

Evaluation of a Human-Machine Teaming Approach for Probabilistic Maritime Mission Planning

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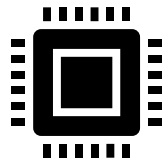
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HMT for Complex Planning Problems

Complex planning problems are ideal for human-machine teaming (HMT):



Transform data

Explore large decision spaces

Uncertainty and probabilities

Optimize over multiple constraints



Understand mission goals

Incorporate context

Reason about trade-offs

Adaptability to new information

**Effective HMT requires careful design to
create collaborative workflow and enable
efficient decision-making**

Maritime Missions with Commercial Vessels



DARPA Phorcys:

Develop planning and execution monitoring tools for employing commercial vessels for asset deployment, monitoring, and recovery

Phorcys goals:

- Expand options for missions
- Provide resiliency in operations
- Reduce risk to traditional platforms

Image from: <https://www.darpa.mil/program/phorcys>

Shown in image: a UAV is launched autonomously from a commercial vessel, flies a surveillance mission, and is recovered by a specially provisioned container on another vessel

- Lift and Deployment for Naval missions (LADON) is a software suite developed by STR and Aptima to address Phorcys challenges.
- The LADON Planner:
 - Reasons over current commercial schedules and historical traffic to provide robust launch, monitoring, and recovery plans for containerized assets.
 - Significantly reduces the lead time required for planning by utilizing commercial vessels and containers pre-positioned in regional ports.

The screenshot displays the STR LADON software interface, showing three mission planning scenarios. Each scenario includes a map, performance metrics, and a detailed task list with vessel assignments.

Scenario 1: Plan-SinglePhase_UAV-7

- # Assets: 14
- Mission Duration: 4 hours
- Success: 82%
- Resilience: 0.51
- POL Adherence: 0.13
- Distance (nm): 18699

Scenario 2: Plan-SinglePhase_UAV-€

- # Assets: 13
- Mission Duration: 4 hours
- Success: 76%
- Resilience: 0.51
- POL Adherence: 0.56
- Distance (nm): 16274

Scenario 3: Plan-SinglePhase_UAV-€

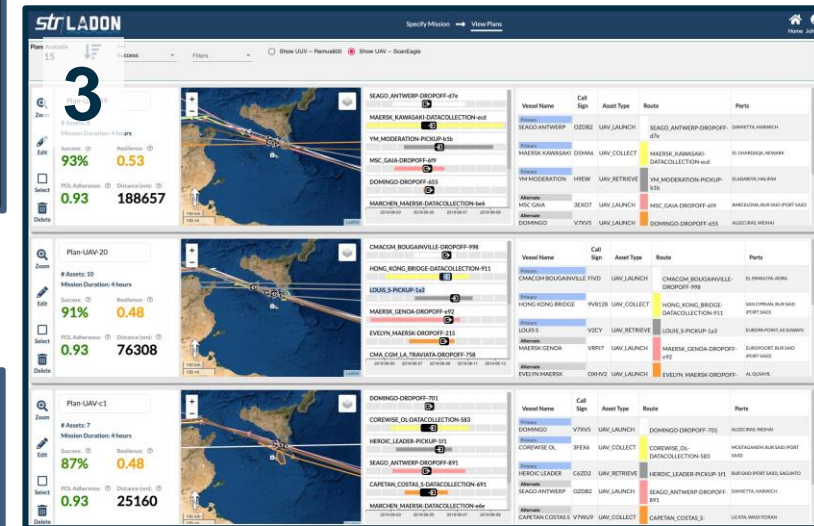
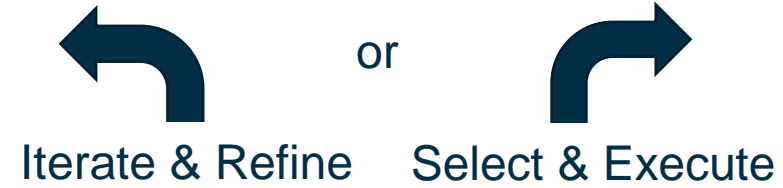
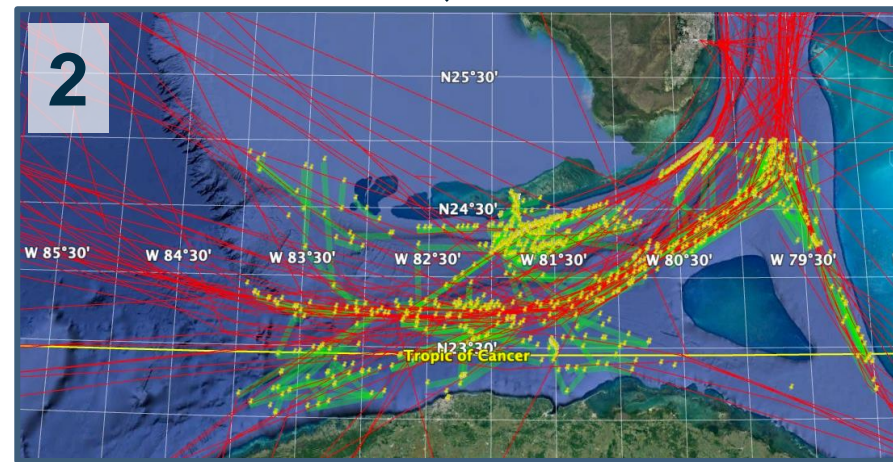
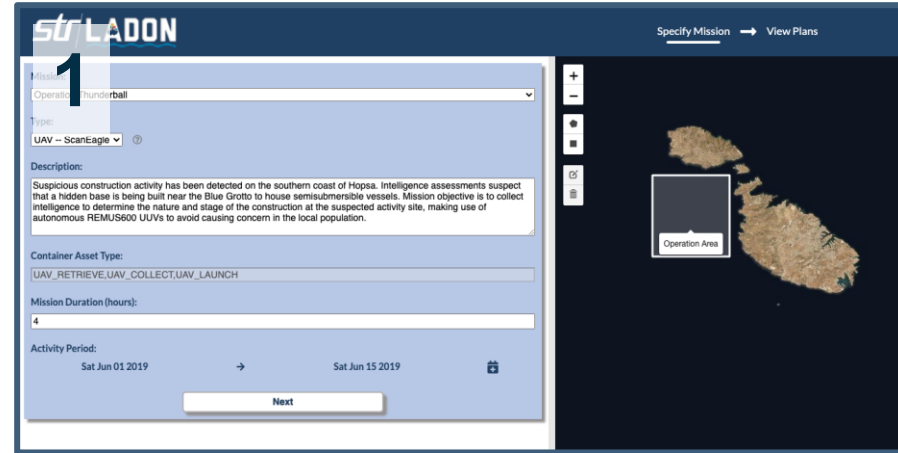
- # Assets: 10
- Mission Duration: 4 hours
- Success: 72%
- Resilience: 0.51
- POL Adherence: 0.48
- Distance (nm): 6731

