Optimizing Ground Systems: An Operator's Perspective

Firsthand Observations from Mission Ops Support

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Observations from Mission Ops Support Experience

- Recently worked for almost a year as a certified Satellite Operator
  - *Part of a team of mission ops support specialists, including:*
    - Crew Chief, Mission Director, Relay Satellite Controllers, Vehicle Engineers/Subject Matter Experts (SME), and Support Engineers

- Key Responsibilities
  - *24/7 data monitoring and vehicle commanding of multiple satellites*
  - *Contingency responses to anomalies*
  - *Planned and ad hoc vehicle activities*
  - *Planned and ad hoc maintenance*

- Summary of Observations
  - *Legacy software increases the likelihood of troubleshooting*
  - *The rise in the number of satellites launched into space that need to be monitored by operators increases the potential for anomaly oversight/operator error*
  - *Ground systems are not benefiting from rapid advances in technology*

Problem Statement

- Even though space vehicles are continuously advancing, the same attention has not been placed on ground systems.*
  - *Some vehicles are running on decades old software*
- Instead of focusing on the mission, ground operators spend time troubleshooting and creating workarounds for ground hardware and software.
  - *Over the course of a 12-hour shift, up to 1 hour can be spent on troubleshooting/workarounds*
  - *Having to troubleshoot during an anomaly takes time away from the solution and puts the satellite at risk*
    - *Time spent without an operational satellite is time and money lost to the customer*
- As the number of vehicles in orbit increases, there is a need for progress in ground system modernization and optimization to rapidly identify and mitigate threats and anomalies.

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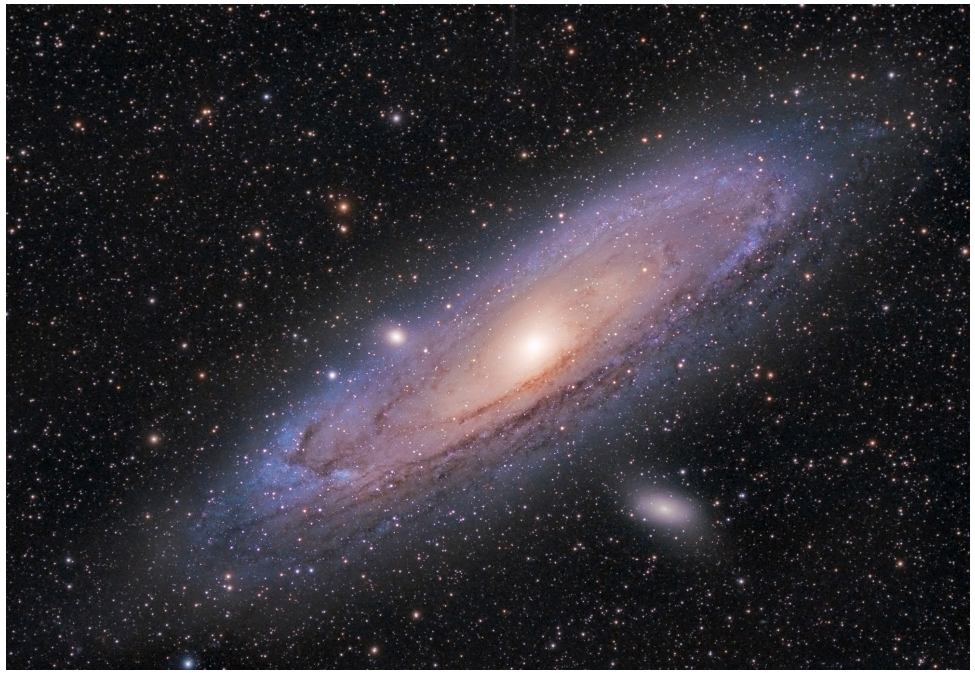
Ground system modernization and optimization allows for more situational awareness to rapidly respond to mission critical events

* Source: https://spacenews.com/119100-2/#:~:text=WASHINGTON%20%E2%80%94%20The%20ground%20stations%20and%20tracking%20antennas,up%20with%20the%20projected%20growth%20in%20space%20activities

