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# UAS Loss of Link (UL2) Project Overview

Sponsor: GMU, Andy Lacher (MITRE Corporation)

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# Background

- MITRE Corporation
  - This project is being sponsored by The MITRE Corporation, which is a not-for-profit organization that manages Federally Funded Research and Development Centers (FFRDCs).
  - Work is specifically from the Center for Advanced Aviation System Development (CAASD)
- Unmanned Aircraft System (UAS)
  - A UAS is remotely piloted from ground stations via a real-time command and control (C2) data link.



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Unmanned Aircraft (UA)

Loss of Link

UA is unpredictable to ATC

- ATC cannot adequately control airspace
- Risk of a loss of separation or collision
- Unnecessary rerouting of air traffic
- Excess workload for ATC

Air Traffic Control (ATC)

**Standardized procedures for loss of link situations are necessary to make these events more predictable and easier to manage**

Ground Station

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# Methodology

- A standardized procedure is a community wide issue
- Develop methodology for evaluating loss of link procedures
  - Purpose is to take a set of procedures and allow the sponsor to narrow down to the top few for further investigation
  - Human in the Loop experiments (HITLs) can then be designed for top procedures
- Expected Results
  - Set of metrics that are important to UAS stakeholders
  - A methodology that can be used to evaluate procedures
    - Repeatable and adaptable to different procedures
    - Capable of being used for further research and analysis by the sponsor

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# Scope

- In Scope
  - Within non-segregated civil airspace- National Airspace System (NAS)
  - Primary focus on UAS that are capable of extended flight operations in Class A airspace
  - To test/evaluate our approach with proposed procedure
- Out of Scope
  - Identification of optimal procedure for loss of link situations



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# Next Steps from Last Time

- Continue meeting with Sponsor
  - ✓ Met with sponsor and his UAS research team
  - ✓ Conducted a critical design review with sponsor's UAS team
- Complete proof of concept & develop predictability model
  - ✓ Completed proof of concept
  - ✓ Created model in both Excel and Arena
- Adapt scenarios for *airspace*Analyzer
  - ✓ Created 3 scenarios to analyze with *airspace*Analyzer (automated ATC tool)
  - ✓ Working with lead developer for *airspace*Analyzer to finalize details
- Start documenting our methodology and assemble our report
  - ✓ Started a rough draft of final report



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# Approach

- Qualitative
  - Interviews to determine metrics from different stakeholders
- Absolute/Binary
  - Determine thresholds that must be met
- Analytical
  - Develop simulations that analyze individual procedures based on specific metrics



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# SME Interviews

- Met with all the SMEs recommended to us by our sponsor:
  - Global Hawk UAS pilot
  - ATC human-in-the-loop experiment analyst
  - UAS loss of link data analyst
  - Lead developer of automated ATC tool
  - Traffic flow management lead architect
  - Lead UAS Architect



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# Modeling

- Analytical modeling approaches based on:
  - Feedback from sponsor
  - Interviews with SMEs
  - Feedback led us to focus on predictability and the effect on ATC
- Focus is on two main metrics:
  - Predictability
    - Monte Carlo simulation
    - Process modeling- using Arena as the primary tool
  - Air Traffic Control workload
    - Using a graphical linear programming tool called *airspace*Analyzer



