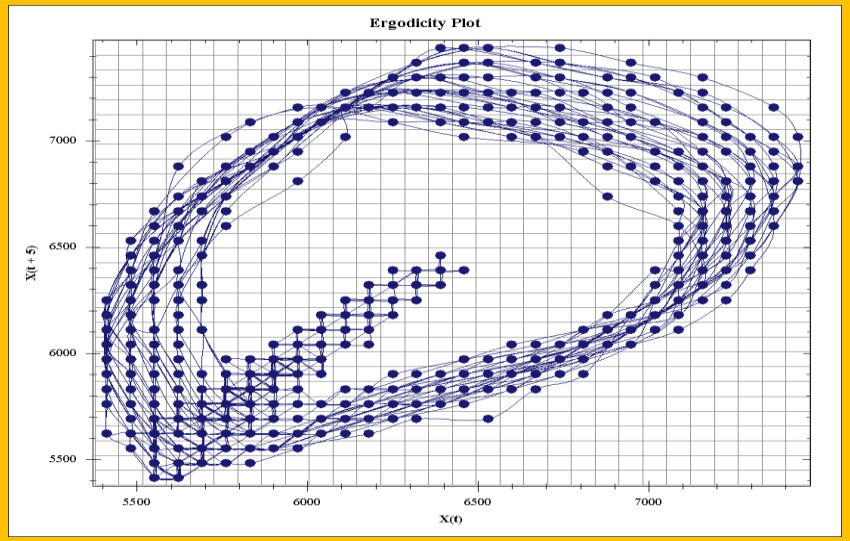
Partitioning Embedding Phase Space



Ergodicity Transition Matrix (ETM)



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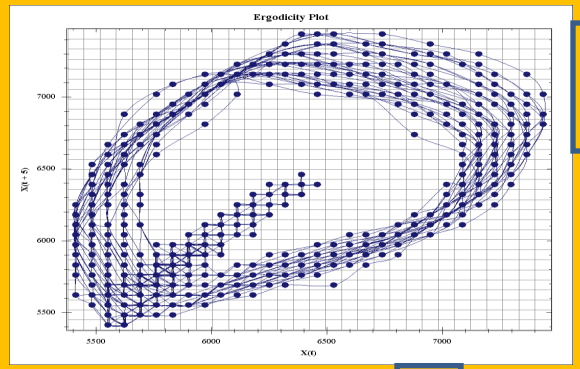
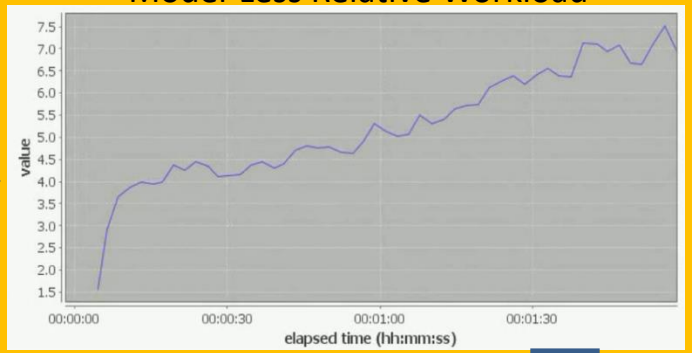
Classifying Workload

Near Real-Time Ergodicity Transition Matrix (ETM) Contains Transition Probabilities



$$\frac{1}{\text{(Transition Probability Variance)}}$$

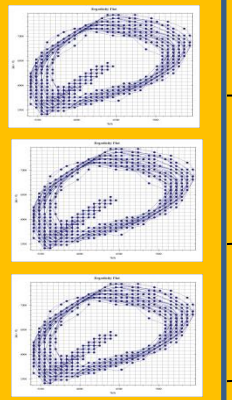
Model-Less Relative Workload



Next Slide

Nearest Neighbor Classifier

Real Time Lookup



A priori ETM Models

HIGH

MEDIUM

LOW

Discrete Absolute Workload

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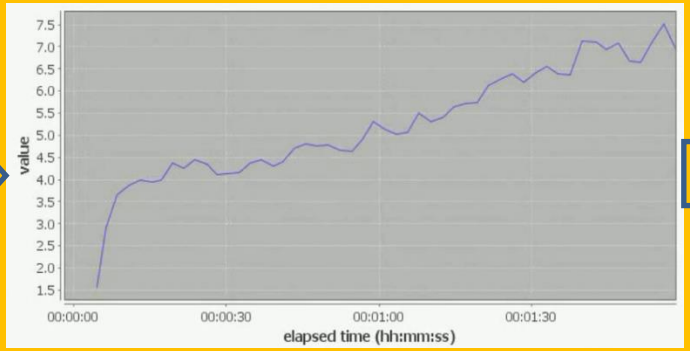
Classifying Workload

