

# Decision Support for Workload Mitigation in Supervisory Control of Multiple UAVs

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Workshop

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# Outline

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- Supervising Multiple UAVs
- Experiment Motivation
- MAUVE Interface
- StarVis Decision Support Design
- Experiment Design
- Experiment Results
- Future Work



# Supervising Multiple UAVs

**Team of people flying  
one UAV**



**One person supervising  
mission of multiple UAVS**





# Experiment Motivation

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- Multiple UAVs → More Tasks → Higher Workload
- How do we manage the schedule?  
Prioritize activities?

**Need workload mitigation  
decision support!**



# Experiment Focus

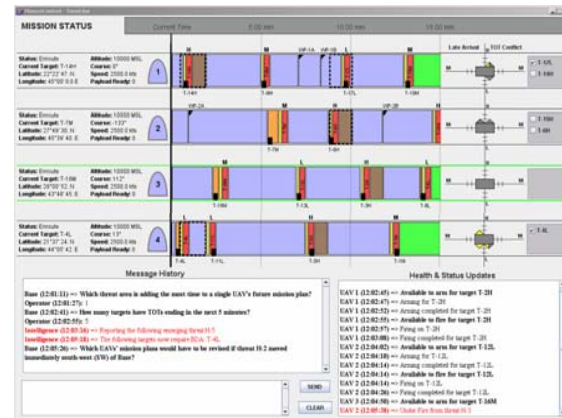
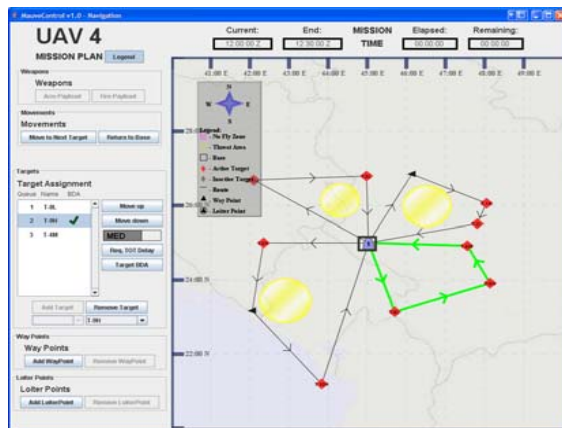
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- Does a workload mitigation decision support visualization increase a multi-UAV operator's performance by helping them manage their schedule?
- Using a simulated environment, test human subjects conducting a multi-UAV mission under two conditions
  - With schedule management decision support
  - Without schedule management decision support



# MAUVE Interface

- Multi-Aerial Unmanned Vehicle Experiment
- One user, four homogenous & independent UAVs
- Mission: Destroy/Image multiple targets
- Supervisory control of schedule, path replanning, emergent events





# Map Display

MauveControl v1.0 - Navigation

**UAV 4**

**MISSION PLAN** Legend

**Weapons**

Weapons

Arm Payload Fire Payload

**Movements**

Movements

Move to Next Target Return to Base

**Targets**

Target Assignment

Queue Name BDA

|   |      |   |
|---|------|---|
| 1 | T-8L |   |
| 2 | T-9H | ✓ |
| 3 | T-4M |   |

Move up Move down

MED

Req. TOT Delay Target BDA

Add Target Remove Target

T-9H

**Way Points**

Way Points

Add WayPoint Remove WayPoint

**Loiter Points**

Loiter Points

Add LoiterPoint Remove LoiterPoint

Current: 12:00:00 Z End: 12:30:00 Z MISSION TIME Elapsed: 00:00:00 Remaining: 00:00:00

41:00 E 42:00 E 43:00 E 44:00 E 45:00 E 46:00 E 47:00 E 48:00 E 49:00 E

28:00 N 26:00 N 24:00 N 22:00 N

Legend:

- No Fly Zone
- Threat Area
- Base
- Active Target
- Inactive Target
- Route
- Way Point
- Loiter Point



# Timeline Display

MauveControl - TimeLine

**MISSION STATUS**
Current Time
5:00 min
10:00 min
15:00 min

|  |   |  |   |
|--|---|--|---|
| <p><b>Status:</b> Enroute<br/> <b>Current Target:</b> T-14H<br/> <b>Latitude:</b> 22°22' 47. N<br/> <b>Longitude:</b> 45°00' 0.0 E</p> <p><b>Altitude:</b> 10000 MSL<br/> <b>Course:</b> 0°<br/> <b>Speed:</b> 2500.0 kts<br/> <b>Payload Ready:</b> 0</p>   | 1 |  | <input checked="" type="checkbox"/> T-17L<br><input type="checkbox"/> T-14H |
| <p><b>Status:</b> Enroute<br/> <b>Current Target:</b> T-7M<br/> <b>Latitude:</b> 27°49' 30. N<br/> <b>Longitude:</b> 45°39' 40. E</p> <p><b>Altitude:</b> 10000 MSL<br/> <b>Course:</b> -133°<br/> <b>Speed:</b> 2500.0 kts<br/> <b>Payload Ready:</b> 0</p> | 2 |  | <input type="checkbox"/> T-15H<br><input type="checkbox"/> T-6H             |
| <p><b>Status:</b> Enroute<br/> <b>Current Target:</b> T-18M<br/> <b>Latitude:</b> 28°00' 52. N<br/> <b>Longitude:</b> 43°48' 45. E</p> <p><b>Altitude:</b> 10000 MSL<br/> <b>Course:</b> 112°<br/> <b>Speed:</b> 2500.0 kts<br/> <b>Payload Ready:</b> 0</p> | 3 |  |   |
| <p><b>Status:</b> Enroute<br/> <b>Current Target:</b> T-4L<br/> <b>Latitude:</b> 21°37' 24. N<br/> <b>Longitude:</b> 44°05' 42. E</p> <p><b>Altitude:</b> 10000 MSL<br/> <b>Course:</b> 13°<br/> <b>Speed:</b> 2500.0 kts<br/> <b>Payload Ready:</b> 0</p>   | 4 |  | <input checked="" type="checkbox"/> T-4L                                    |

**Message History**

Base (12:01:11) => Which threat area is adding the most time to a single UAV's future mission plan?  
 Operator (12:01:27): 1  
 Base (12:02:41) => How many targets have TOTs ending in the next 5 minutes?  
 Operator (12:02:55): 5  
**Intelligence (12:03:16) => Reporting the following emerging threat:H-5**  
**Intelligence (12:05:18) => The following targets now require BDA: T-4L**  
 Base (12:05:26) => Which UAVs' mission plans would have to be revised if threat H-2 moved immediately south-west (SW) of Base?