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# Predictability Model



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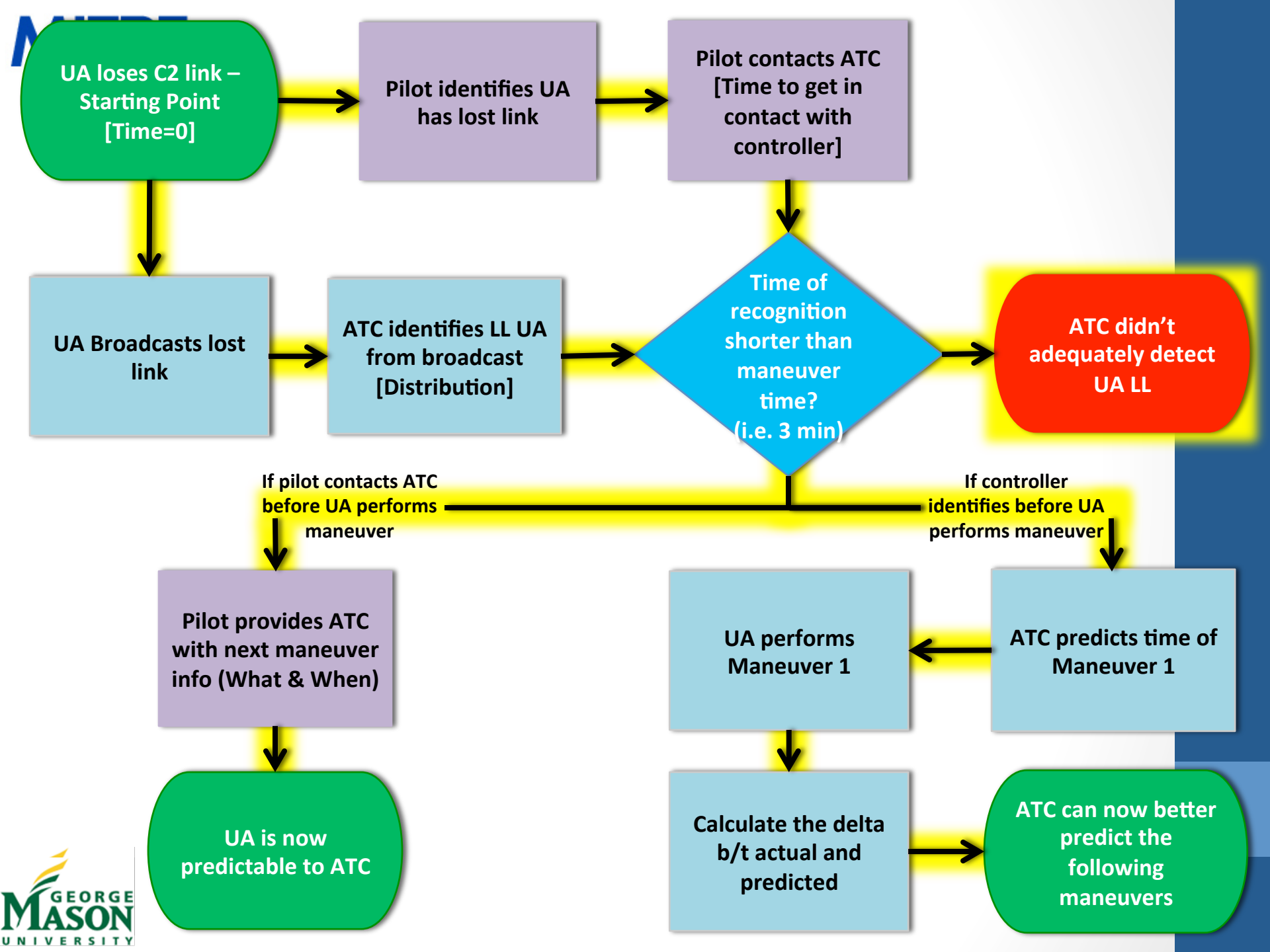
UA loses C2 link – Starting Point [Time=0]
Pilot identifies UA has lost link
Pilot contacts ATC [Time to get in contact with controller]
UA Broadcasts lost link
ATC identifies LL UA from broadcast [Distribution]
Time of recognition shorter than maneuver time? (i.e. 3 min)
ATC didn't adequately detect UA LL
If pilot contacts ATC before UA performs maneuver
If controller identifies before UA performs maneuver
Pilot provides ATC with next maneuver info (What & When)
UA is now predictable to ATC
UA performs Maneuver 1
ATC predicts time of Maneuver 1
Calculate the delta b/t actual and predicted
ATC can now better predict the following maneuvers

# Predictability Model Assumptions

- Times of UA maneuvers based on sample procedure provided by sponsor
- The pilot/ATC knows the sample contingency procedure
- All other functions (other than C2 link) on the UA are operating properly
- Loss of Link is indicated by change of transponder code- Radio Frequency loss (RDOF)
- If the pilot gets in contact with ATC (before the controller realizes LL from UA broadcast), the pilot will tell ATC exactly what/when maneuvers will happen
- There will be no conflicts within two minutes because ATC probes for conflicts up to two mins in advance