Model-Less Discrete Relative Workload



HIGH

State Machine

MEDIUM

LOW

Driving Technical Performance

Perform Bridge

State Vector

Next Slide

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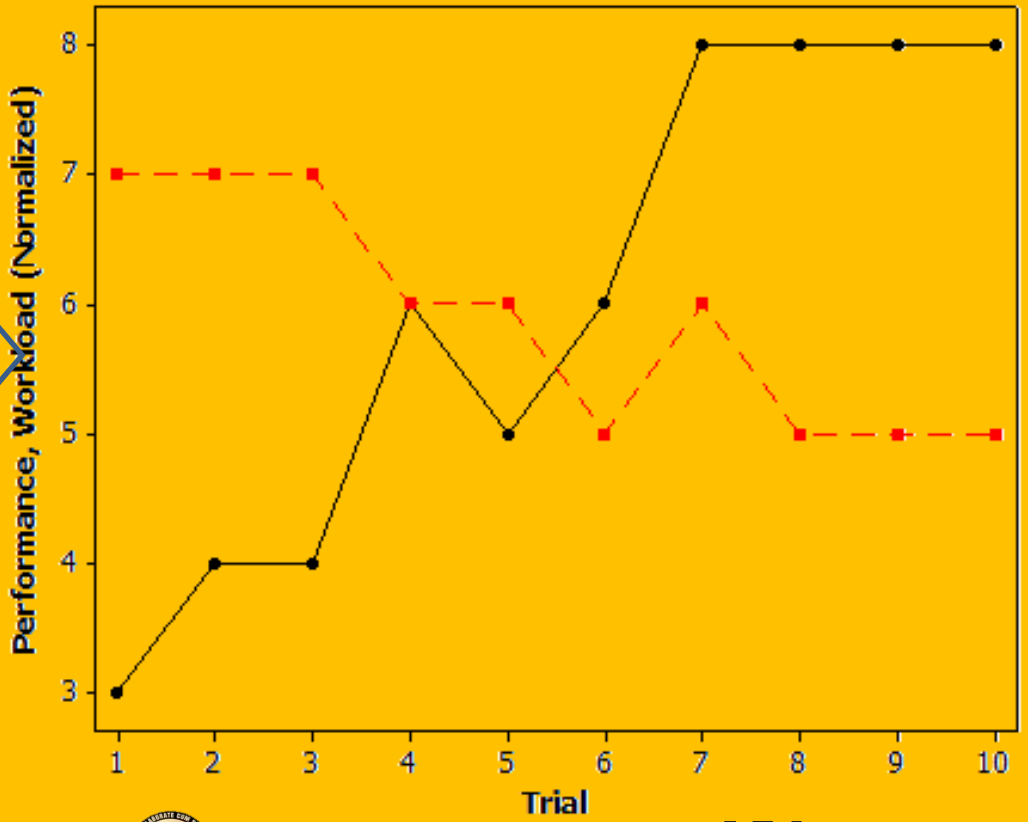
Performance vs. Workload, and Example

State Vector



Adapt Scenario

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SIMULATOR AND INSTRUMENTED VEHICLE

