Optimizing ISS Consumable Resources through Data Analysis

Will Hennig, Sonpaorong Muchhim, Ryan Dewey

Advisor: Dr. Erdogan Dogdu

Department of Computer Science, Angelo State University

Abstract

As a collaboration with Barrios Technology, this project's goal is to analyze logged data collected from the International Space Station (ISS) in order to understand the consumption rate of items aboard from January 1, 2022, to September 5, 2023. The data provided included an inventory log of consumables aboard the ISS, a data dictionary providing context for the inventory log (item name, category, physical dimensions, status, etc.), a log of all ships that have docked and undocked from the ISS in the given timeframe, a log of the number of crew aboard for the given timeframe, and predicted rates of consumption for each category of items. Using the Pandas Python library and the data files listed, the analysis shows the linear trends in consumption rate over time and how they compare with historical data. Additionally, possible scenarios that may be encountered while aboard the International Space Station, such as varying the number of people aboard and duration on the space station, will be explored. These results may prove relevant for future trips to the ISS and lead to better-informed logistics for space travel.

Consumables and Consumption

The ISS crew depends on various consumable items that need to be periodically restocked. These items are primarily food and waste management supplies. For the purposes of this project, these categories of consumables were analyzed:

- Pretreat tank (for water recovery)
- KTO (human solid waste container)
- ACY Inserts (for toilets)
- Filter Inserts
- EDV (urine tank)
- Food (US and Russian)

Managing consumable items is critical in ensuring the maintenance of the crew aboard a space mission. In order to prevent a shortage, it is important to know how quickly the consumables aboard will deplete given a number of people on board.

Data of the consumables from the main log file were sorted based on whether they were in stowage, awaiting to be used. From this data, the items were counted by date and graphed.

Our study's analytical framework is designed to transform raw ISS data into actionable insights, adhering to the following process:

- A. Data Preprocessing:
  This involved loading all relevant data to be reviewed, reformatting for ease of use (i.e. reformatting date-times)
- B. Exploratory Data Analysis (EDA):
  Utilizing a variety of EDA techniques, we scrutinized the data to discern preliminary trends and relationships. Our visualizations, including time-series analyses and regression charts attempt to illuminate consumption behaviors, guiding the subsequent modeling phase.
- C. Predictive Modeling:
  With the insights gained from EDA, we aim to formulate and calibrate further predictive models. Linear regression aims to forecast future consumable depletion rates, while logistic regression aims to provide classifications to alert us to events where inventory may deplete below threshold levels.

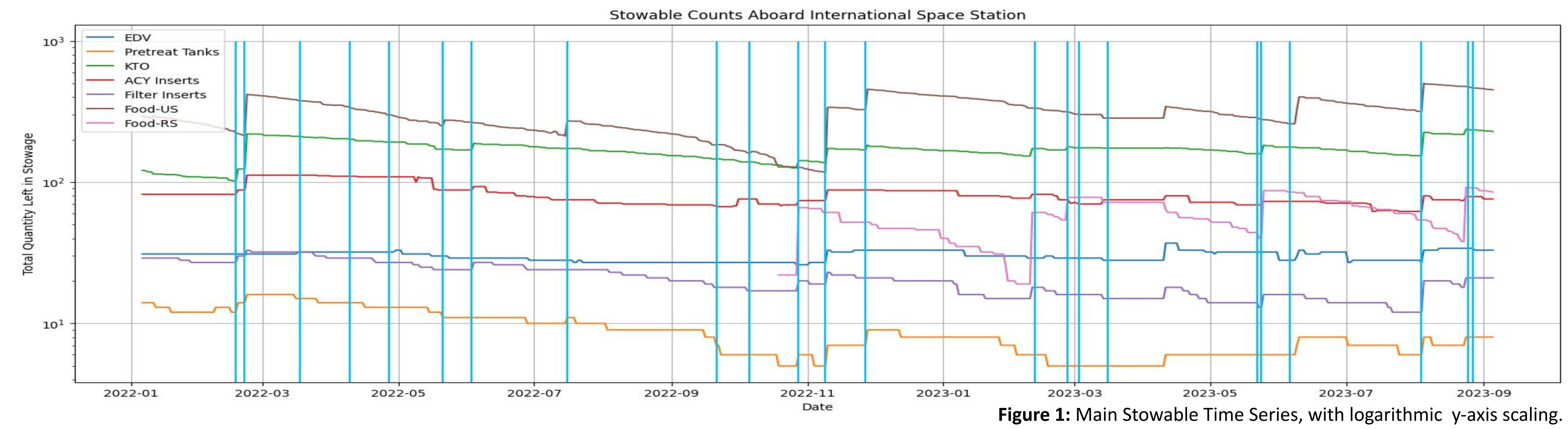

Figure 1: Main Stowable Time Series, with logarithmic y-axis scaling. Units of change are simply individual items