**Health & Status Updates**

UAV 1 (12:02:45) => Available to arm for target T-2H  
 UAV 1 (12:02:47) => Arming for T-2H  
 UAV 1 (12:02:52) => Arming completed for target T-2H  
 UAV 1 (12:02:55) => Available to fire for target T-2H  
 UAV 1 (12:02:57) => Firing on T-2H  
 UAV 1 (12:03:08) => Firing completed for target T-2H  
 UAV 2 (12:04:02) => Available to arm for target T-12L  
 UAV 2 (12:04:10) => Arming for T-12L  
 UAV 2 (12:04:14) => Arming completed for target T-12L  
 UAV 2 (12:04:14) => Available to fire for target T-12L  
 UAV 2 (12:04:14) => Firing on T-12L  
 UAV 2 (12:04:26) => Firing completed for target T-12L  
 UAV 3 (12:04:50) => Available to arm for target T-16M  
**UAV 2 (12:05:38) => Under Fire from threat H-3**





# Previous Work

- Different automation levels in multiple UAV control task
- Hypothesis - Active level as best performance
- Result – Active level was worst performance at high re-plan levels
- Reason – Subjects overly focused on schedule replanning

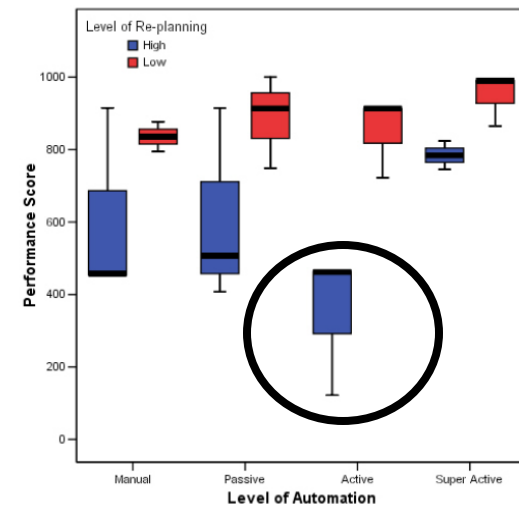
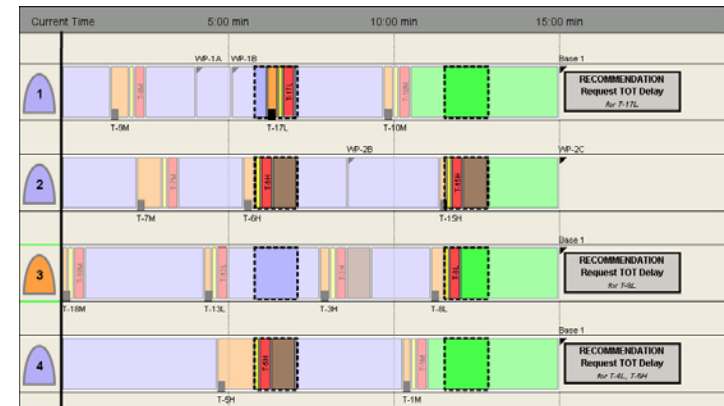


Figure 5-1: Performance Scores Across Levels of Automation and Re-planning



# Experiment Overview

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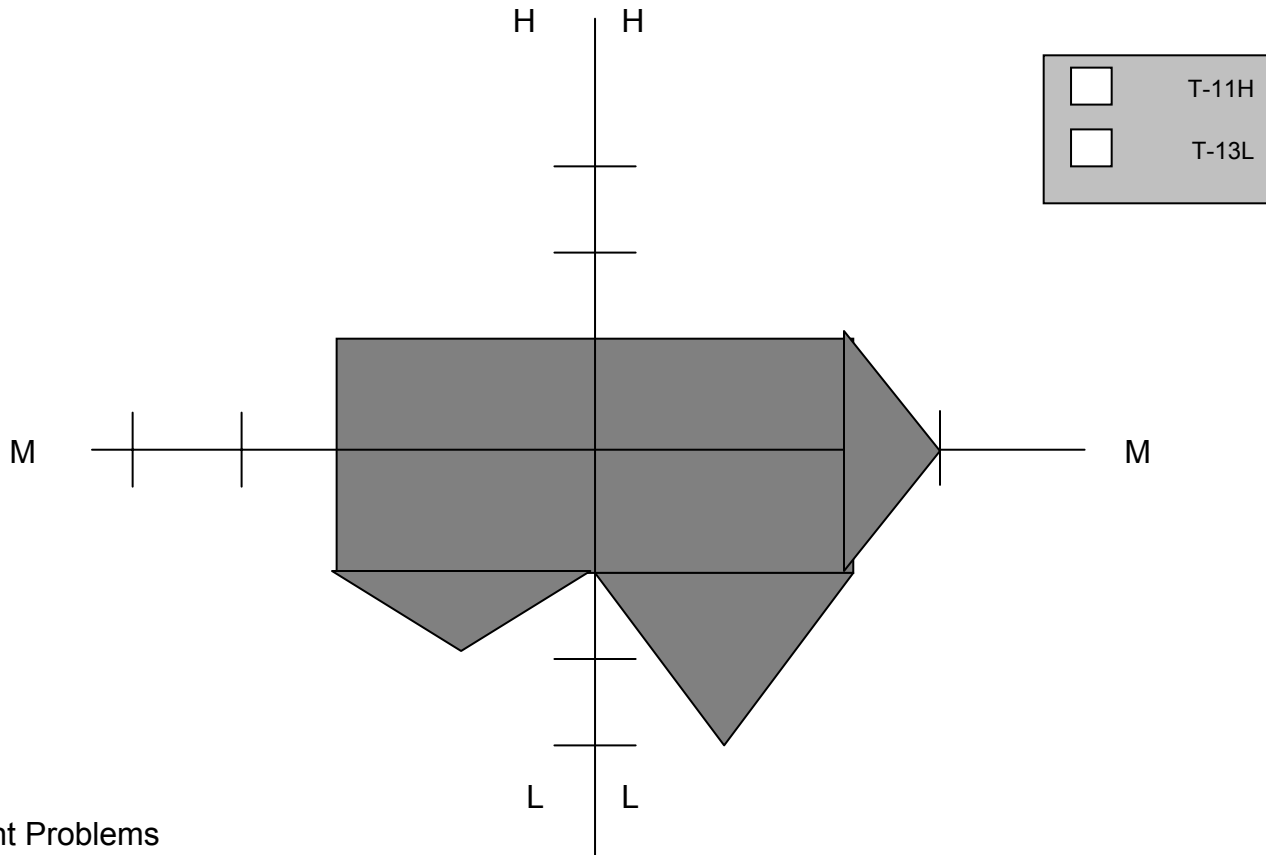
- Active Automation: Operator arms & fires UAV weapon at scheduled Time on Target (TOT)
- Miss targets in two ways
  - Arrive to target late
  - Have multiple actions to perform at once for multiple targets
- Solve by requesting TOT delay to manage schedule – make future worse?
- Provide Decision Support to optimize schedule – StarVis configural display