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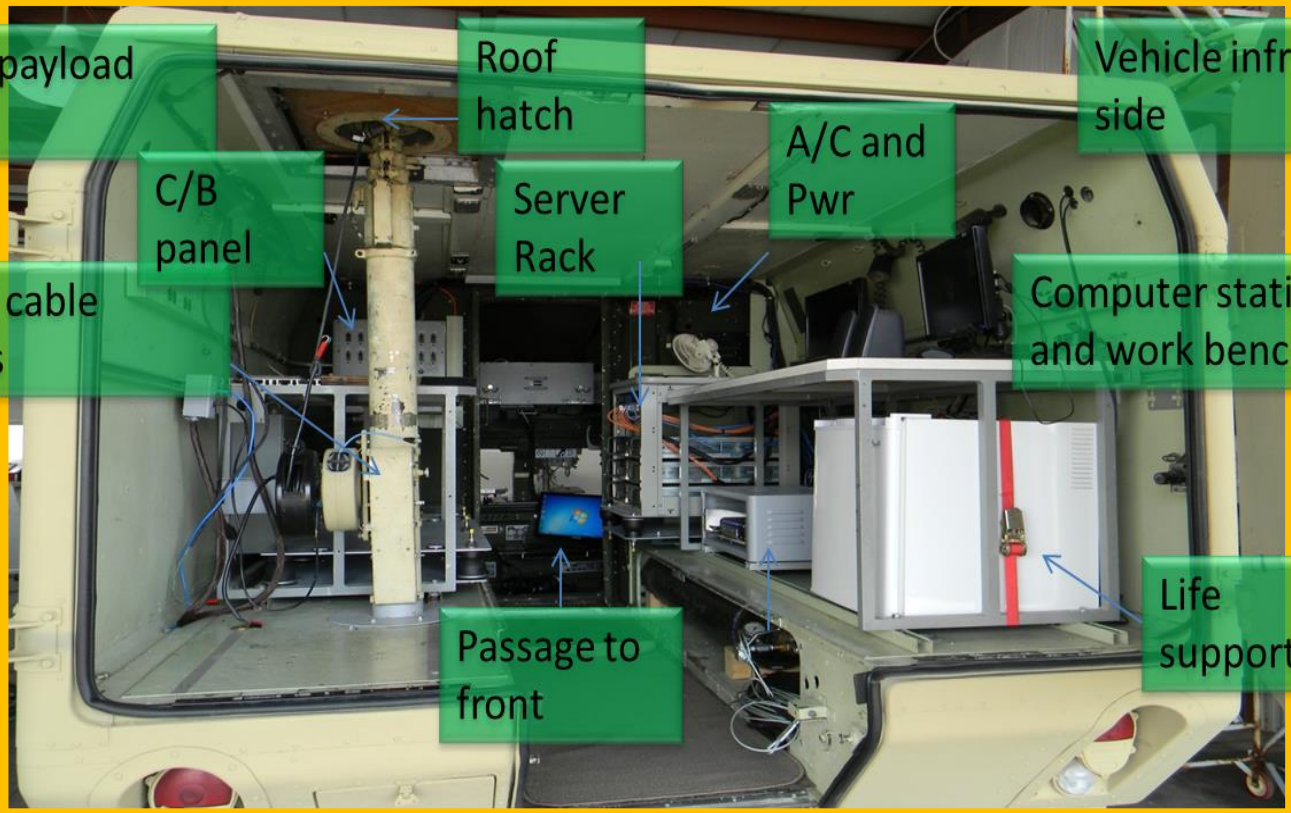
Rear Compartment



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Eye Tracker and Sensor Vest

- Single point umbilical for quick ingress and egress
- Remote optics eye tracker