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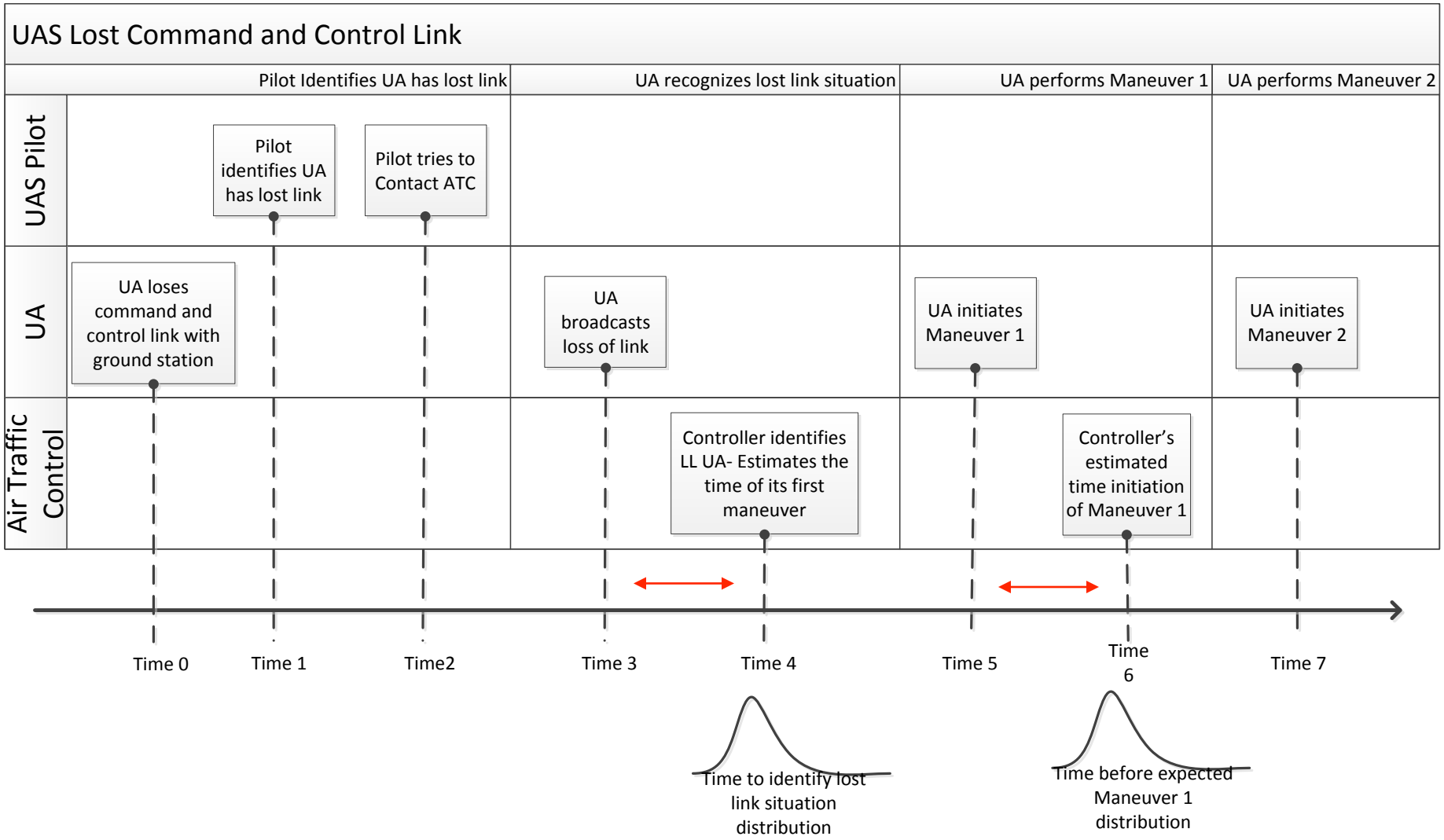
# Predictability Model - Timeline



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# Predictability Model - Details

- Pseudo-measure for predictability will be time
- Aimed to have a flexible model that can incorporate new data easily
- Input
  - Controller reaction times to UA signaling loss-of-link
- Outputs
  - Times of interest:
    - Delta between UA broadcasting loss of link and the controller identifying the UA as loss of link
    - Delta between when the controller estimates the UA will initiate its first maneuver and the actual time of initiation
- Enhanced Output
  - To enhance the model, the model will also include the possibility of conflict
    - Tc is the time to conflict (loss of separation)
    - Analyze the probability the UA will be in conflict before the controller realizes there is a loss of link situation