# Star Configural Display

Late Arrival

TOT Conflicts



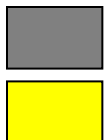
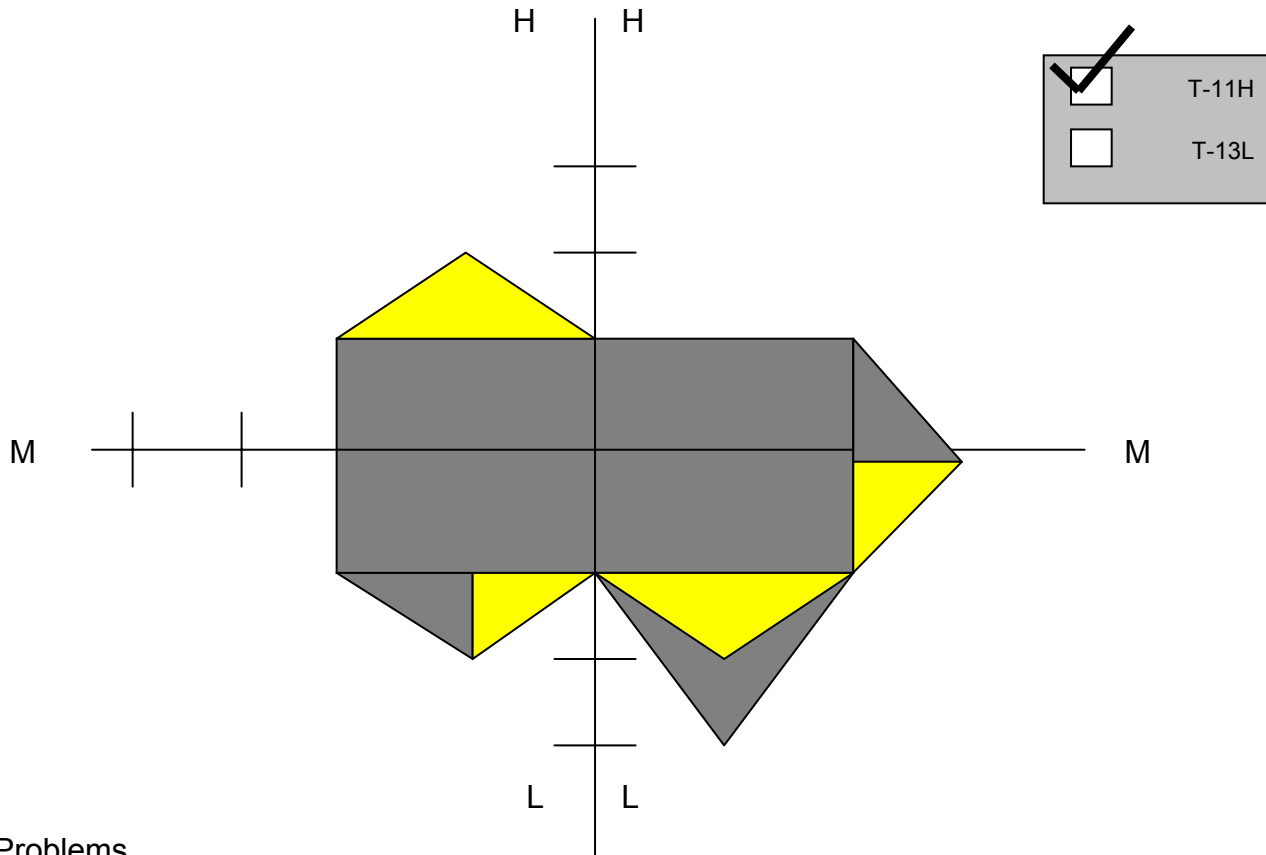
 Current Problems