Ground Systems Optimization

Assessment Approach

- Created workflows based on my experience and feedback from other controllers
- Identified mitigation options for optimizing ground system operations, leveraging research, experience, and feedback from other controllers/SMEs
- Developed a Decision Matrix to rank the mitigation options
- Identified key matrix results to provide final recommendations for the most viable and impactful optimization options



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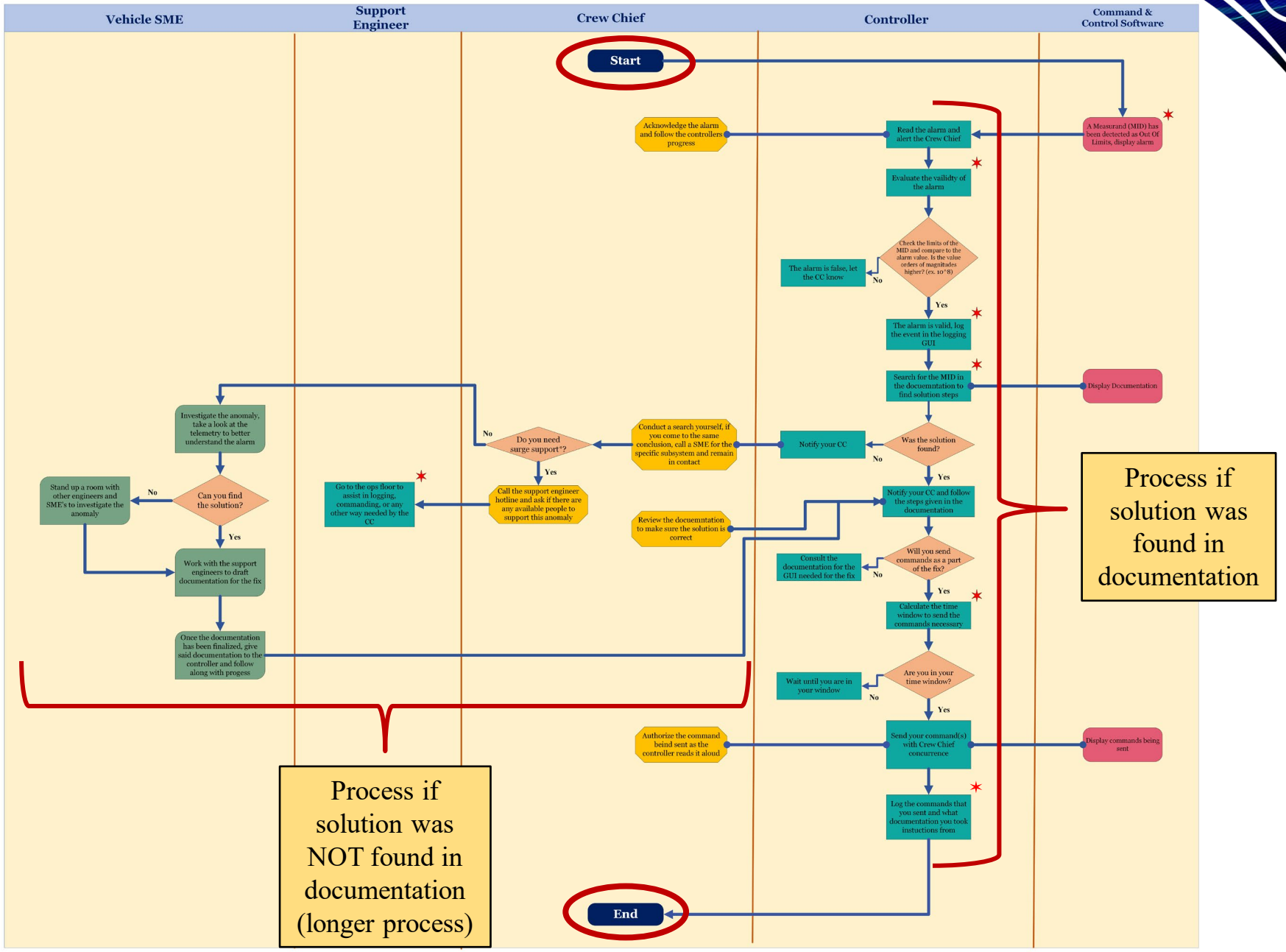
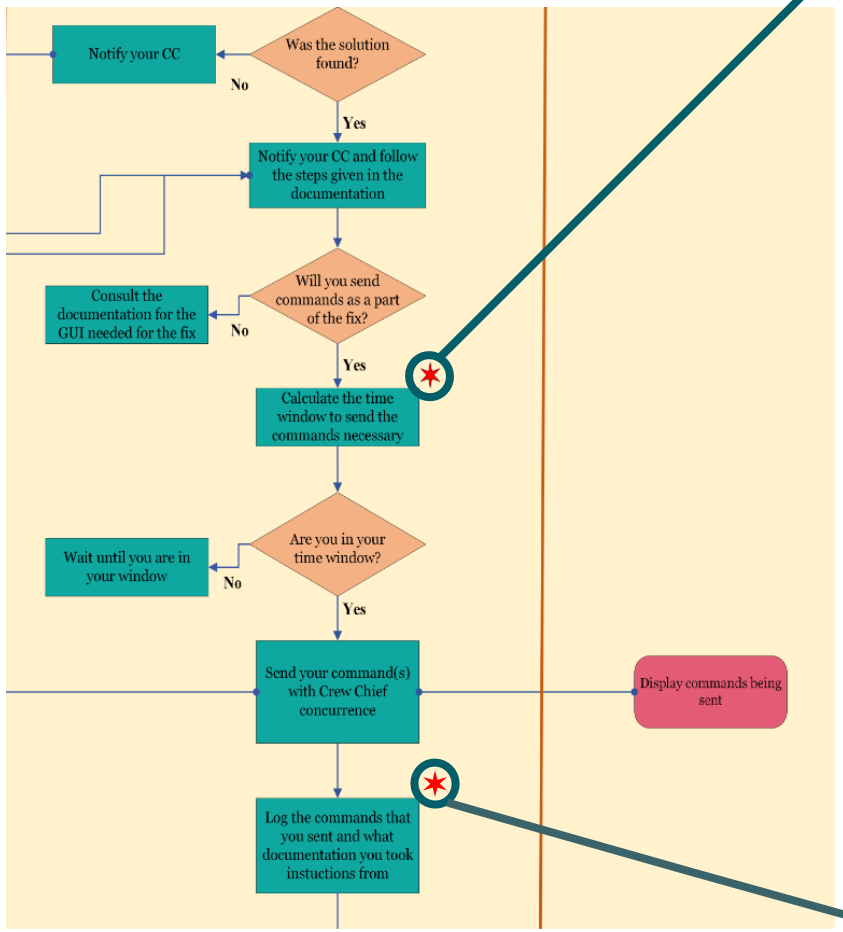
Current Workflow