The interface also shows a table of vessel assignments for each scenario, including Vessel Name, Call Sign, Asset Type, Route, and Ports.

The LADON planner uses evolutionary algorithms to search the space of commercial vessel schedules and assemble and assess feasible sealift support options.

The LADON Approach

- 1. User specific parameters & constraints**
- 2. Evolutionary search generates pareto-optimal plans**
- 3. Visualize plans to support evaluation & selection by user**



Understanding User's Interaction with Plans

2 options for viewing generated plans:

"List View"

"Model View"

The 'List View' interface displays a grid of mission plans. Each plan card includes a map, key metrics like Success (97.0%), Resilience (0.72), and PCL Adherence (0.15), and a table of vessel details.

Vessel Name	Call Sign	Asset Type	Route	Ports
STADT DRESDEN	CQI77	UAV_LAUNCH	STADT_DRESDEN-DROPOFF-117	BORUSAN FERTILIZER JETTY, TANGIER-MEDITERRANEAN
Hired_MARSAXLOKK	FV562A67	UAV_COLLECT	Hired_MARSAXLOKK-DATA_COLLECTION-F73	MARSAXLOKK, MARSAXLOKK
NEPTUNE ILIAD	9HA2406	UAV_RETRIEVE	NEPTUNE_ILIAD-PICKUP-DeD	BORUSAN FERTILIZER JETTY,RADES

The 'Model View' interface displays a table of mission plans with columns for Plan Name, Probability of Success, PCL Adherence, Resilience, and More. To the right is a 3D scatter plot of these metrics.

Plan Name	Probability of Success	PCL Adherence	Resilience	More
Plan-SinglePhase_UAV-91	97.0%	0.15	0.72	View Details
Plan-SinglePhase_UAV-b7	97.0%	0.07	0.59	View Details
Plan-SinglePhase_UAV-50	95.4%	0.30	0.41	View Details
Plan-SinglePhase_UAV-6b	94.8%	0.05	0.52	View Details
Plan-SinglePhase_UAV-b7	86.7%	0.30	0.49	View Details
Plan-SinglePhase_UAV-b6	86.5%	0.98	0.50	View Details
Plan-SinglePhase_UAV-9d	84.6%	0.30	0.56	View Details
Plan-SinglePhase_UAV-bf	81.0%	0.30	0.63	View Details
Plan-SinglePhase_UAV-79	80.3%	0.67	0.41	View Details
Plan-SinglePhase_UAV-53	79.8%	0.07	0.47	View Details
Plan-SinglePhase_UAV-58	78.0%	0.98	0.40	View Details
Plan-SinglePhase_UAV-20	78.0%	0.15	0.49	View Details

How do users understand the information across multiple plans?

