Advances in Simulations for Training and Education: U.S. Navy

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Simulations used in the U.S. Navy

- DDG51 Engineering Trainer
- Multi-Mission Tactical Team Trainer
- Tactical Action Officer (TAO) Sandbox
- Shiphandling Trainer (COVE) – Conning Officers Virtual Environment
  - COVE-ITS (Stanford)
  - Automated Assessment Engine
- Engineering Plant Technician Maintenance Training

DDG51 Engineering Trainer

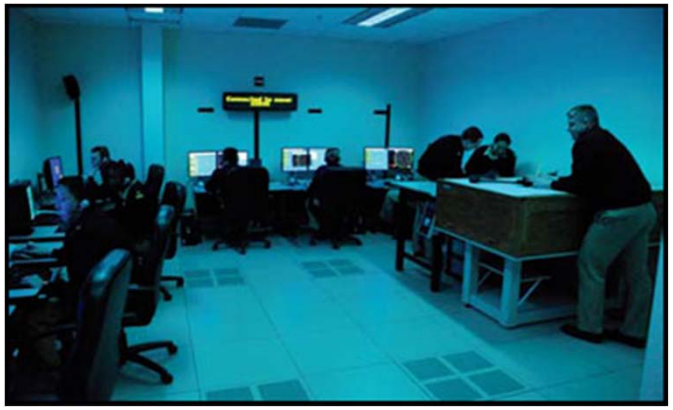
DDG-51 Gas Turbine Propulsion Plant Trainer (19G4) at SWOS

SOURCE: Photo courtesy of Surface Warfare Officers School Engineering Department, Newport, R.I.

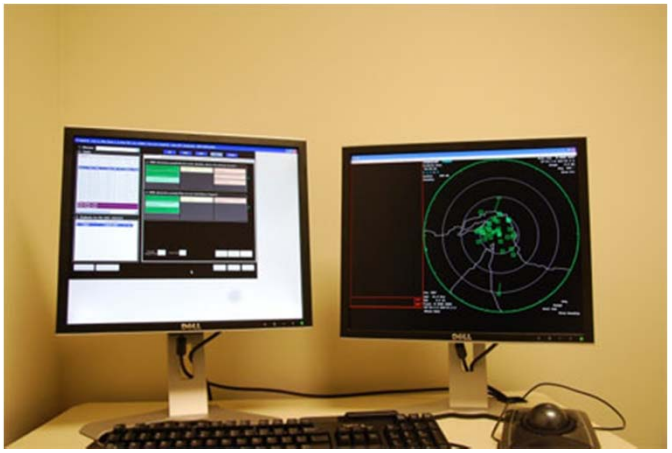
RAND *MG874-4.2*

Student:	Engineering Officer of the Watch (EOOW)
Skills assessed:	Engineering Operations Casualty Control
Other team members:	controlling generators and engines, auxilary power and steering, damage control
Instructor Station:	monitor progress, modify scenario/trigger events

Multi-Mission Tactical/Team Trainer (MMTT)



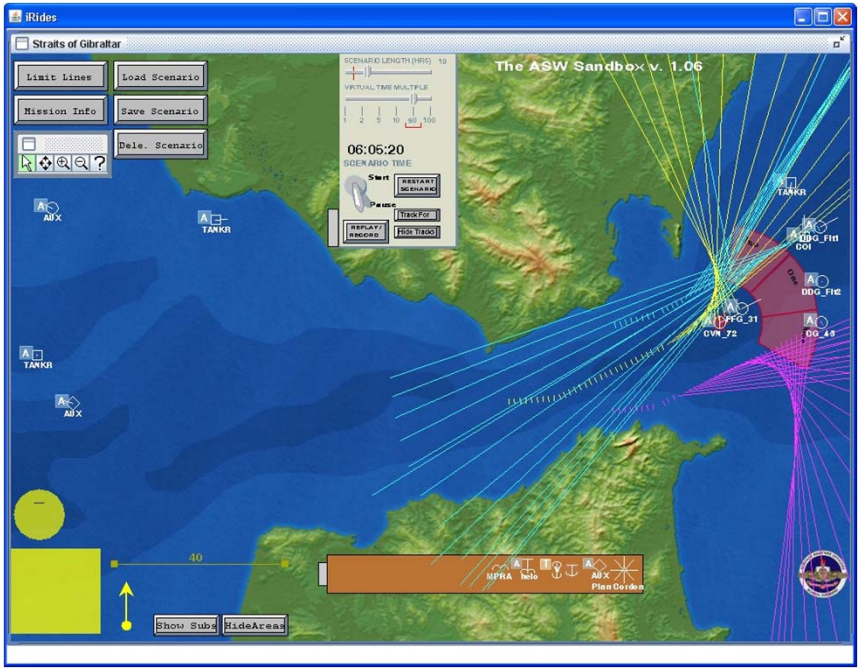
Simulated Combat Information Center
(Air Defense, Surface Warfare, Anti-Submarine Warfare)



MMTT Assessment Tool & Radar

Student:	Tactical Action Officer (TAO)
Skills assessed:	Tactics execution including pre-planned responses in a team environment
Other team members:	Other watchstanders in separate room, evaluator and person in commanding officer role in room for more realistic setting

TAO Sandbox



Student:	Tactical Action Officer (TAO)
Skills assessed:	Tactical strategy and planning
Affordances:	Ability to plan out scenario from bird's eye view and speed up time to see real consequences of decisions made