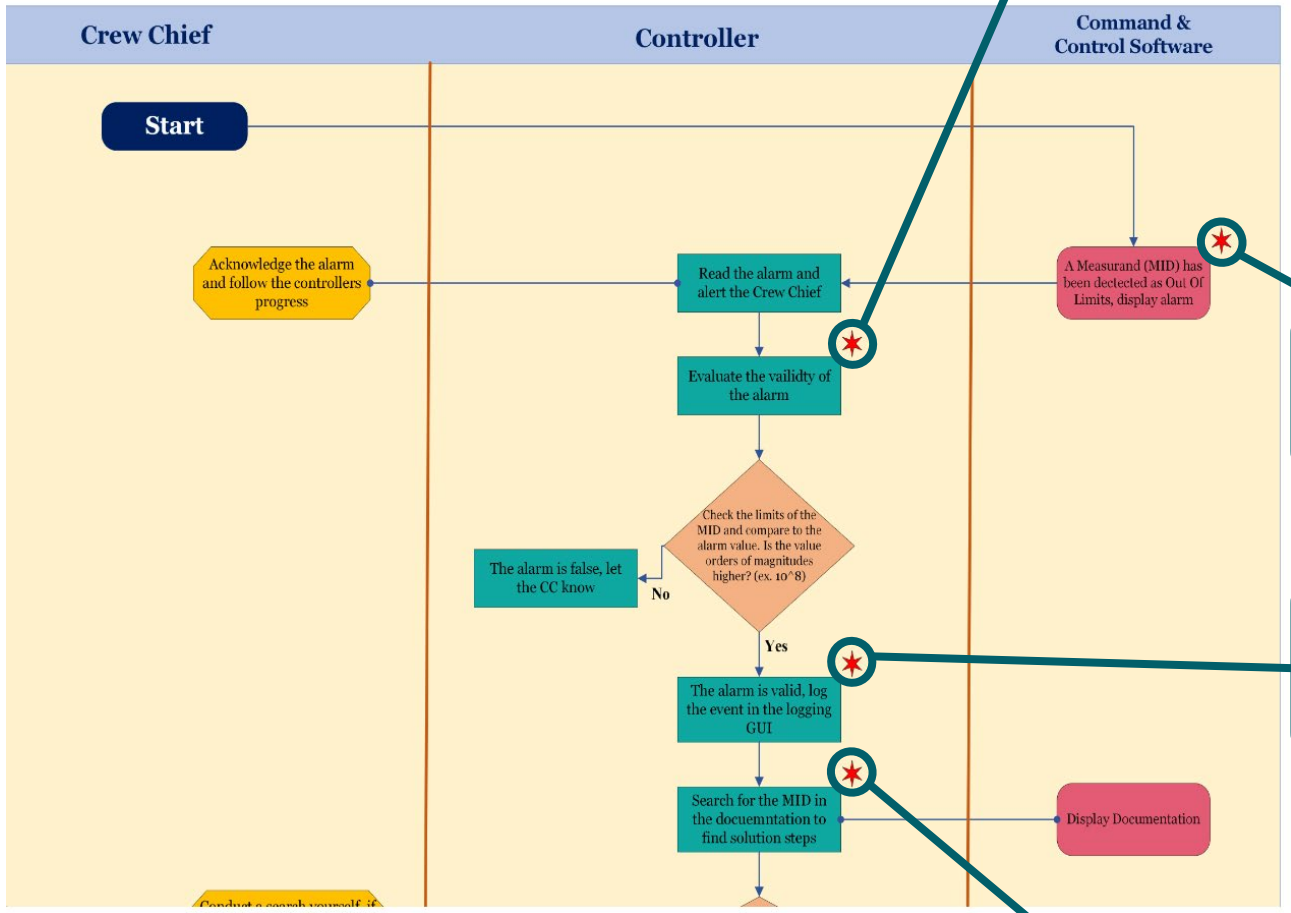
- Shows a general flow of actions taken when an anomaly appears
  - *Each person has their role to play*
- Red stars signify blockers/areas for improvement
  - *Blockers are anything that impedes or stalls a controller from completing their duties*
    - Can be hardware related or software
  - *Blockers take time away from the mission and can slow down anomaly response*