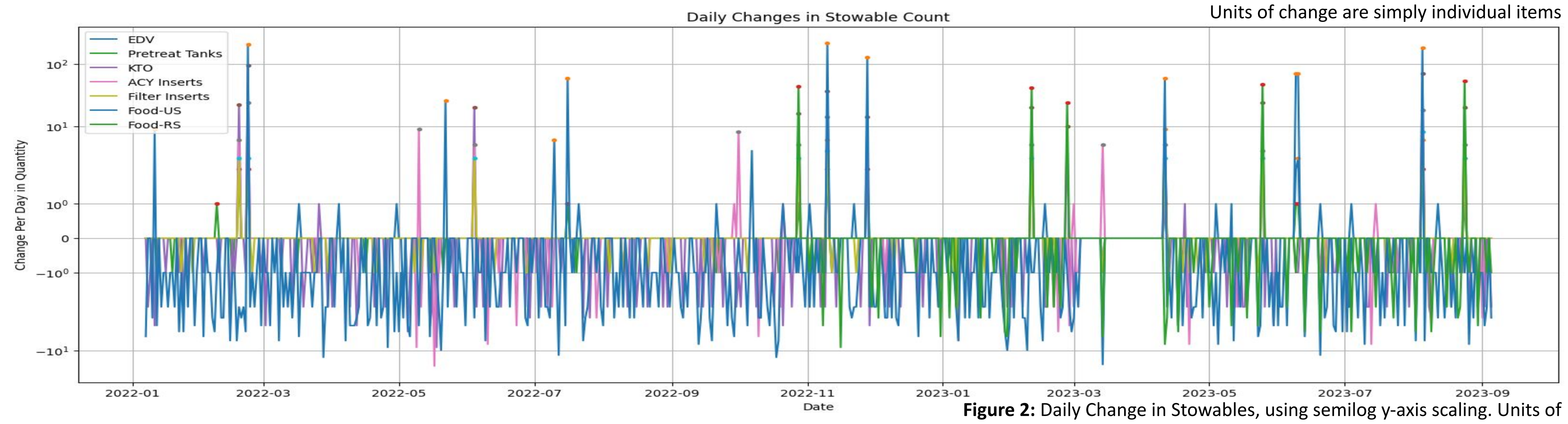

Figure 2: Daily Change in Stowables, using semilog y-axis scaling. Units of change are simply individual items