(Built by USC/CCT using iRides)

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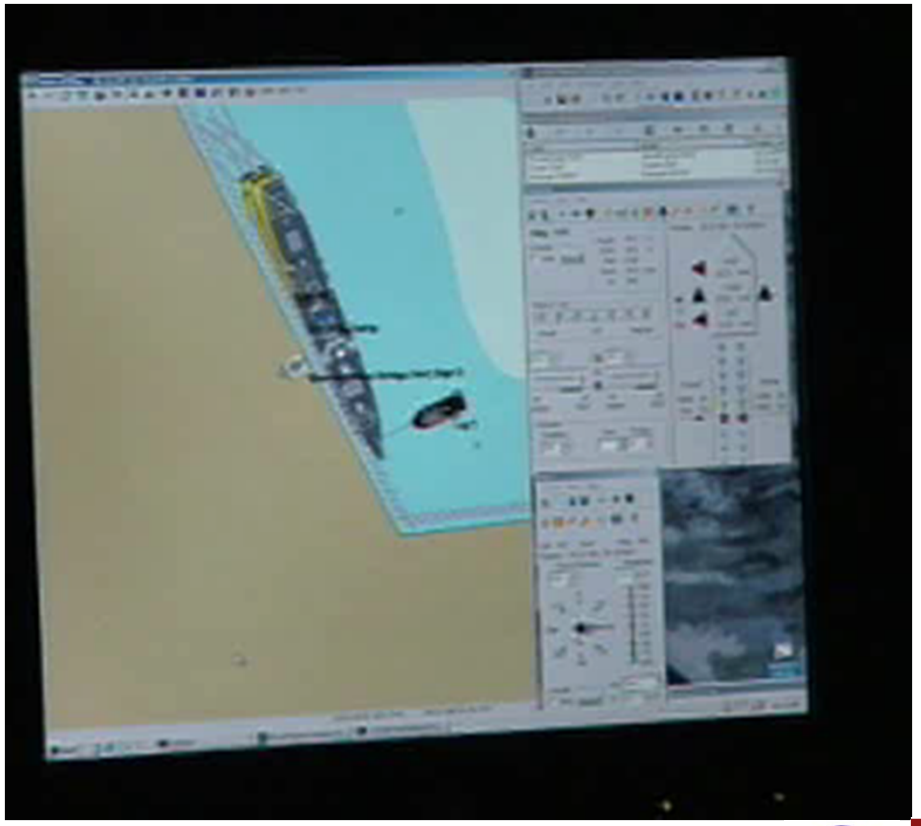
The COVE ITS – Spoken Coaching

Conning Officers Virtual Environment



Student:	Conning Officer
Skills assessed:	Shiphandling maneuvering in different scenarios
Affordances:	Head Mounted Display (HMD) Uses voice recognition for standard commands

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The COVE ITS – Spoken Coaching

Student: Starboard engine back 1/3; Say again?

Instructor: I was just asking what that tug's doing to your stern there?

Student: I was pretty sure that it was pulling it out. Looks like it's slowing. I guess I should move it out faster.

Instructor: The bow or the stern?

Student: The bow.

Instructor: Actually I would say no; you're killing your lateral movement on your stern there.

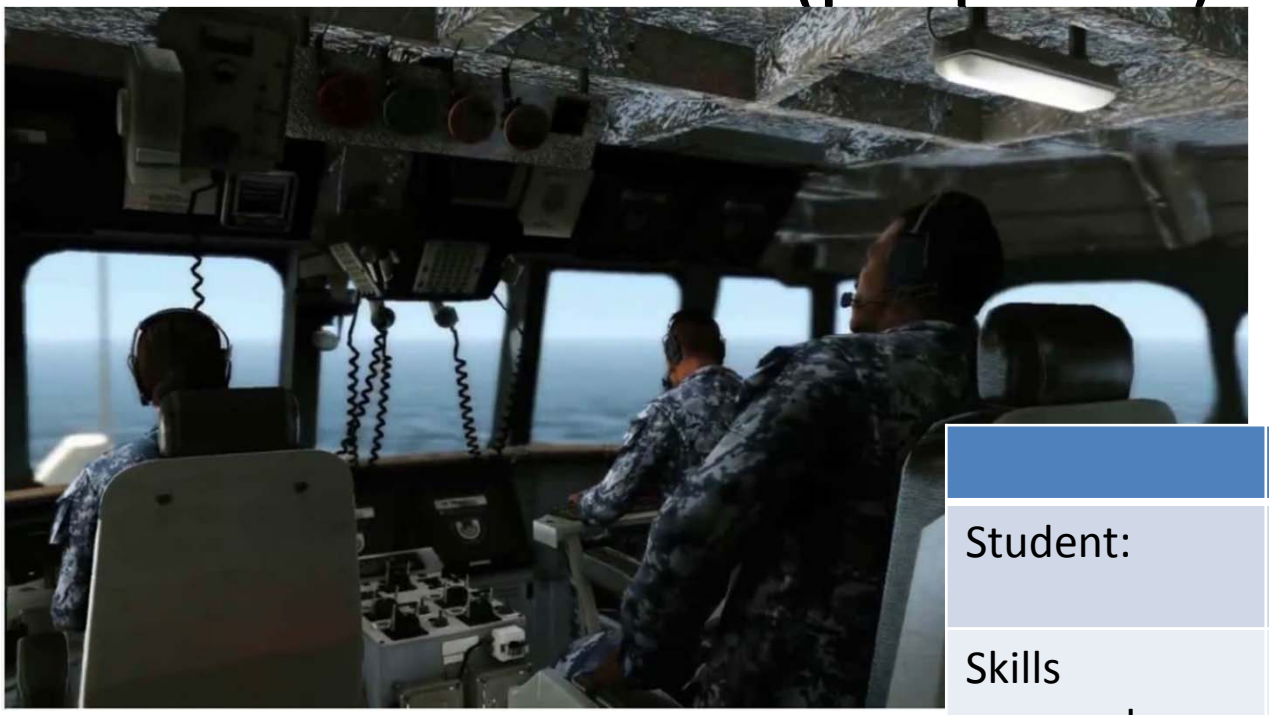
Student (x2): Move to the Starboard bridge wing.