Current Workflow

Closer Look at Blockers





Using a calculator leads to human error and can waste time in critical moments

False positive alarms that take time to validate

Small alarm notifications are easy to miss, coupled with no audio

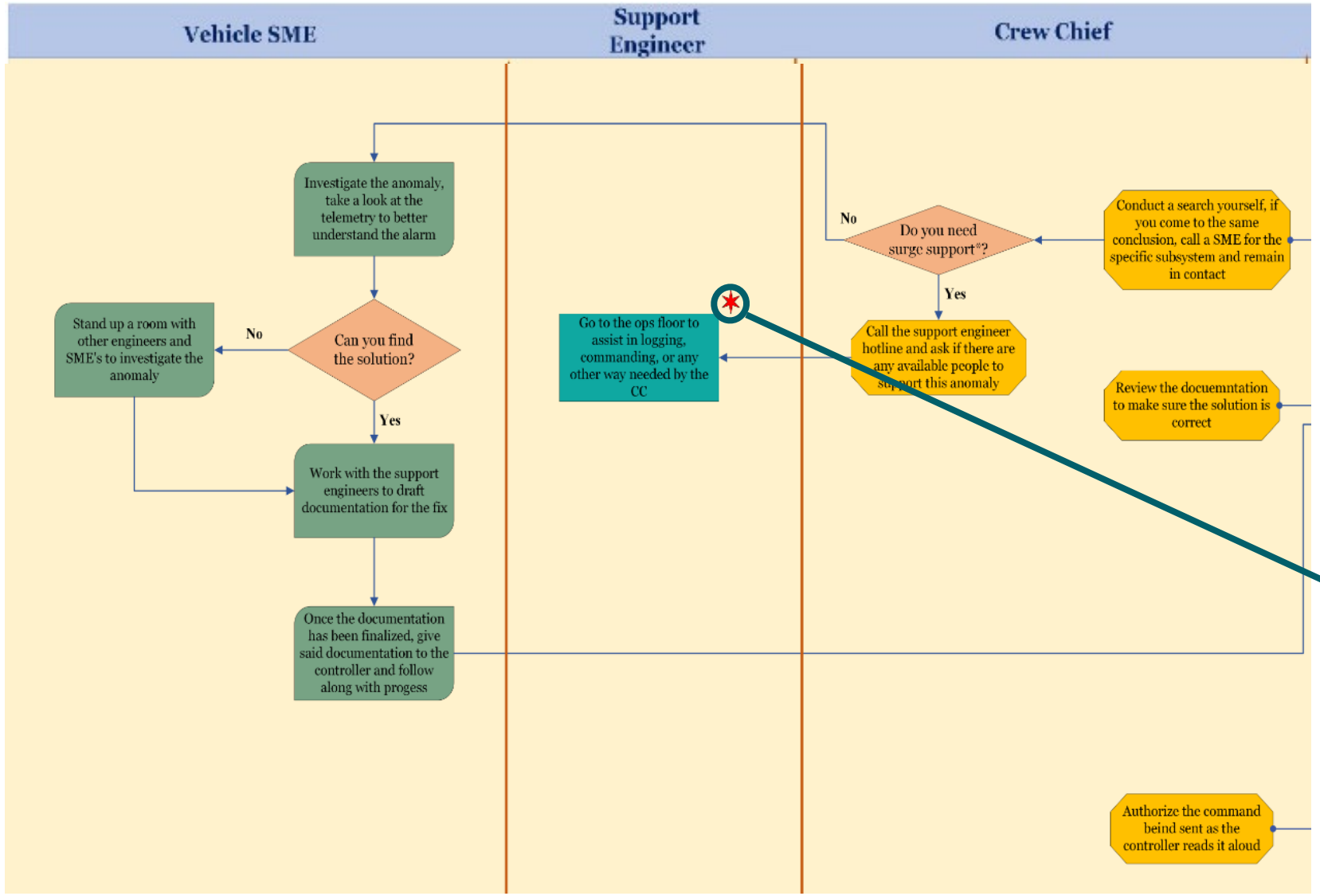
Logging can take time away from commanding in critical moments

Documentation can be difficult to search and take time

✶ = blocker / area for improvement

Current Workflow

Closer Look at Blockers



Support Engineers take time away from their normal duties to assist in logging

✶ = blocker / area for improvement

Blockers

Blocker Examples

- High level of logging needed during a serious anomaly
- Lack of audio capability
- No pop-up notifications for errors
  - *Items that turn red can be easily missed when an operator is monitoring multiple screens*
- User Interface (UI) for the software is not intuitive
  - *High learning curve, can take months to get familiar*
- Legacy tools and scripts no longer work as originally intended
  - *Controllers update tools to assist in mission execution*
- False positive alarms that take time to validate
- Manually calculate to find a window for sending time critical commands

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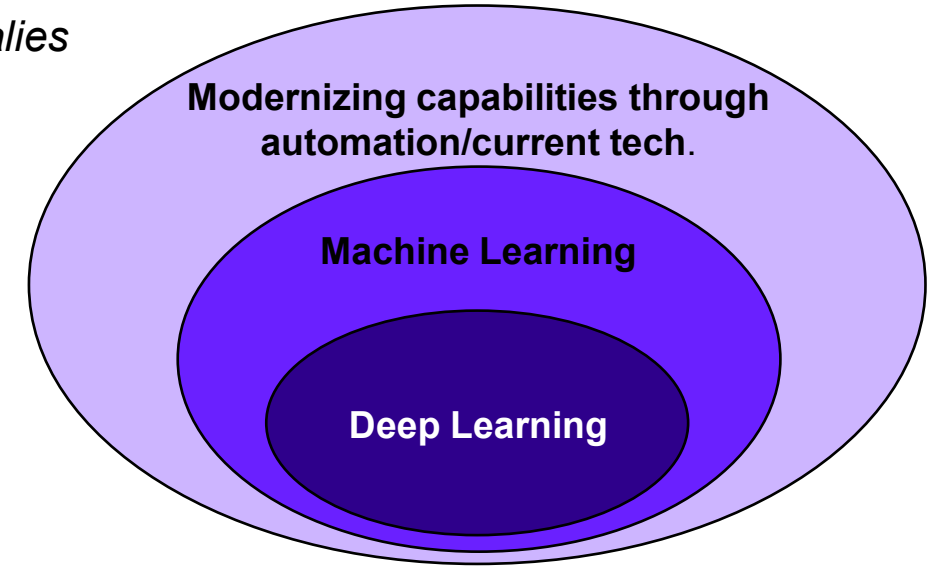
Mitigation Options