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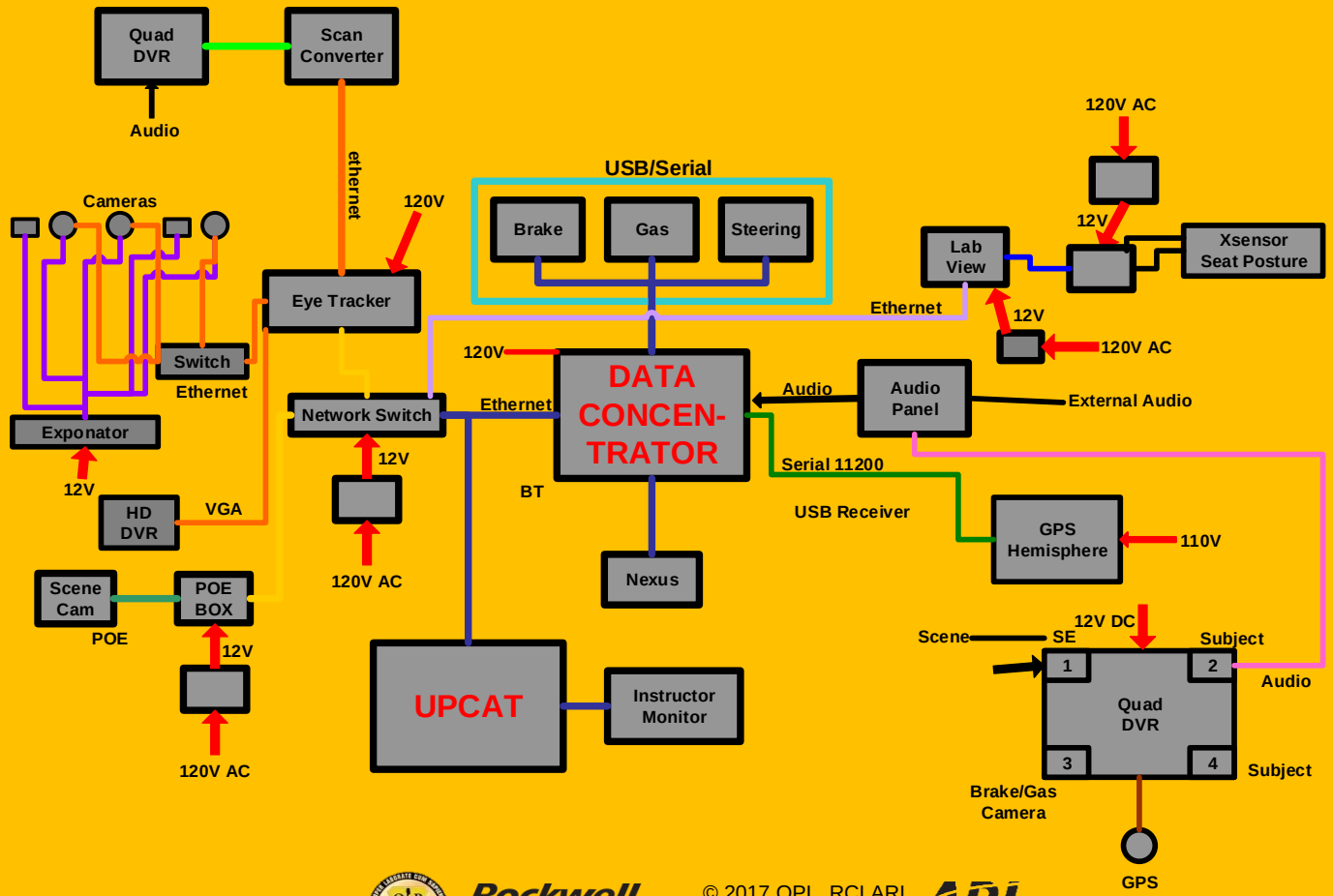
HMMWV ARCHITECTURE



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OPL's HMMWV

CH:04
15/09/03
20:36:01
67.2KMH
A +41.622482 -91.523872

CH:03
15/09/03
20:36:01
67.2KMH
A +41.622482 -91.523872

CH:01
15/09/03
20:36:01
67.2KMH
A +41.622482 -91.523872

CH:02
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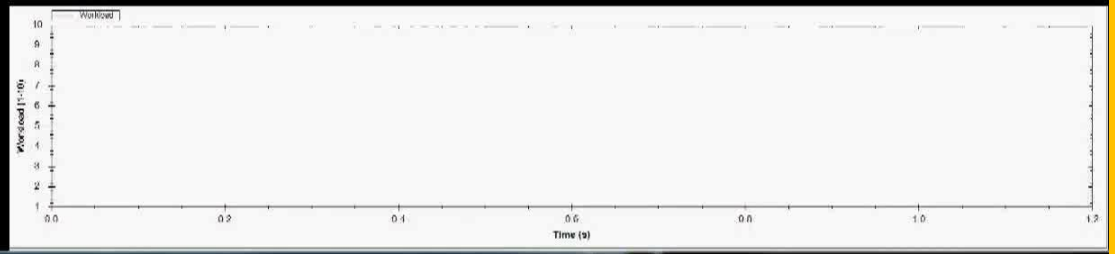
A +41.622482 -91.523872

AIRBORNE WORKLOAD ASSESSMENT