Instructor: (It got stalled back there)

Student: (Oh I see. Ok) Tug 1 away dead slow; Port engine ahead 2/3.

Instructor: There you go; good job.

Littoral Combat Ship (LCS) Training (proposed)



Student:	Engineering Plant Technician
Skills assessed:	Maintenance of ships engines for LCS variants 1 and 2
Affordances:	Virtual Reality/Augmented Reality Haptic Glove

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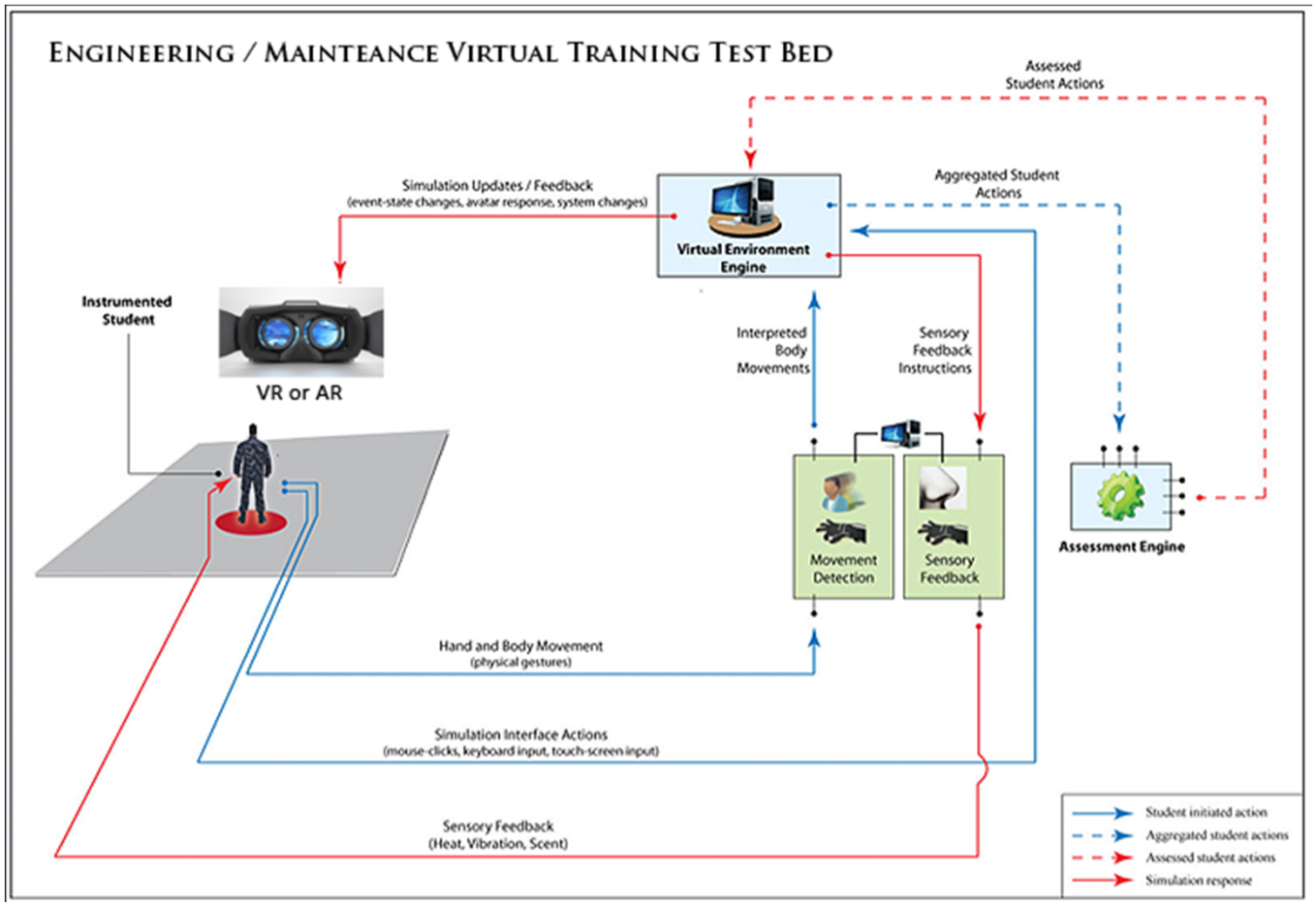
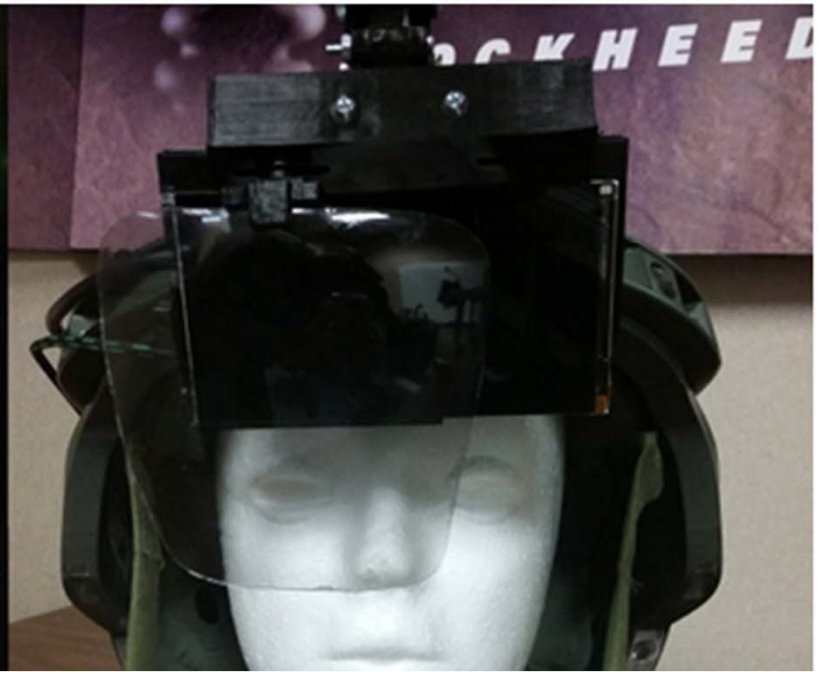

