# Visual Communication of Potential Anomalies with Boundary Lines in ISS Mission Control

Paul C. Parsons* Zixu Zhang†

Purdue University

## 1 Introduction

Boundary lines for telemetry data have been used widely among International Space Station (ISS) flight controllers on their displays [1] (e.g., see Fig. 1). These programmable lines are used as important references to aid in anomaly detection and response. Investigating how ISS flight controllers currently use boundary lines helps us understand how potentially anomalous data is handled under conditions of uncertainty and ambiguity. In future deep space exploration missions, anomalies are expected to occur despite our best efforts to avoid them [4]. As crews get farther away from Earth, significant communication delays will be inevitable [3], and as real-time support becomes less practical, more responsibility will need to be placed on autonomous monitoring and anomaly response. It is unclear what role visualization might play in situation awareness for these future missions. Can visualization techniques be used to alert users to potentially worrisome data values when continuous monitoring is not possible?

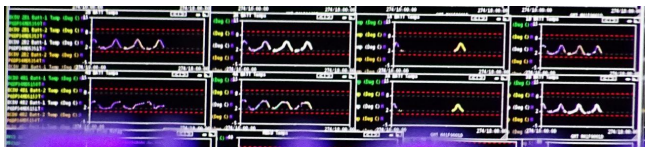

Figure 1: Boundary lines (in red) on ISS mission control displays.

## 2 Preliminary Methods

As part of broader efforts to study Resilient Extra-Terrestrial Habitats [2], we have conducted an interview study to better understand how flight controllers and astronauts for ISS missions respond to anomalies with a focus on visual interface uses. We have talked with participants about topics related to data, displays, and situation awareness—e.g., asking questions about how flight controllers assess the current state of the station, what data they look for to see when something might be off-nominal, what they see and interact with on their displays when doing so, and how the tacit aspects of their expertise support adaptation under uncertainty. Data from 22 participants currently or previously in roles as flight controllers, backroom engineers, astronauts, or flight instructors for ISS and shuttle missions have been collected.

## 3 Preliminary Findings

We asked participants specifically about the kinds of visualizations they use and how potentially anomalous data is visually communicated. Currently, data values that fall outside expected ranges are communicated visually to flight controllers with boundary lines and/or textually in tables and log files. Flight controllers monitor the data and determine what do to when a potentially worrisome value is spotted. In our discussion, participants generally reported that there is too much situational knowledge wrapped up in interpreting the data to automate a response or have the visualizations communicate anything specific when the boundary lines are crossed. Participants described situations in which their expertise made judgments about the values easy, but automating the judgments would not be possible. Participants described often not taking action when boundary lines were crossed, when they knew the values were okay for the situation, but other times taking action when the boundary lines were crossed and it did not match their expectations for the situation. This presents a challenge for future deep space missions, when bandwidth limitations and communication delays make continuous monitoring of telemetry data impracticable. If so much tacit and situational knowledge is required to interpret the data, what is the possibility for automation? How can visualization displays alert users to worrisome values without causing too many false alarms?

## 4 Questions For Attendees

We would like to discuss with attendees how visualizations can be designed to aid decision making when continuous monitoring is not possible but skilled interpretation of data is required. How should potential anomalies be communicated when users are not constantly monitoring their displays? How can tacit knowledge of users be incorporated into the design of future visualizations? Can tacit knowledge be used to create personalized visualizations that change their behavior dynamically (e.g., hourly or daily based on current mission objectives and activities)?

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## References

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*e-mail:parsonsp@purdue.edu

†e-mail:zhan1575@purdue.edu