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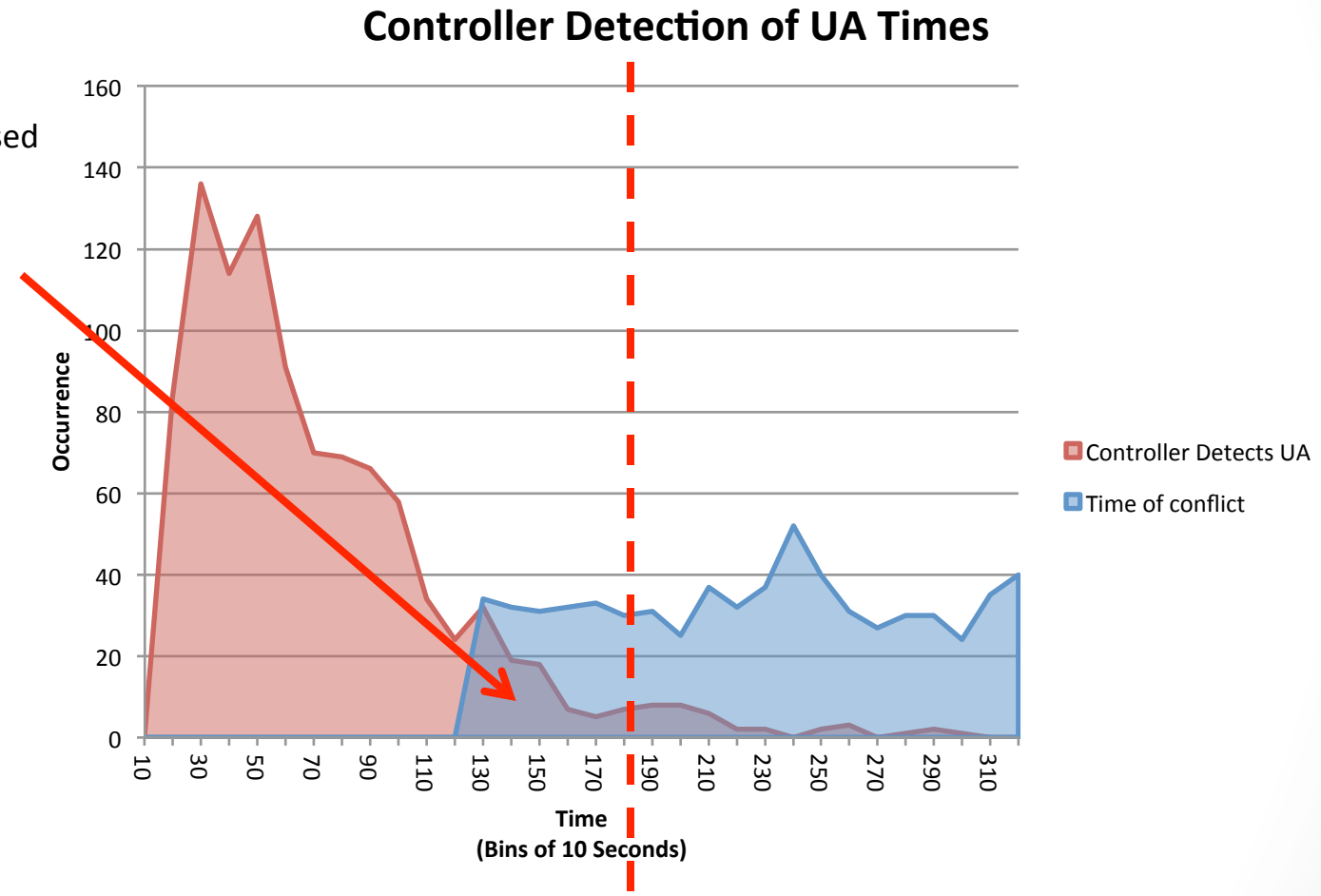
# Predictability Model - Sample Output

Overlapping – Area of increased risk of collision




Time of when the UA performs its first maneuver

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# Controller Workload Model



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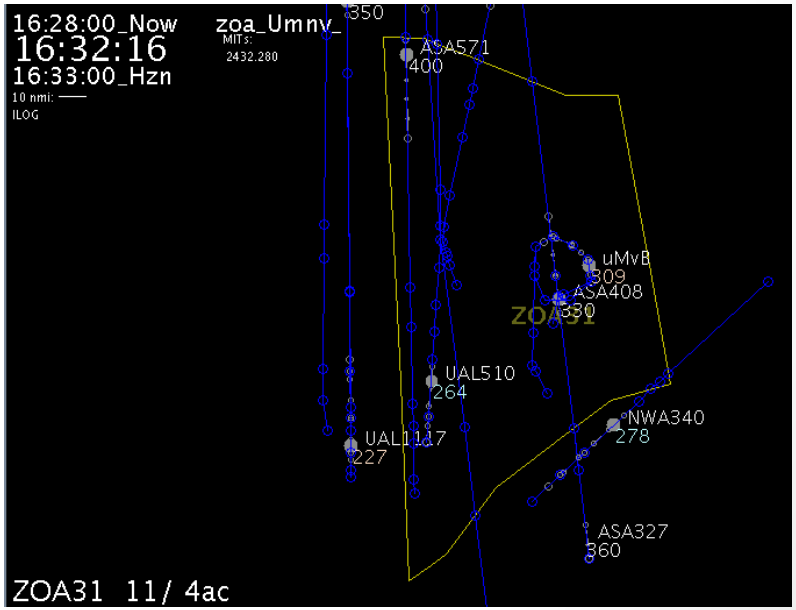
# *airspace*Analyzer – Controller Workload