# Star Configural Display

Late Arrival

TOT Conflicts



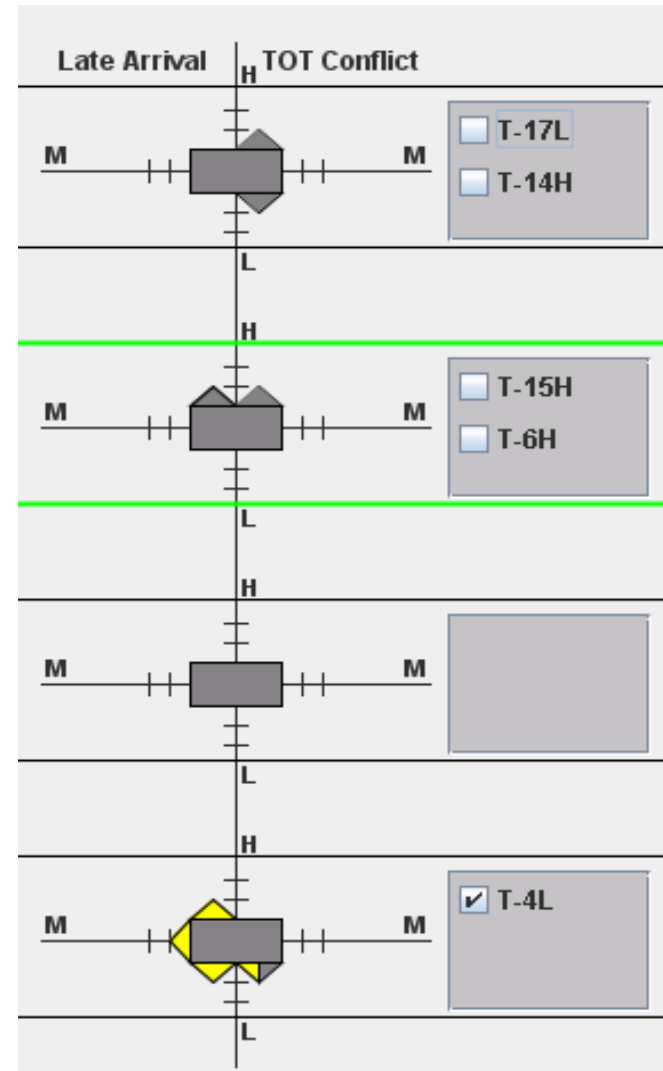
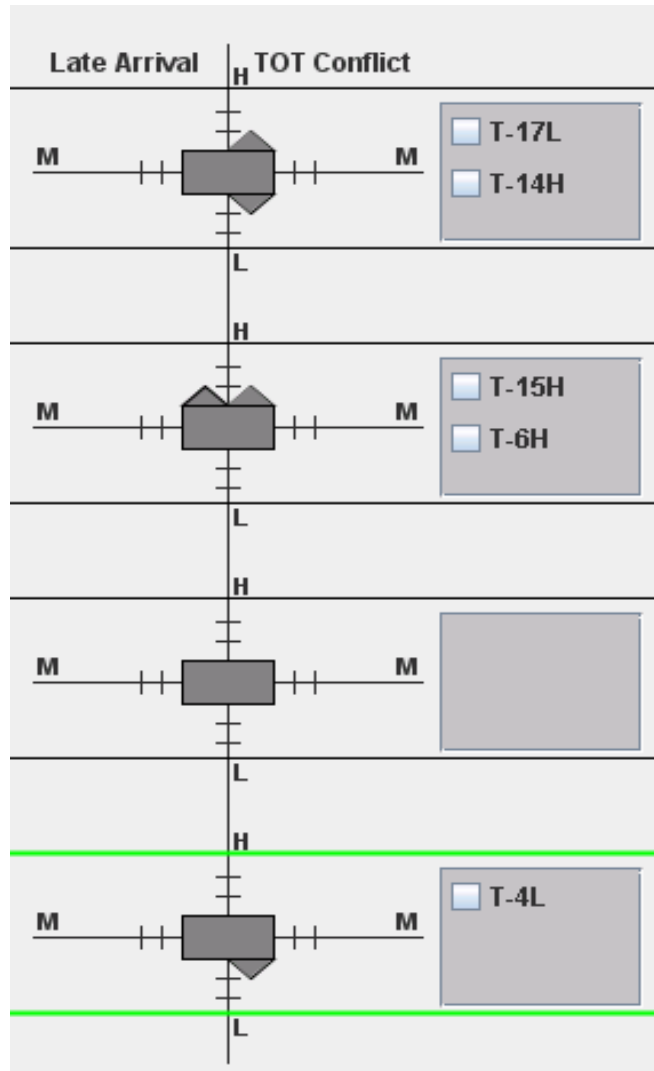
Current Problems