ENGINEERING / MAINTEANCE VIRTUAL TRAINING TEST BED
Assessed Student Actions
Simulation Updates / Feedback
(event-state changes, avatar response, system changes)
Aggregated Student Actions
Virtual Environment Engine
Instrumented Student
VR or AR
Interpreted Body Movements
Sensory Feedback Instructions
Movement Detection
Sensory Feedback
Assessment Engine
Hand and Body Movement
(physical gestures)
Simulation Interface Actions
(mouse-clicks, keyboard input, touch-screen input)
Sensory Feedback
(Heat, Vibration, Scent)
Student initiated action
Aggregated student actions
Assessed student actions
Simulation response

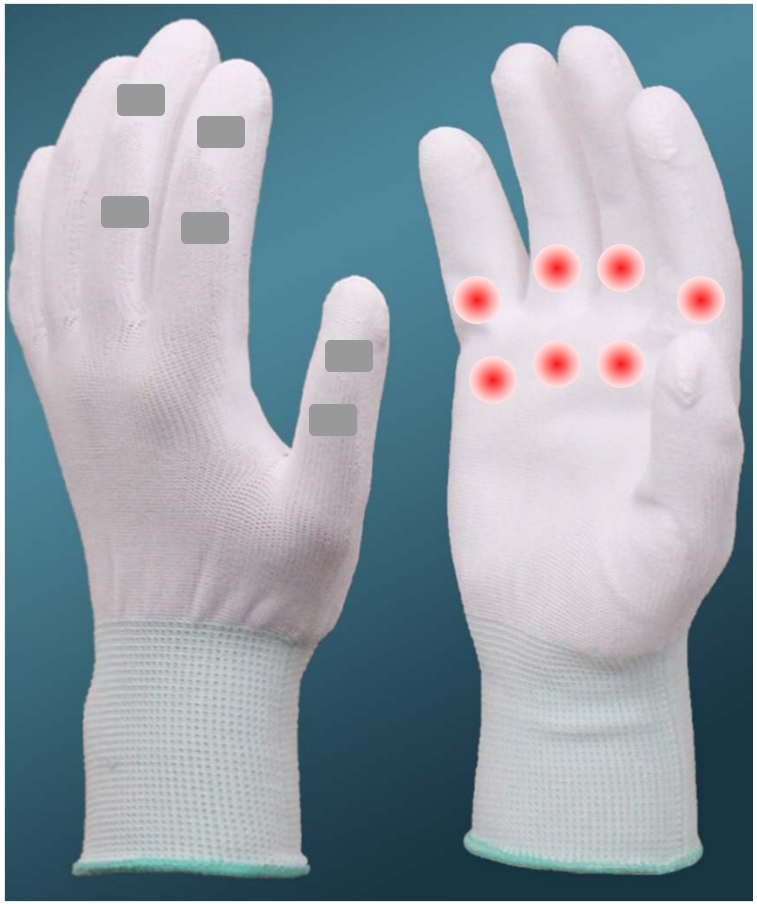
Virtual Reality or Augmented Reality

Lockheed Martin's wireless devices and HD virtual reality devices use commercial-off-the-shelf (COTS) tablets that can be inserted to provide the visual display on the headset. Inside the headset, Fresnel lenses provide an ultra-wide field of view for exceptional fidelity and a more immersive virtual reality environment.