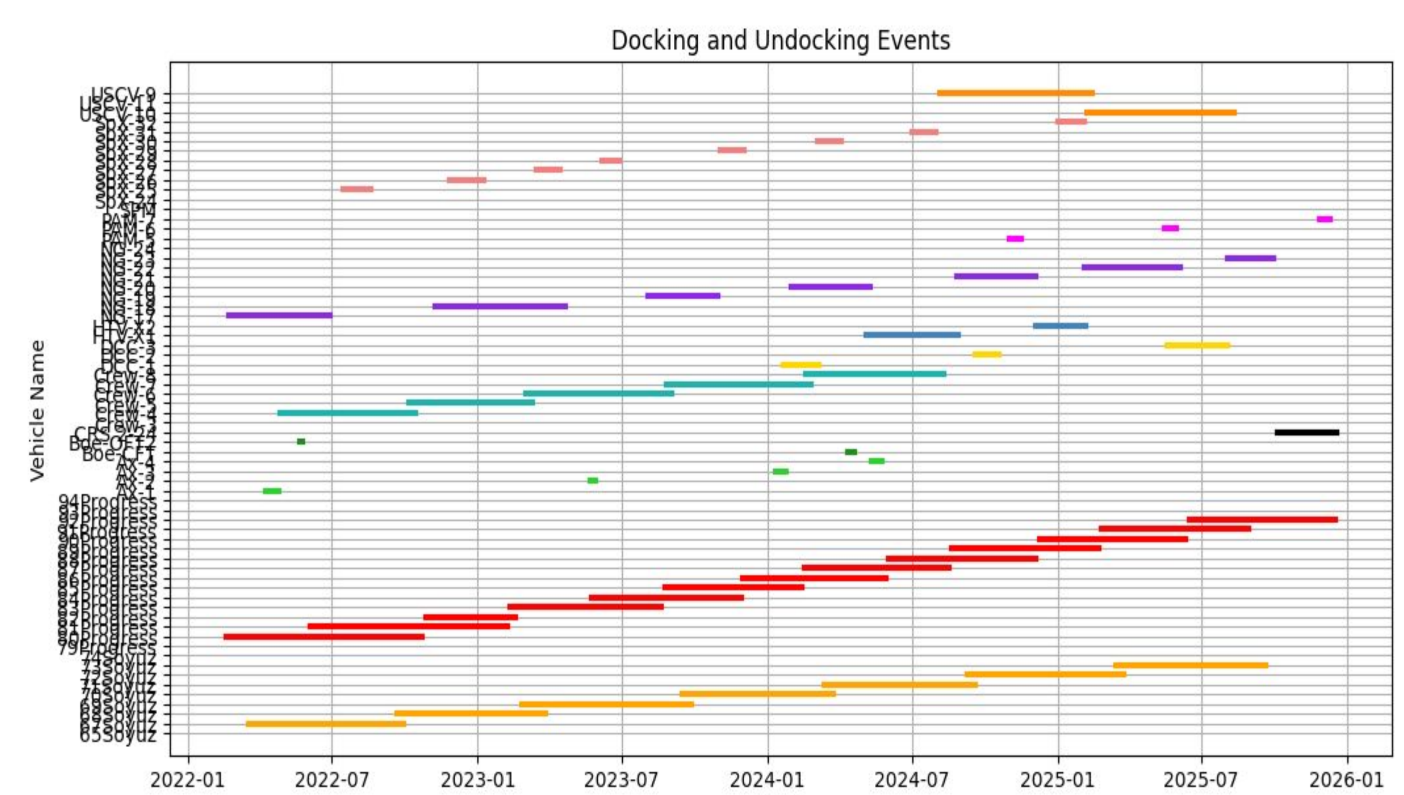

Figure 3: Docking of vehicles to ISS (including future scheduled dates)