Action Generated Problems



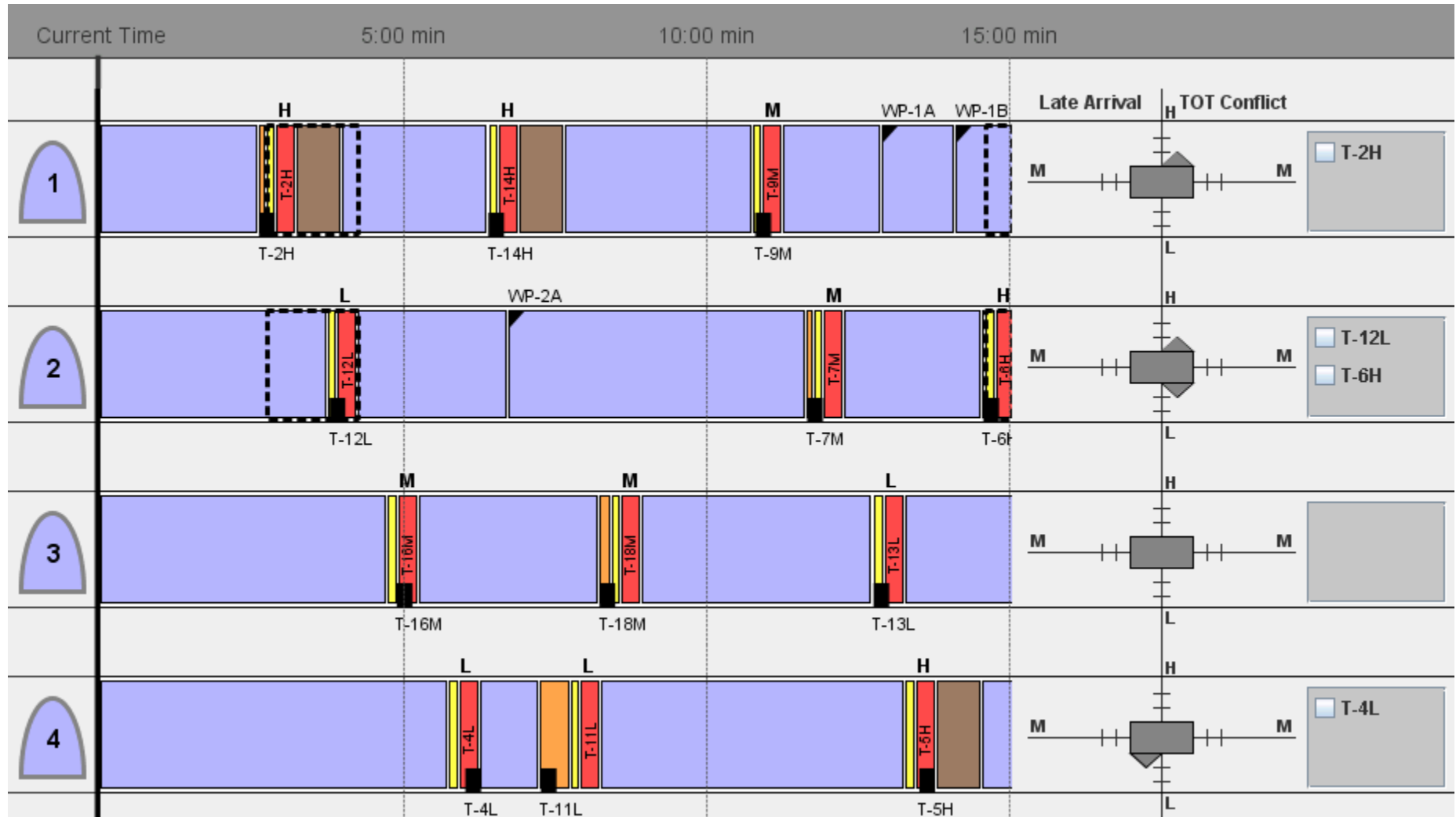


# Local Design in MAUVE





# Video Example





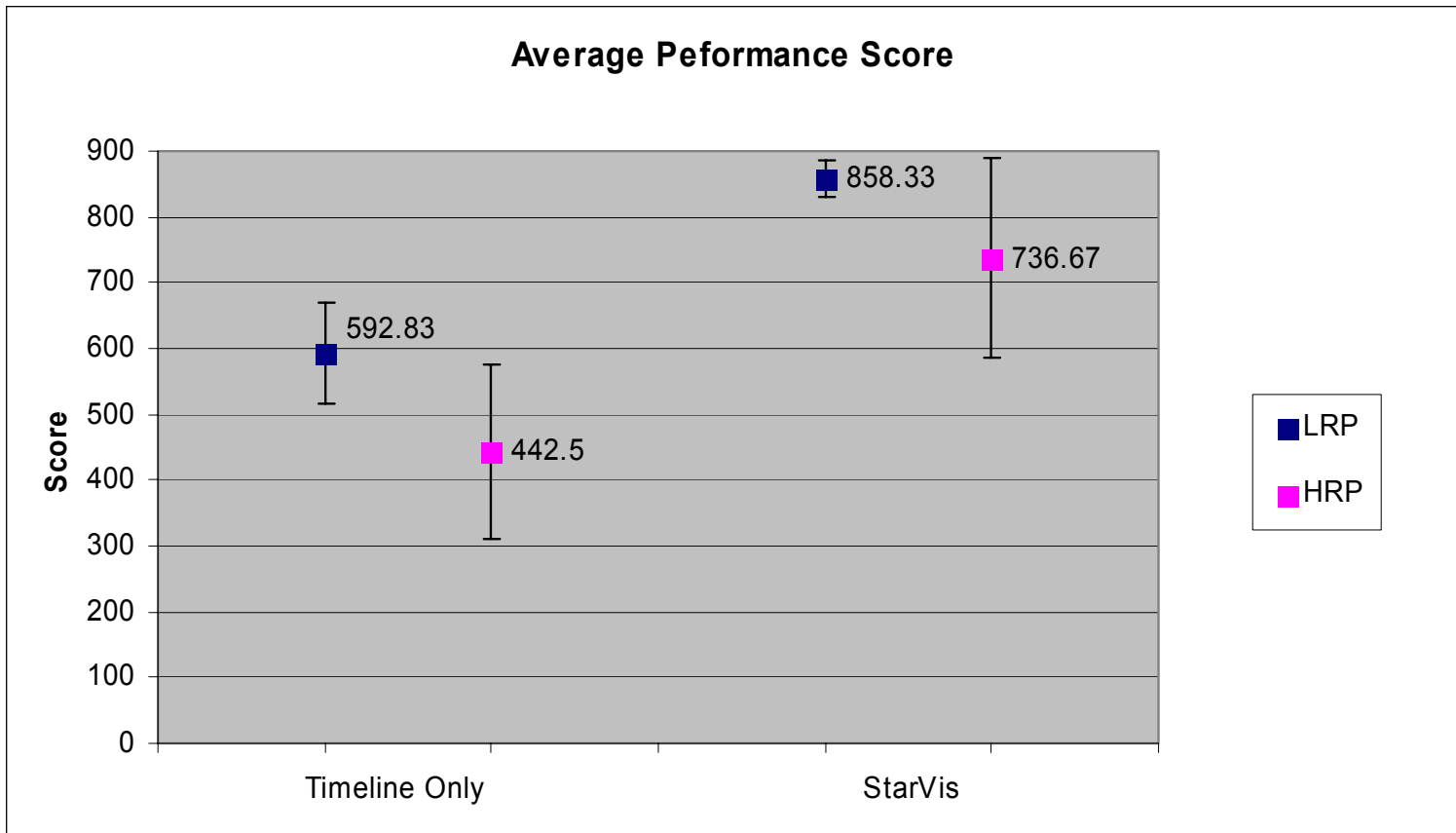
# Experiment Design

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- Independent Variables
  - Decision Support Visualization: no visualization, StarVis display (Between Subjects)
  - Level of Scenario Re-planning: high, low (Within Subjects)
- Dependent Variables
  - Performance Scores – Optimistic & Pessimistic
  - Number of TOT delay Requests
  - Incorrect Firing Events
  - Workload - Objective & Subjective