Haptic Feedback Glove

- **Adapted from gesture recognition glove**
  - Contains multiple inertial measurement sensors to detect hand movement
- **Currently Implementing Automated Vibrotactile Feedback**
  - Glove recognizes pre-recorded gestures (i.e., climbing a ladder) and activates vibrotactile feedback on the palm and fingers
  - Glove recognizes proportional inputs (e.g, grip strength, degree of valve rotation) and increases vibration
  - Currently investigating integration with multiple engineering maintenance VE platforms



Accelerometer
Gyroscope
Magnetometer

Haptic Feedback Actuator

AnthroTronix

Haptic Feedback for VR

- **Haptic Feedback in VR and Teleoperation**
  - Haptic displays have been shown to increase realism and presence in VR environments, as well as teleoperation tasks (Galambos, 2012)
- **Vibrotactile Feedback to Convey Force**
  - Sensory substitution has been successfully demonstrated in a variety of research areas
    - Rehabilitation (Bach-y Rita, 1967, 1972; Proulx, Ptito, & Amedi,2014)
    - Prosthetics (Antfolk et al., 2013)
    - Entertainment (Morelli, 2014)
    - Virtual collaboration (Galambos & Baranyi, 2011)
    - Robotic surgery (Kitagawa, Dokko, Okamura, & Yuh, 2005)
    - Training (Wottawa et al., 2013; Cutler et al., 2013)
  - Teleoperation performance increases when using vibrotactile displays to present force feedback (Massimino & Sheridan, 2014)

Latent Skills/Proficiencies (inferred)	Associated Observable Measures/Actions
Root-Cause Analysis (problem solving)	– **Time taken to determine root cause from when problem was detected** – **Steps taken to identify root-cause (tasks, sequence, and timing)**
Problem Resolution (content & SOP understanding)	– **Steps taken to remedy the problem (tasks, sequence, and timing)**
Situation Awareness	– **Eye-tracking of readouts/gauge scans** – **Eye-tracking of areas/equipment as they move through the engine room** – **Time taken to detect problem after system (game state) activates problem**
Communication	– **Initiating reporting / messages** – **Responding to messages received** – **Completeness of explanation (problem identification, causes, affected systems, actions taken, etc.)**

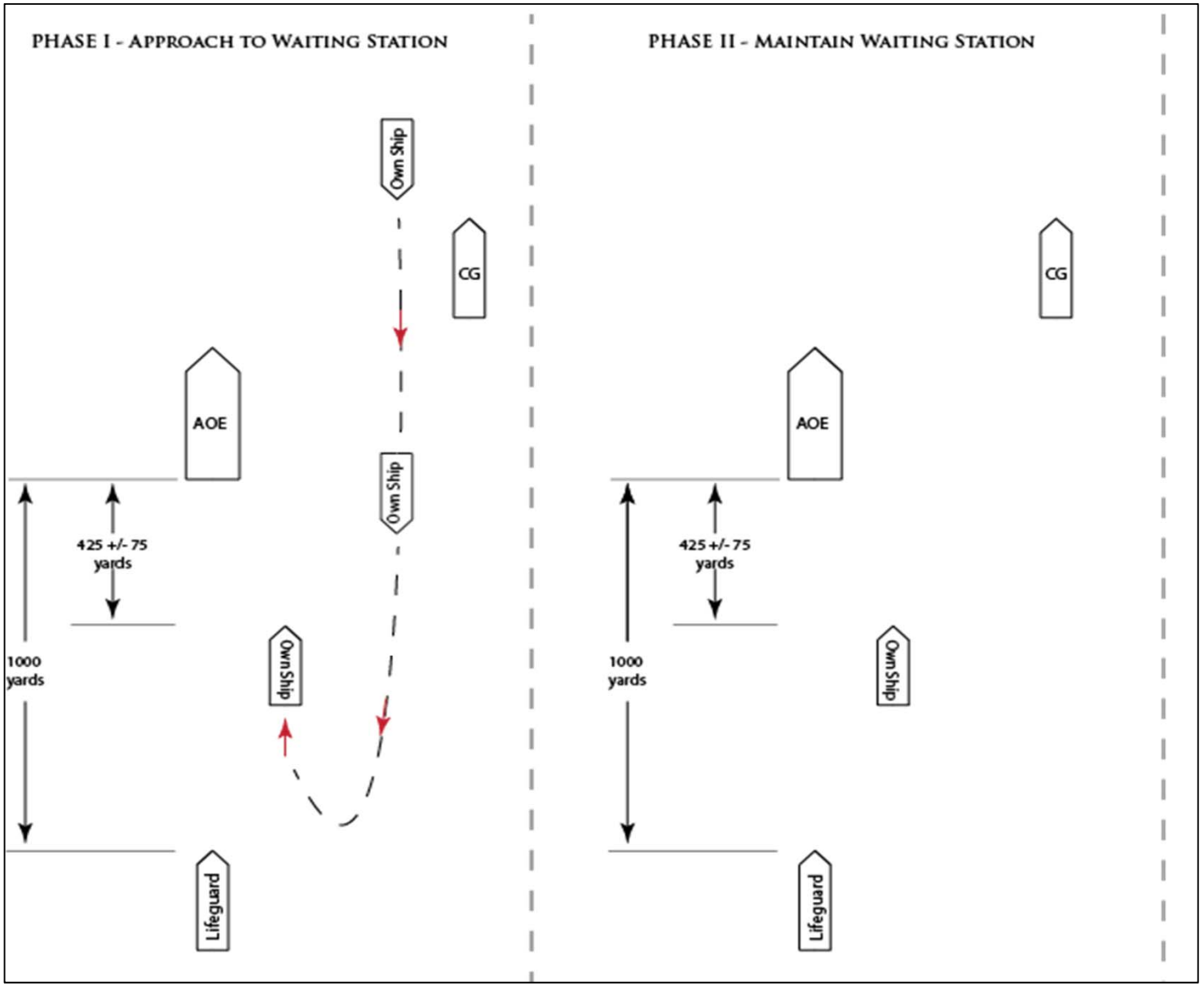
Engineering Plant Technician Training
Research Questions as Compared to Conventional Instruction