How do users navigate between plans and between views?

What elements are most useful for decision making?

Method: Usability Study

- Two groups of 11 participants each
 - Group 1 started with List View, then switched to Model View
 - Group 2 started with Model View, then switched to List View
- Think-aloud protocol with directed tasks, followed by feedback elicitation
 - Feedback in the form of rating statements on a 1-10 agreement scale
- After the second portion, participants were given open response questions to answer about their experience with the LADON system

Example Rating Statements:

The task was easy to complete

I feel confident that I accurately assessed the array of plans presented

The information was displayed in a way that makes sense to me

I feel confident I could use the LADON system successfully

Example Open Response Questions:

What was your impression of the two different layouts?

Can you offer some pros and cons of the different layouts?

Did you find it easier to choose your desired plan using one layout over another?

Which features stuck out to you, good or bad?

Results: Qualitative

- General preference for whichever UI was used second
- Desire for easier comparison of metrics between each other. Need contextualization of the metrics, and how they should influence decisions.

Zoom

 Select

 Delete

Plan-SinglePhase_UAV-9

Assets: 12
Mission Duration: 2 hours

Success: 97.0% Resilience: 0.72

POL Adherence: 0.15 Distance (nm): 14927

Zoom

 Select

 Delete

Plan-SinglePhase_UAV-b

Assets: 8
Mission Duration: 4 hours

Success: 97.0% Resilience: 0.59

POL Adherence: 0.07 Distance (nm): 8091

List View shows more metrics and context of plan details

	Probability of Success	POL Adherence	Resilience	More
	97.0%	0.15	0.72	View Details
	97.0%	0.07	0.59	View Details
	95.4%	0.30	0.41	View Details
	94.8%	0.05	0.52	View Details
	86.7%	0.30	0.49	View Details
	86.5%	0.98	0.50	View Details
	84.6%	0.30	0.56	View Details
	81.0%	0.30	0.63	View Details
	80.3%	0.67	0.41	View Details

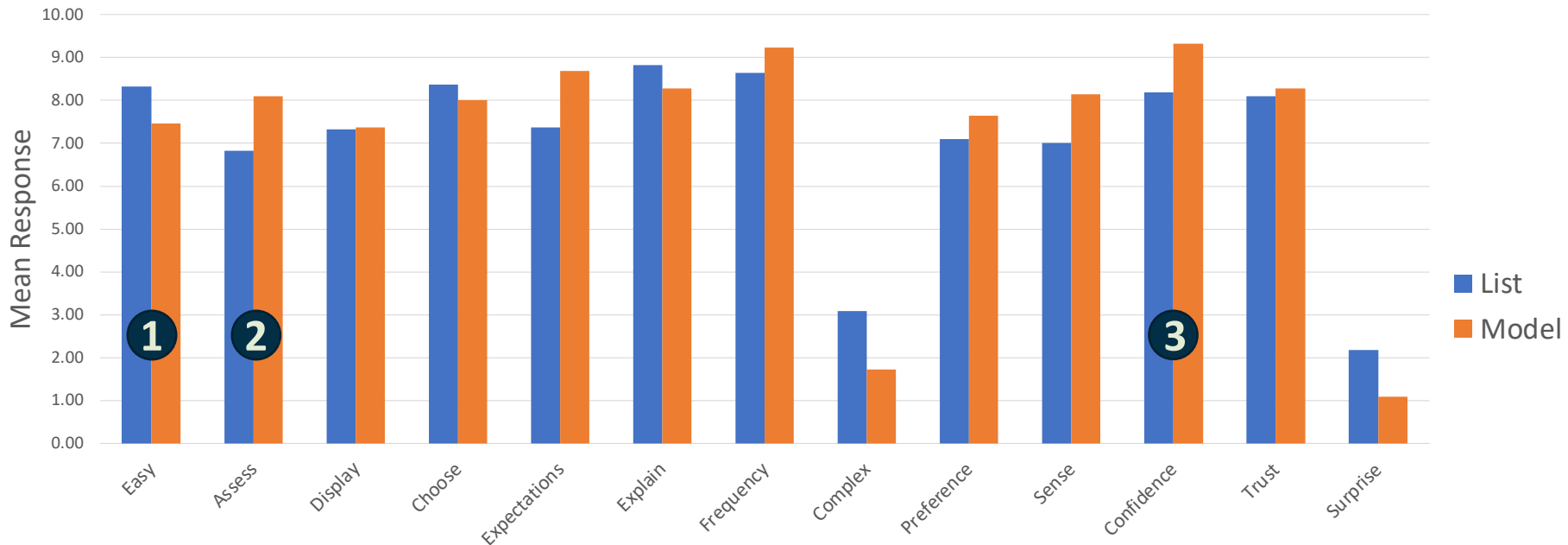
Model View shows visually aligned metrics across multiple plans