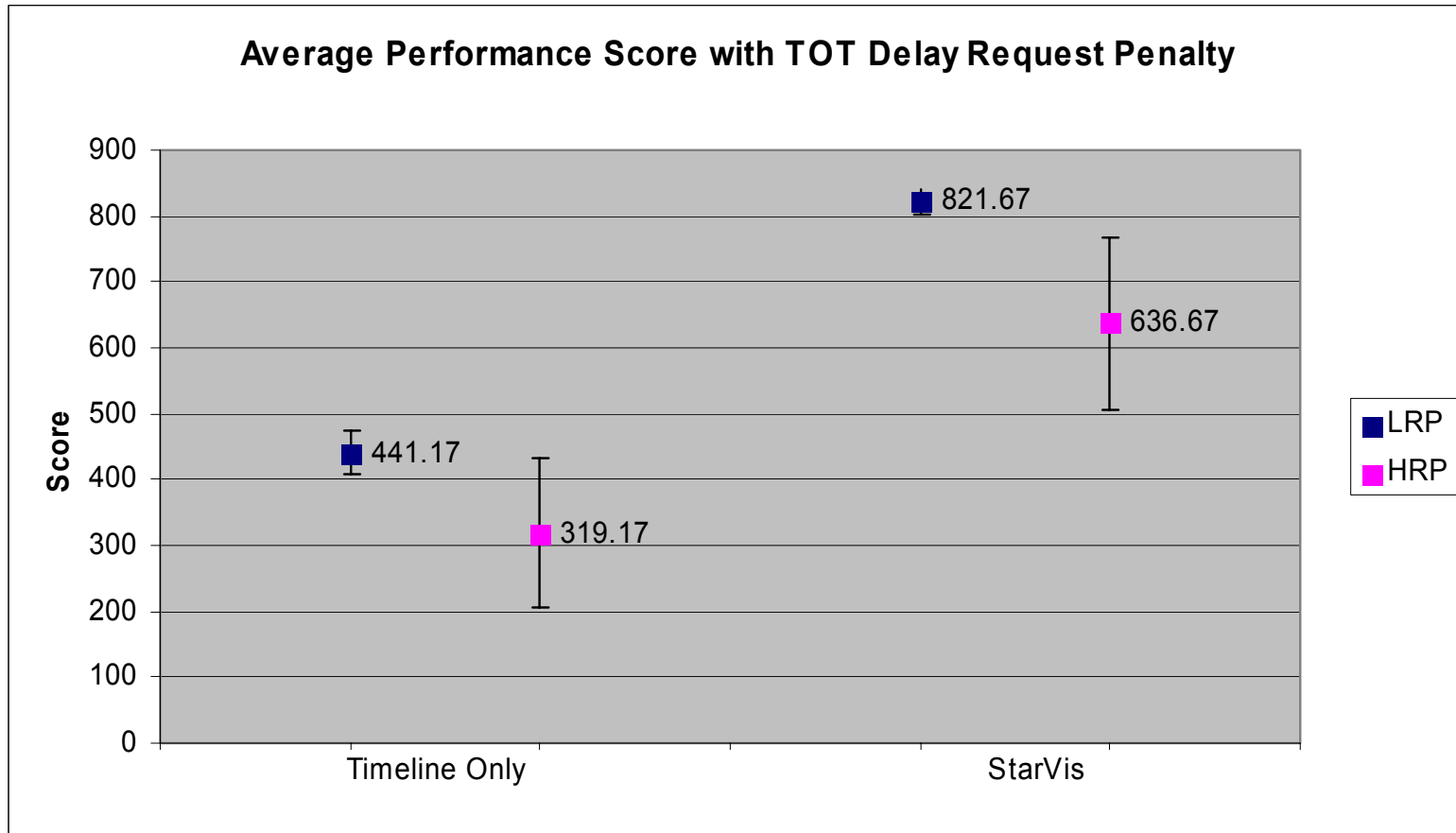
# Performance - Optimistic





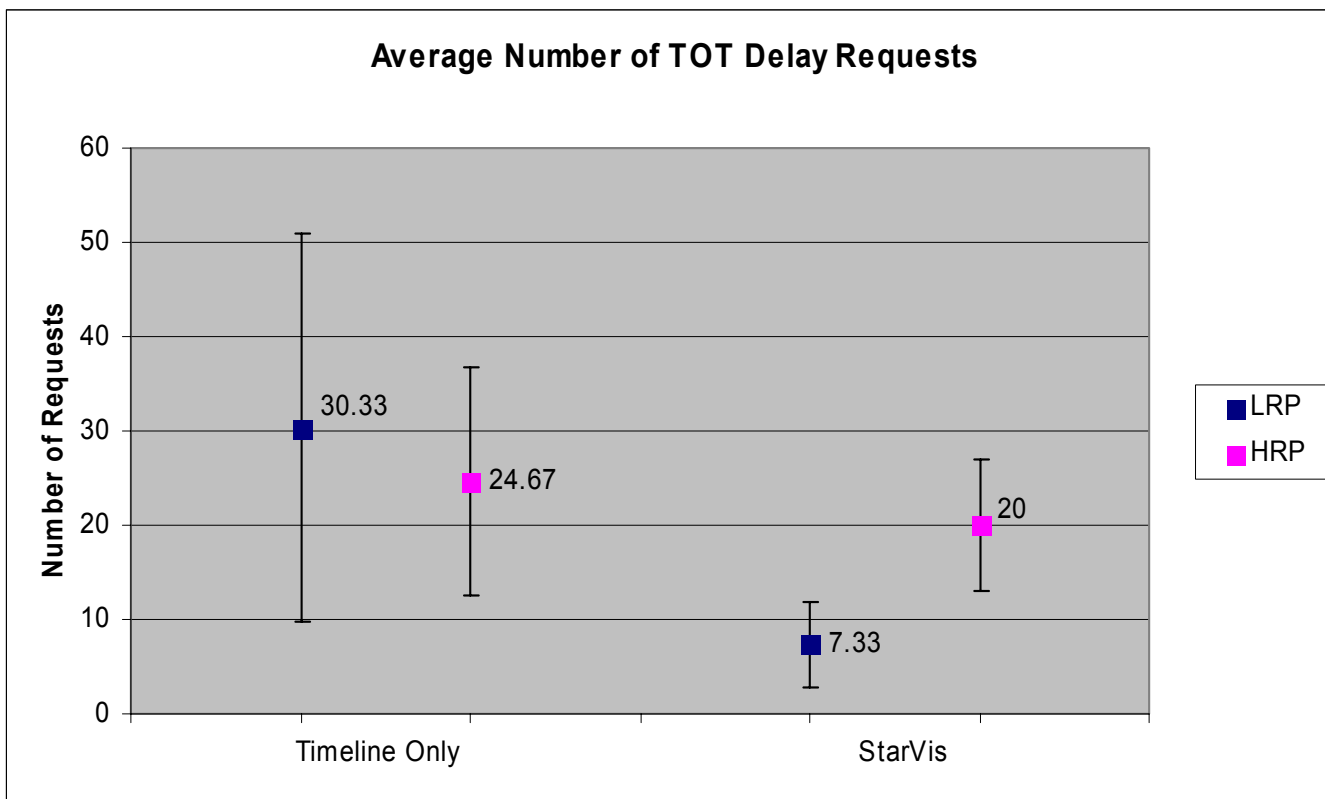


# Performance - Pessimistic