1. Auto-Logging
2. Applying Machine Learning to Anomaly Detection and Tasks
   - *Analyzing abundant amounts of telemetry data to understand/predict anomalies*
   - *Perform duties that operators would normally perform*
3. Operator Friendly UI
4. Audio Capability
5. Alarm Validity Self Check
6. Large Language Model (LLM) for better anomaly troubleshooting
   - *Deep learning algorithms that understand and generate text in a human-like fashion*
7. Auto Command Window Calculator



These options will produce time efficiencies and enable more operator focus on the mission

Mitigation Options

Decision Matrix

- Developed a Decision Matrix to rank the mitigation options
  - Calculates and ranks the options
  - Matrix template is customizable
- Matrix Tool process:
  1. Review the criteria and their descriptions
  2. Based on importance (e.g., cost, schedule, risk), rank the criteria from 1-4, this will weight the score of the decision matrix
  3. Review the criteria scale for application
  4. Evaluate each mitigation option, giving a score from 1-10 based on the criteria

Criteria Description	
Impact	How much of an impact will this option make to the operators and the mission as a whole?
Effort	How much time and labor will this option need to implement?
Time Saved	How much time will this option save? Will there be any other saved metrics?
Vision	Is this option in line with our goals of modernization and optimization?

Criteria Selection

Rank	Criteria	Weight	% of Decision
0	Impact	1	25%
0	Effort	1	25%
0	Time Saved	1	25%
0	Vision	1	25%
		Total Weight	4

Rank Each Criteria on a Scale on 1-10
(1 = little **impact**, 10 = huge **impact**)
(1 = a lot of **effort**, 10 = almost no **effort**)
(1 = little **time saved**, 10 = a lot of **time saved**)
(1 = not in line with the **vision**, 10 = very in line with the **vision**)

Decision Matrix

Options	Impact	Effort	Time Save	Vision	Raw Score	Weighted Scor
Sample Options	9	7	8	9	33	8.25
Sample Options	8	8	8	7	31	7.75
Sample Options	9	6	7	7	29	7.25

Mitigation Options

Example Matrix

Rank directly correlates to percent used in weighted score

Criteria Selection

Rank	Criteria	Weight	% of Decision
1	Impact	4	40%
4	Effort	1	10%
2	Time Saved	3	30%
3	Vision	2	20%
		Total Weight	10

Criteria Description	
Impact	How much of an impact will this option make to the operators and the mission as a whole?
Effort	How much time and labor will this option need to implement?
Time Saved	How much time will this option save? Will there be any other saved metrics?
Vision	Is this option in line with our goals of modernization and optimization?

Decision Matrix

Options	Impact	Effort	Time Saved	Vision	Raw Score	Weighted Score
ML for anomaly pred.	9	2	8	9	28	8
Auto-Logging	8	6	8	7	29	7.6
LLM for better anomaly troubleshooting	9	1	7	8	25	7.4
Audio Capability	9	3	7	7	26	7.4
Operator Friendly UI	8	5	5	6	24	6.4
Alarm Validity Self Check	5	5	4	7	21	5.1
Auto Command Window Calculator	5	8	4	5	22	5

Rank Each Criteria on a Scale on 1-10
(1 = little impact, 10 = huge impact)
(1 = a lot of effort, 10 = almost no effort)
(1 = little time saved, 10 = a lot of time saved)
(1 = not in line with the vision, 10 = very in line with the vision)