Using multi-modal inputs like virtual/augmented reality and haptic gloves:

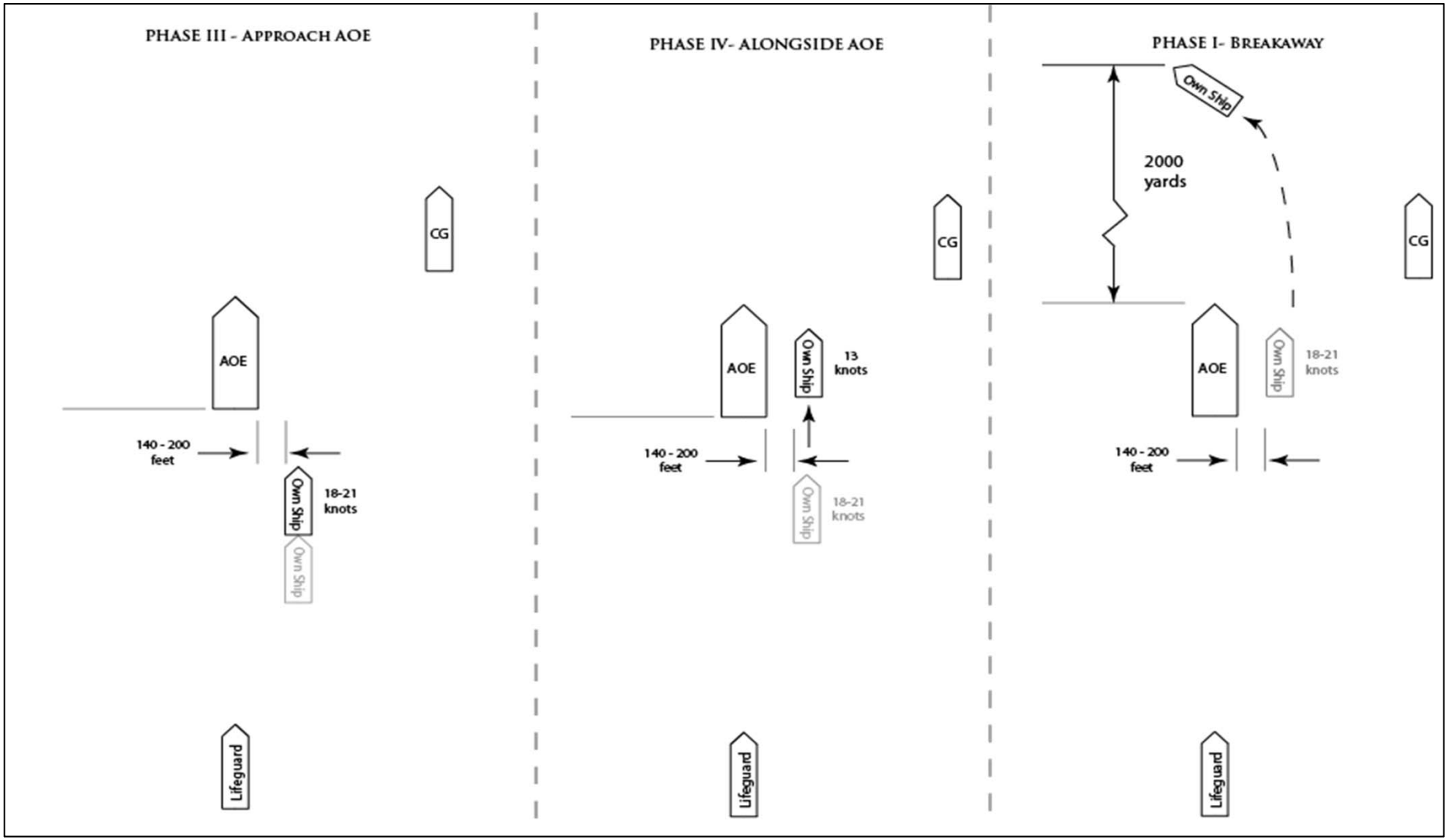
- Do students acquire skills faster?
- Do they retain their skills longer?