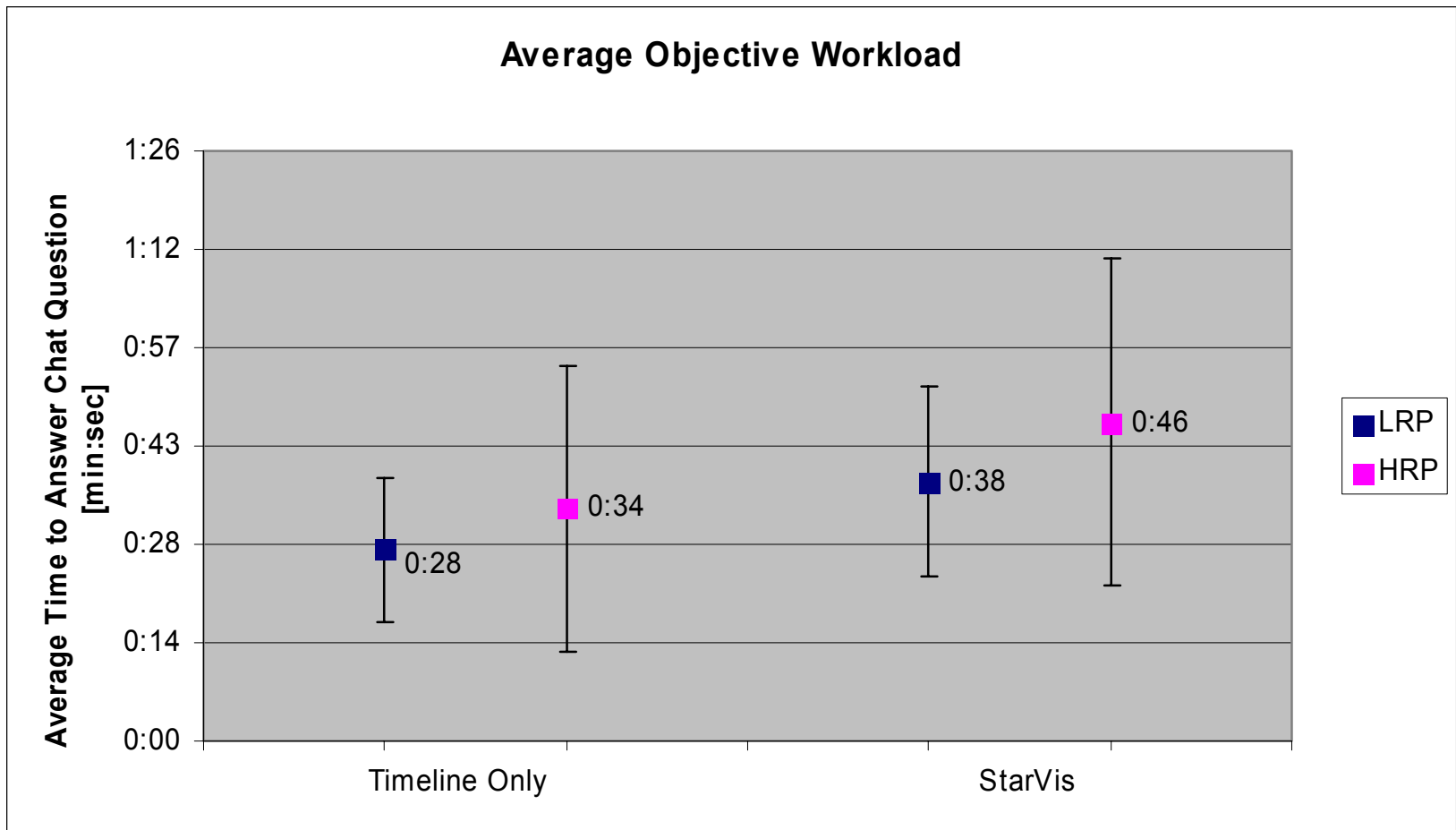
# TOT Delay Requests



- Global SA Measure: Incorrect Firing Events
  - Timeline Only: 2                      StarVis: 0