- Simulation tool developed by MITRE to automatically separate, sequence, and space aircraft
- Measures sector complexity based on the amount of effort required to separate traffic
- Evaluates the impact of changes to sector on controller workload. Examples of potential changes include:
  - New Traffic Flows
  - New Sector Boundaries
  - Airspace Restrictions
  - Moving weather systems
- What about UAS?




*airspace*Analyzer
Sample Display

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# *airspace*Analyzer – Adaptation for UAS

- Tool can be used to evaluate the impact of a specific UAS loss of link procedure on sector complexity and controller workload
- Specific metrics can be gathered to evaluate the increase in controller workload if UA goes lost link
  - Lateral separation effort
  - Vertical separation effort
  - Lateral spacing effort
  - Vertical spacing effort
- Some maneuver uncertainty can be modeled by adjusting the amount of protection required for UA (e.g. increase from 5 NM to 10 NM in En Route airspace)



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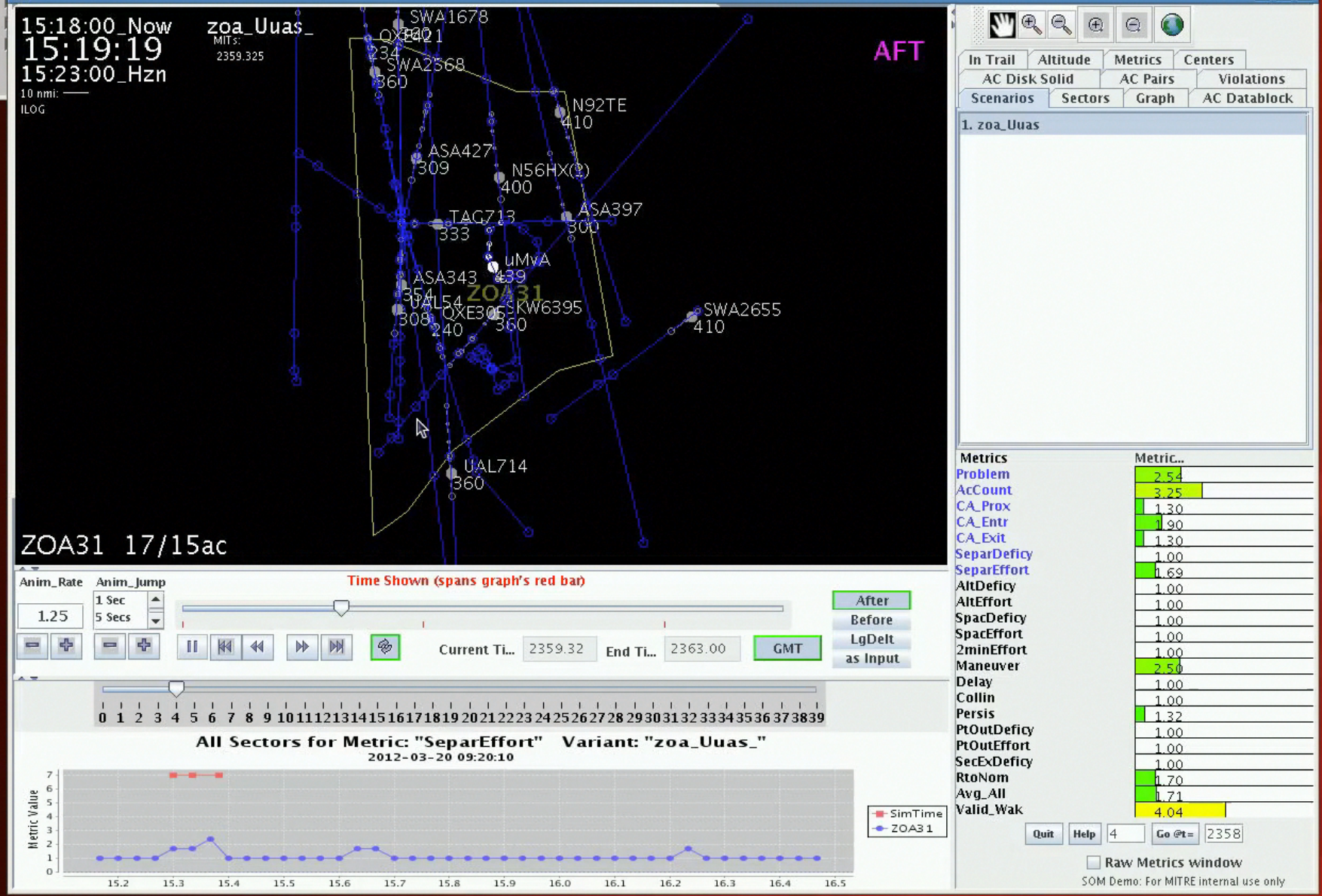
15:18:00_Now
15:19:19
15:23:00_Hzn