Example:
Underway Replenishment (UNREP)

UNREP Phases 1-2



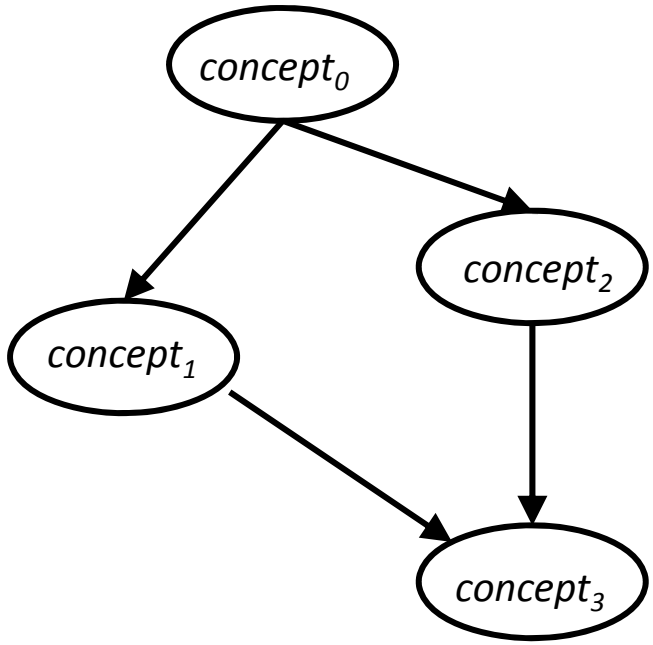
UNREP Phases 3-5



UNREP
Refueling at Sea
(13 knots/hr)

What is a Bayesian Network (BN)?

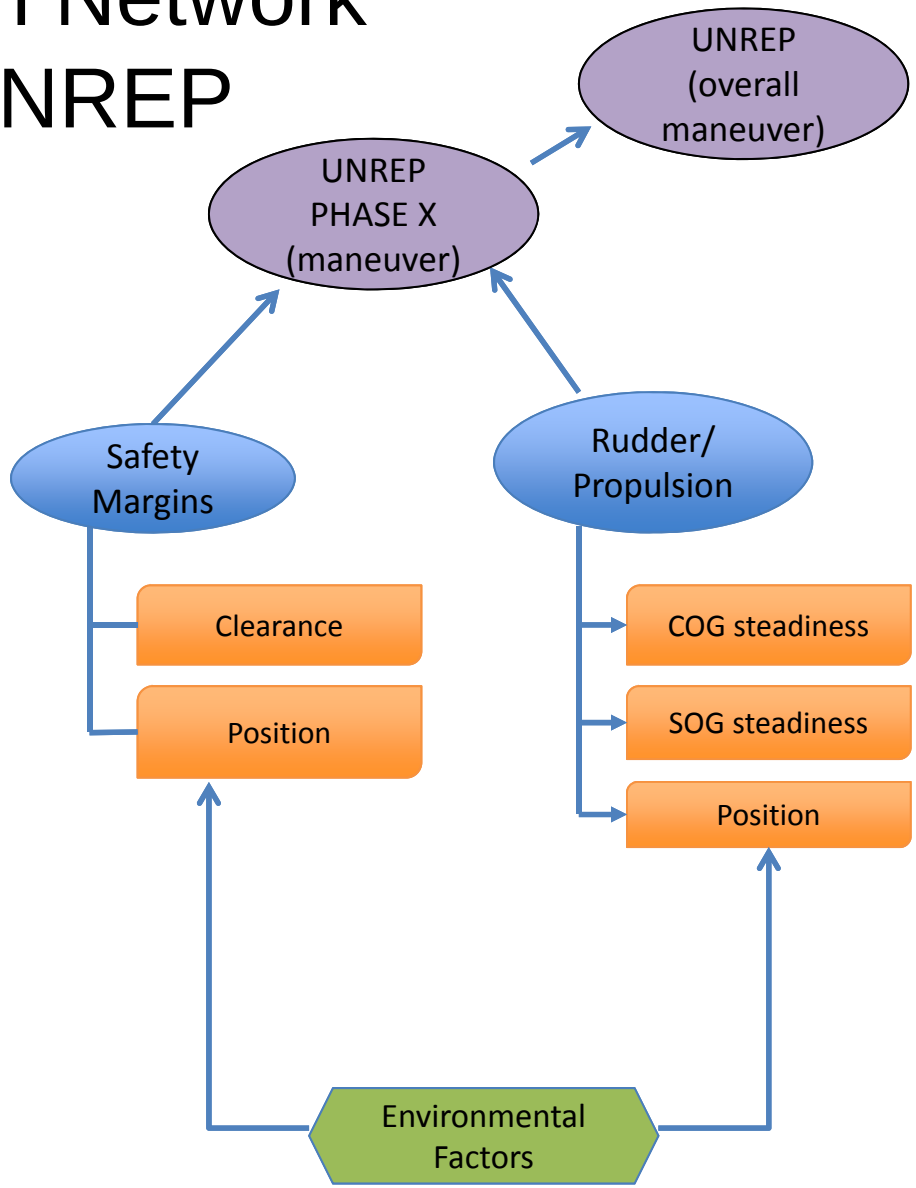
- A directed acyclic graph with nodes and links.
- BN nodes represent ontology *concepts*.
- BN links represent *dependencies* between ontology concepts.
- Arrows indicate the direction of dependencies (i.e. $concept_3$ is dependent on $concept_1$ and on $concept_2$).



Why use Bayesian Networks?

- BNs can handle uncertainty arising from:
  - Latent variables, such as situation awareness or decision making
  - Missing data, such as unobserved or partially observed performance
  - Measurement noise, such as instrument error
- BNs can make inferences and predictions of performance.
- BNs are theoretically well founded in graph theory and probability theory.
- BNs can be connected to simulations in real-time to provide formative assessments and remediation (as needed).
- BNs can be expanded to dynamic Bayesian Networks (DBNs) to model time sequences of events

Bayesian Network for UNREP



Assessment Engine Overview

What is the Automated Assessment Engine (AAE)?