Results: Quantitative

Rating Statement

Result

- | | | |
|---|--|--|
| 1 | “The task was easy to complete” | List view ($M=8.32$) better than model view ($M=7.45$)
($W=93$, $p=.031$) |
| 2 | “I feel confident that I accurately assessed the array of plans presented” | Model view ($M=8.09$) better than the list view ($M=6.82$)
($W=33.5$, $p=.076$) |
| 3 | “I feel confident I could use the LADON system successfully” | Model view ($M=9.32$) better than the list view ($M=8.18$)
($W=36.5$, $p=.107$) |



Discussion: LADON-specific Lessons

Each view is good for...

List View

- Comparing between 2-3 similar plans
- Visually representing data
- Answering more in-depth questions (e.g., recovery from a faulty launch asset)

Model View

- Preliminary comparisons to narrow down the plans
- Table is useful for a high-level view of the data
- Answering metrics-based questions (e.g., which plan has lowest distance traveled)



Therefore...

Create an integrated view that combines elements of both to allow users to work in a way that meets their mental model

- Participants stated that they want to be able to easily select a top 2-3 plans they can then compare on a deeper, more detailed level.
- Multiple participants transitioned back and forth between the two views

Discussion: General Findings

Good interfaces for HMT should:

- Support easy comparison of data and metrics
- Support exploration and selection
- Help users maintain context throughout view manipulation

Key insight:

Separation of interface styles lessens utility because of the added friction of having to move back-and-forth and cognitive overhead of needing to maintain context while moving between views

Design Principles for Human-Machine Teaming for Planning:

- *Let the user work from a logical starting point*
- *Guide them to a meaningful end point*
- *Give them the freedom to drill down their desired level of detail.*

Information Seeking Mantra:

“Overview first, zoom and filter, then details on demand”

(Shneiderman, 1996)

This concept of an integrated view demonstrates the implementation of the best parts of both the Model and List view.

From the List view, there is the main component of **being able to see metrics, map, and assets.**

From the Model view, there is the **table of metrics and the model itself.**

LADON
Specify Mission | View Plans | Select Plans
JOHNNY

6 Plans

1 Plan Selected

Next

View Only Selected

Zoom

Rotate

Move

May 25th 1100-1800

Plan	Assets	Probability of Success	Flexibility	Map	Timeline
Plan 1	7 3 hour active window	91%	82%		<p>DROPOFF_B ETA: 17:30</p> <p>PICKUP_A ETA: 17:30</p> <p>COLLECTION_A ETA: 17:30</p> <p>MAY 14th</p> <p>+ 4 Alternate Assets</p>
Plan 2	8 3 hour active window	91%	82%		<p>DROPOFF_B ETA: 17:30</p> <p>PICKUP_A ETA: 17:30</p> <p>COLLECTION_A ETA: 17:30</p> <p>MAY 14th</p> <p>+ 5 Alternate Assets</p>
Plan 3	6 3 hour active window	91%	82%		<p>DROPOFF_B ETA: 17:30</p> <p>PICKUP_A ETA: 17:30</p> <p>COLLECTION_A ETA: 17:30</p> <p>MAY 14th</p> <p>+ 3 Alternate Assets</p>
Plan 4	8 3 hour active window	91%	82%		<p>DROPOFF_B ETA: 17:30</p> <p>PICKUP_A ETA: 17:30</p> <p>COLLECTION_A ETA: 17:30</p> <p>MAY 14th</p> <p>+ 5 Alternate Assets</p>

Plan Name	Assets	Metric 1	Metric 2	Metric 2	Metric 3
Plan Name 1	6	98%	0.20	15	89
Plan Name 2	8	91%	0.15	10	89
Plan Name 3	12	93%	0.25	10	90
Plan Name 4	7	93%	0.20	10	89
Plan Name 5	8	98%	0.20	20	89
Plan Name 6	10	95%	0.10	10	89

Thank you!

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