Max Raw Score - 40

Max Weighted Score - 10

Raw score is the sum score of criteria. Weighted is the sum multiplied by percentage

The higher the number, the better the option performs in that criteria

Mitigation Options

Impact and Time Saved

Criteria Selection

Rank	Criteria	Weight	% of Decision
1	Impact	4	40%
4	Effort	1	10%
2	Time Saved	3	30%
3	Vision	2	20%
		Total Weight	10

Decision Matrix

Options	Impact	Effor	Time Sav	Vision	Raw Scor	Weighted Sco
ML for anomaly pred.	9	3	8	9	29	8.1
Auto-Logging	8	7	8	7	30	7.7
Audio Capability	9	6	7	7	29	7.7
LLM for better anomaly troubleshooting	9	2	7	8	26	7.5
Operator Friendly UI	8	5	5	6	24	6.4
Alarm Validity Self Check	5	5	4	7	21	5.1
Auto Command Window Calculator	5	8	4	5	22	5

- Impact and time saved are the top ranked criteria
- The top three options are highlighted in green
  - *All have high impact and time saved scores*

Mitigation Options

Time Saved and Effort

Criteria Selection

Rank	Criteria	Weight	% of Decision
3	Impact	2	20%
2	Effort	3	30%
1	Time Saved	4	40%
4	Vision	1	10%
		Total Weight	10

Decision Matrix

Options	Impact	Effor	Time Sav	Vision	Raw Scor	Weighted Sco
⇧ Auto-Logging	8	7	8	7	30	7.6
⇧ Audio Capability	9	6	7	7	29	7.1
⇩ ML for anomaly pred.	9	3	8	9	29	6.8
LLM for better anomaly troubleshooting	9	2	7	8	26	6
Operator Friendly UI	8	5	5	6	24	5.7
Auto Command Window Calculator	5	8	4	5	22	5.5
Alarm Validity Self Check	5	5	4	7	21	4.8

⇧/⇩ = position change compared to first matrix

- Time saved and effort are the top ranked criteria
- The top three options are highlighted in green
  - *Machine Learning option required large amounts of data/software development*
  - *Machine Learning takes more effort, lowering its position compared to the first matrix*

Mitigation Options

Vision and Effort

Criteria Selection

Rank	Criteria	Weight	% of Decision
3	Impact	2	20%
2	Effort	3	30%
4	Time Saved	1	10%
1	Vision	4	40%
		Total Weight	10

Decision Matrix

	Options	Impact	Effor	Time Sav	Vision	Raw Scor	Weighted Sco
⇧	Auto-Logging	8	7	8	7	30	7.3
⇧	Audio Capability	9	6	7	7	29	7.1
⇩	ML for anomaly pred.	9	3	8	9	29	7.1
	LLM for better anomaly troubleshooting	9	2	7	8	26	6.3
	Operator Friendly UI	8	5	5	6	24	6
	Auto Command Window Calculator	5	8	4	5	22	5.8
	Alarm Validity Self Check	5	5	4	7	21	5.7

⇧/⇩ = position change compared to first matrix

- Effort and vision are the top ranked criteria
- The top three options are highlighted in green
  - *Machine Learning takes more effort, lowering its position compared to the first matrix*

Proposed Mitigation Options

Recommended Options

- Based on the matrix scenarios, the top recommended options to mitigate blockers are:
  - Auto-Logging
    - *Software automatically logs valid alarms and commands sent by the controller*
    - *Impact: Operator can place full focus on sending accurate commands without needing to stop every few minutes to log*
  - Audio Capability
    - *Able to hear alarms/notifications as they arrive*
    - *Impact: increases situational awareness*
  - Machine Learning
    - *Analyzing abundant amounts of telemetry data can enable anomaly prediction*
    - *System can perform tasks that operators would normally execute*
    - *Impact: reduces operator error and decreases resolution times due to increased foresight*