10 nmi:
ILOG
zoa_Uuas_
MITs:
2359.325
AFT
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QXE421
234
SWA2568
360
N92TE
410
ASA427
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UAL714
360
ZOA31 17/15ac
In Trail
Altitude
Metrics
Centers
AC Disk Solid
AC Pairs
Violations
Scenarios
Sectors
Graph
AC Datablock
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Problem 2.54
AcCount 3.25
CA_Prox 1.30
CA_Entr 1.90
CA_Exit 1.30
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SeparEffort 1.69
AltDeficy 1.00
AltEffort 1.00
SpacDeficy 1.00
SpacEffort 1.00
2minEffort 1.00
Maneuver 2.50
Delay 1.00
Collin 1.00
Persis 1.32
PtOutDeficy 1.00
PtOutEffort 1.00
SecExDeficy 1.00
RtoNom 1.70
Avg_All 1.71
Valid_Wak 4.04
Quit
Help
4
Go @t=
2358
Raw Metrics window
SOM Demo: For MITRE internal use only
Anim_Rate
Anim_Jump
1.25
1 Sec
5 Secs
Time Shown (spans graph's red bar)
After
Before
LgDelt
as Input
Current Ti...
2359.32
End Ti...
2363.00
GMT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39
All Sectors for Metric: "SeparEffort" Variant: "zoa_Uuas_"
2012-03-20 09:20:10
Metric Value
SimTime
ZOA31
15.2 15.3 15.4 15.5 15.6 15.7 15.8 15.9 16.0 16.1 16.2 16.3 16.4 16.5