The AAE is a software module that receives telemetry from the COVE-ITS, and from this information, assesses (and infers) student shiphandling proficiency.

What skills does it assess?

For the UNREP Evolution, we consider 5 phases and measure these skills**:

- UNREP Maneuver (overall)
- Safety Margins
- Use of Rudder and Propulsion
- Clearance
- Position
- COG Steadiness
- SOG Steadiness

**NOTE: Not each skill is assessed in each phase.

How does it work?

1. Every second, all relevant, *observable states* (i.e. SOG steadiness, COG steadiness, clearance, etc.) are received from the ITS and scored [in context].

2. These scores are fed into a Bayesian (statistical) model of nodes and links. This model allows for inferences to be made. To answer questions like:

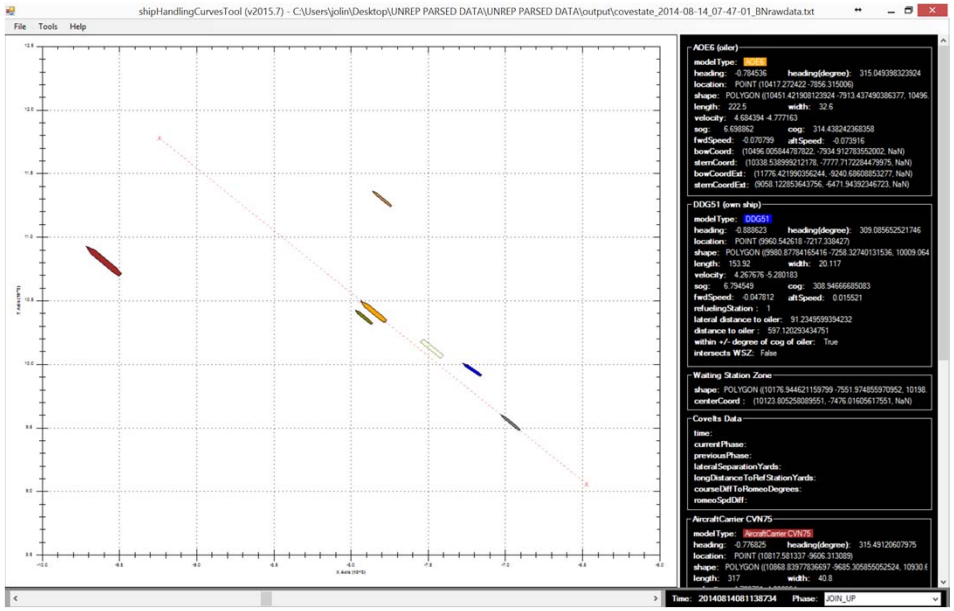
   "If we observe the student do X, what does that tell us about the student's understanding/skill of Y (or Z, or…)?"

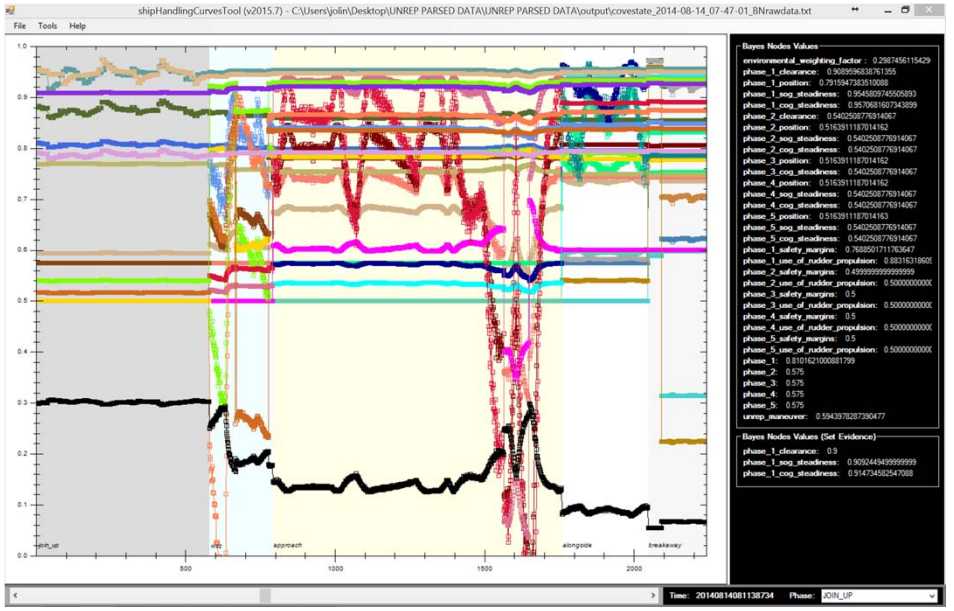
3. The AAE expresses its findings as probabilities. For example, a **Use of Rudder and Propulsion** score of 0.83 means:

   Based on what the system has observed, there's an 83% probability that the student is fully proficient in the "Use of Rudder and Propulsion" skill area.

AAE Visualization Tool (UNREP)

Real-Time Analysis of Observed Shiphandling Skills





The AAE Visualization Tool is used for detailed analysis. It can display moment-by-moment scoring of both observed and inferred skills, and enables investigation of single points in time across multiple screens.

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