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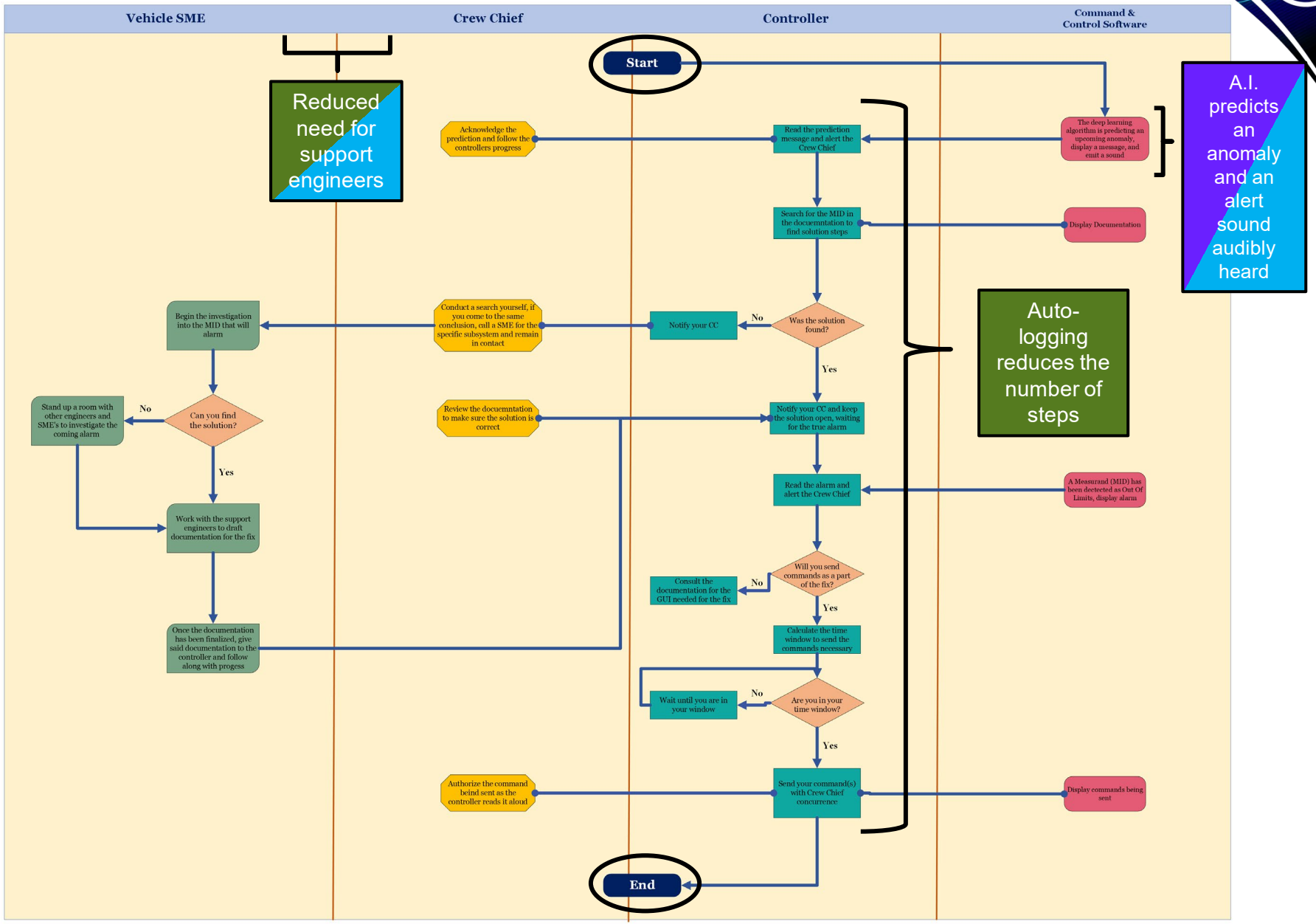
Proposed Workflow

- Shows a general flow of actions taken when accounting for the three implemented options
  - ***Audio grabs the operator's attention***
  - ***Anomaly prediction allows operator to prepare for alarm before it arrives***
  - ***ML performs tasks operators would normally execute***
  - ***Auto-logging reduces the need for support engineers***



Conclusion

- Ground systems have not kept up with technology advances at the same speed as space and launch vehicles
- To modernize and optimize ground systems, the following recommended options will reduce the number of blockers for the controller
  - *Auto-Logging*
  - *Machine Learning*
  - *Audio Capability*

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Employing these options will create efficiencies of time, effort, and cost, infuse modern technologies, and enable faster responses due to increased situational awareness


Questions?