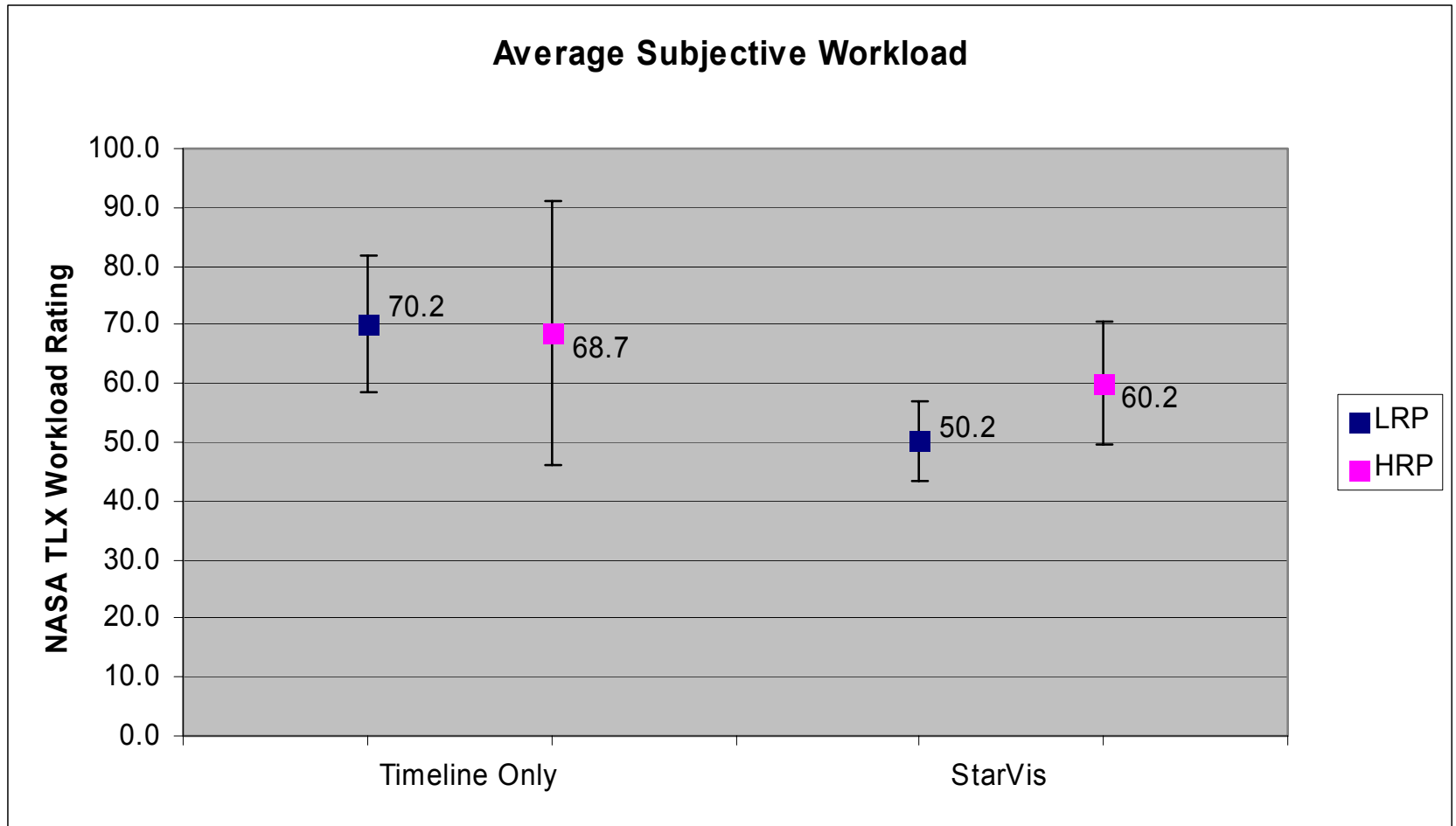


# Objective Workload





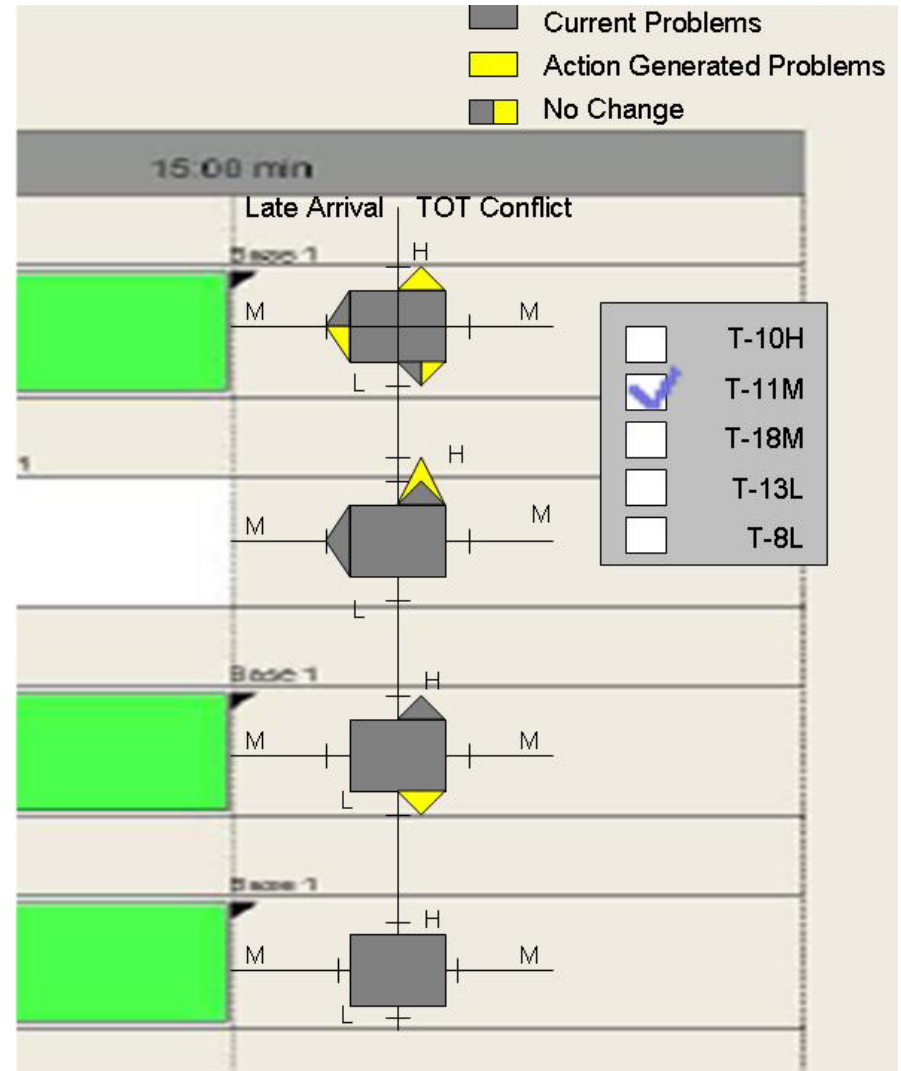
# Subjective Workload





# Future Work

- More Experiments!
- Local Design
- Quasi-Global Design
- Data Analysis
- Recommendation Algorithm





# Acknowledgments

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- The MITRE Corporation
- The Boeing Company
- Albert Leung for software development