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# *airspace*Analyzer – Methodology

- Run three scenarios
  1. Controlled UA
     - UA will respond to ATC commands like normal aircraft
  2. Unresponsive, predictable UA (normal separation)
     - UA will not respond to ATC commands
     - Normal separation around aircraft is 5nm
  3. Unresponsive, unpredictable UA (greater separation)
     - UA will not respond to ATC commands
     - ATC expands separation around lost link UA to 10 nm
     - Note: Separation is estimated- can be adjusted depending on how conservative a controller is



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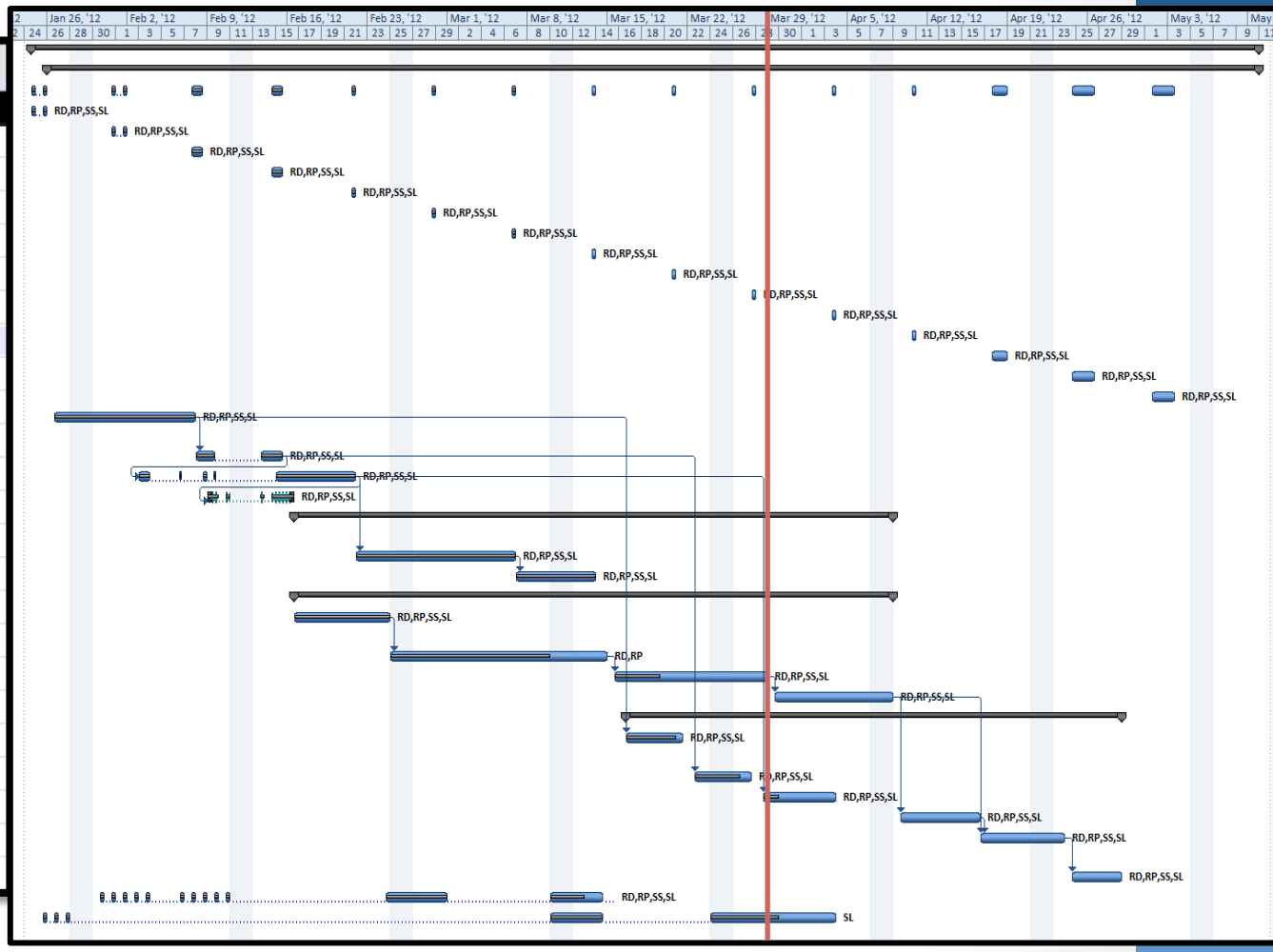
# Schedule

| | WBS | | Task Name |
|---|---|---|---|
| 1 | **1** | | **UAS Lost C2 Link** |
| 2 | **1.1** | | **SEOR Class Milestone** |
| 15 | **1.2** | | **Group Meetings** |
| 31 | 1.3 | | Define Problem Statement |
| 32 | 1.4 | | Define Project Scope |
| 33 | 1.5 | | Identify Approach |
| 34 | 1.6 | | Project Proposal |
| 35 | **1.7** | | **Define Methodology Process** |
| 36 | 1.7.1 | | Solicit Metrics |
| 37 | 1.7.2 | | Define Absolutes |
| 38 | **1.7.3** | | **Simulation** |
| 39 | 1.7.3. | | Define Simulation |
| 40 | 1.7.3. | | Build Simulation |
| 41 | 1.7.3. | | Test Simulation |
| 42 | 1.7.3. | | Validate Results |
| 43 | **1.8** | | **Write Report** |
| 44 | 1.8.1 | | Problem Statement |
| 45 | 1.8.2 | | Project Scope |
| 46 | 1.8.3 | | Project Process |
| 47 | 1.8.4 | | Analysis |
| 48 | 1.8.5 | | Outcomes and Conclusions |
| 49 | 1.8.6 | | Recommendations |
| 50 | 1.9 | | Research Hours |
| 51 | 1.10 | | Web Site Design |

