Characteristics of this relationship include:

- Responsive to evolving needs
- Comprehensive knowledge of needs and problems
- Access to information and proprietary data
- Corporate knowledge and technical memory
- Objectivity and independence from commercial interests
- Quick response capability
- Current operational experience
- Freedom from real and perceived conflicts of interest

As a DoD designated University-Affiliated Research Center (UARC) ARL Penn State...

“...maintains a special long-term strategic relationship with Navy and DoD.”
Applied Research Laboratory
- Locations and Offsite Activities

Keyport Naval Facility
Keyport, WA

Penn State
Electro-Optics S&T Center
Kittanning, PA

ARL Penn State
State College, PA

Distributed Engineering Center
Penn State Fayette Campus

Washington Office
Washington, DC

ARL Tampa
Tampa, FL

ARL Hawaii
Oahu, HI

ARL KEY
Key West, FL

Navigation Research & Development Center
Warminster, PA
Select Program Overviews
Behavior Learning Technologies
Multi-sensor future track prediction for maritime domain awareness

Statistical models are built using novel behavior discovery and quantification technique that couples discrete and continuous statistical techniques in a hybrid model.

Predictions can be made over arbitrary time lengths using patterns multi-level statistical model.
### Multi-sensor future track prediction for maritime domain awareness

Tested on open source ship track data and data available from Naval systems on site.

<table>
<thead>
<tr>
<th></th>
<th>Duration (h)</th>
<th>Error (NM)</th>
<th>Error/Time (nm/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>20.8</td>
<td>32.95</td>
<td>2.83</td>
</tr>
<tr>
<td>Median</td>
<td>16.5</td>
<td>25</td>
<td>2.83</td>
</tr>
<tr>
<td>Standard Error (95%)</td>
<td>14.06</td>
<td>14.73</td>
<td>1.38</td>
</tr>
</tbody>
</table>

Adapted the technique to learn interactive behaviors between several agents.

We tested this on a simulation of the U.S.S. Cole scenario and showed how to make optimal decisions with these models.

\[
\begin{align*}
\max \sum_{q \in Q} \sum_{a \in A} [R_q \xi(q)]_a x_{qa} \\
\text{s.t.} \sum_{q \in Q} \sum_{a \in A} [\delta(q, q') - \beta \Pr(q' | q, a)] x_{qa} = x_{q^0}^0 \quad \forall q' \in Q \\
x_{qa} \geq 0 \quad \forall q \in Q, a \in A
\end{align*}
\]
Planned Future Work

- High Performance Data Fusion Laboratory

- Field sites need responsive systems for
  - Visualizing multi-source sensor data
  - Post-processing multi-source sensor data in a *human oriented* way.

- We aim to provide high performance algorithms and hardware integrated with large-scale visualizations to allow the user best solve their problems.

- Example: Large-scale visualization, clustering and track continuation are critical to understanding and processing large sensor data sets for maritime domain awareness.

- **Our goal is to enable organic problem solving with massive data sets.**
ARL welcomes the opportunity to help solve hard problems of National Importance

- ARL Penn State has a 64-year proud legacy of delivering advanced technology and R&D products to the national defense
- The UARC designation captures our trusted agent status and the strategic relationship that exists between Penn State and the DoD
- Our “track record” is based upon a first principles “systems engineering” research approach
- ARL fulfills a key role in developing a cadre of engineers and scientists needed for the future defense and IC workforce
- We are working on programs that are critical to current forces and their future capabilities

ARL welcomes the opportunity to help solve hard problems of National Importance