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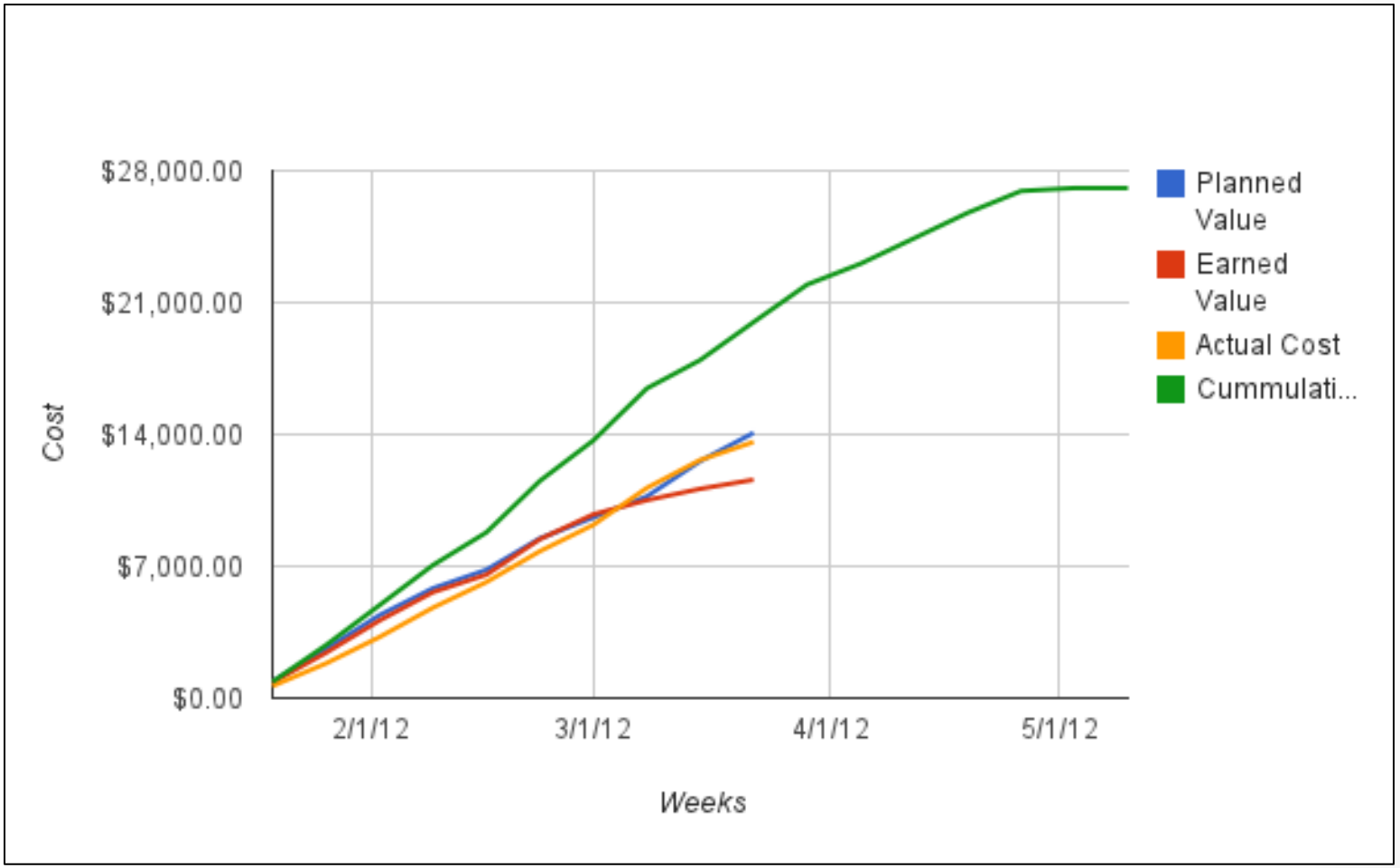
# Earned Value Management



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# Feedback from our Sponsors

- Sponsors team was very excited about our project
- Many ideas to extend this work
- Sponsor requested that we submit this work for a company funded MITRE Innovation Project (MIP)
- UAS group requested that we conduct a Tech Talk
- The lead UAS Architect wants to put this in the work program



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# Next Steps

- Continue meeting with Sponsor
- Complete predictability model
  - Get most accurate data
- Adapt scenarios for *airspace*Analyzer
  - Analyze outputs
- Draw overall conclusions
  - Provide team's insight/recommendations
- Finalize Report/ Methodology



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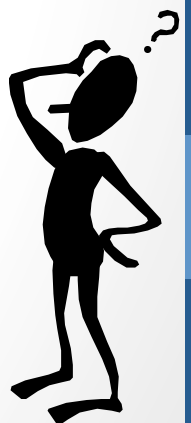
# Questions?





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