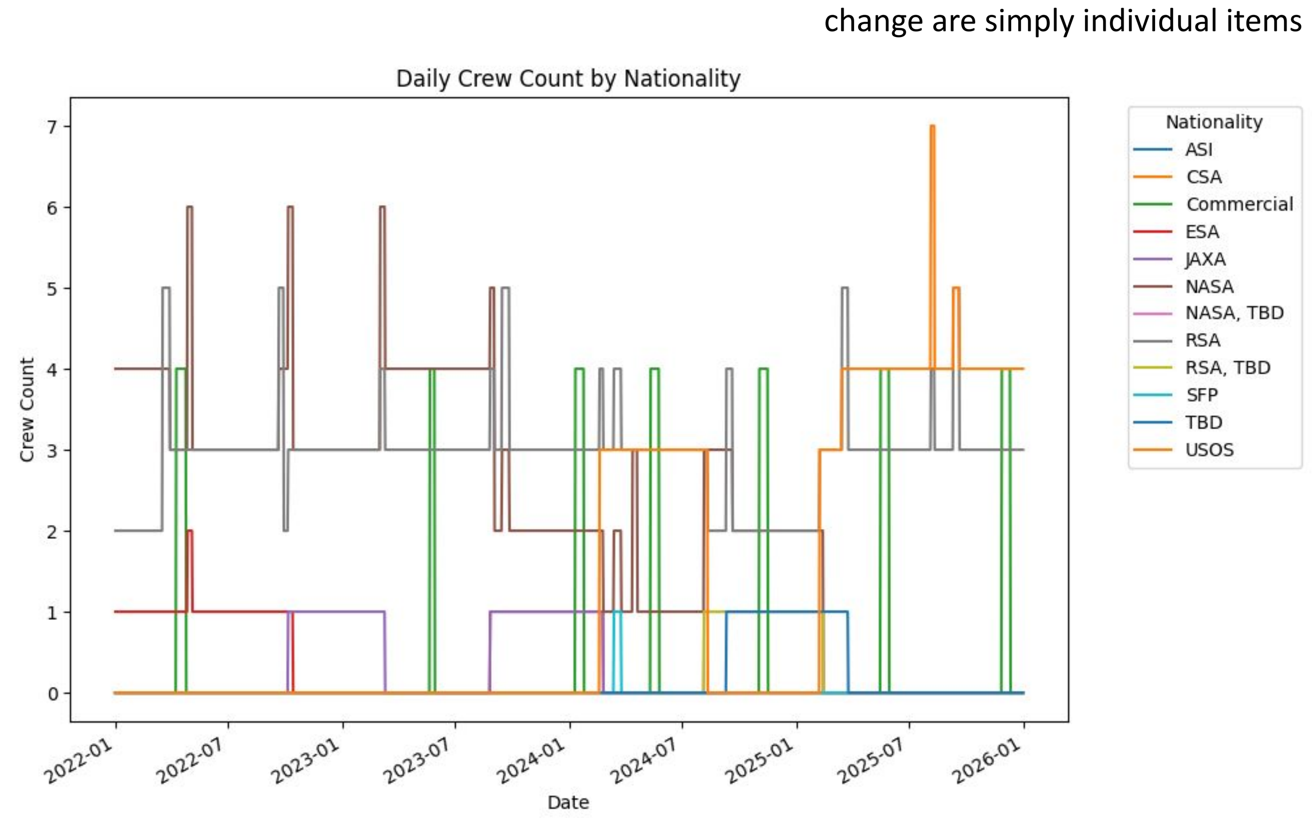

Figure 4: Daily Crew Count Aboard ISS (including future scheduled dates)

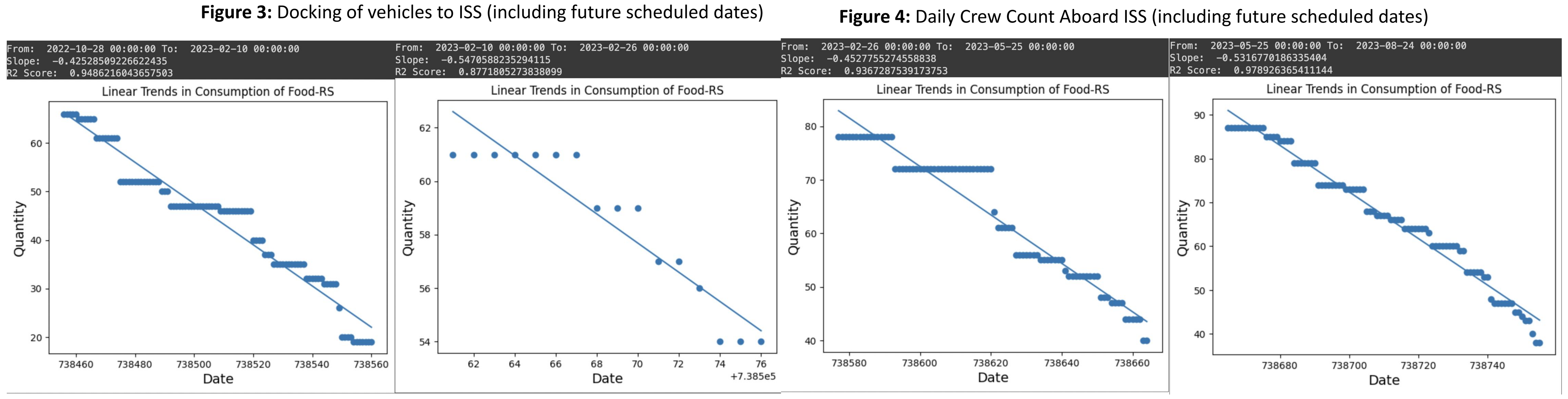

Fig 5a | Fig 5b | Fig 5c | Fig 5d

Figure 5(a-d): Sample Linear Regression for Russian Food Consumption

Graphical Analysis

Figure 1 was generated for the stowable counts for each category of consumables. Vertical lines are included to show where there are new docking events. Figure 2 shows the daily change in consumables. The positive spikes indicate resupply times, while the negative spikes indicate daily consumption. Figure 3 shows the actual docking and undocking events where resupplies may be scheduled, including future missions. The crew count per ship are also shown in Figure 4. Peaks in the daily crew count appear to be from the extra crew from the docking ships. The bottom four graphs (Figure 5a-d) show sample linear regression. However, it appears that the sampling of the intermediary times from resupply are not representative of the given stowable data due to inconsistent sampling. Figure 4 indicates linear trends in Russian food consumption. Most other categories show linear trends as seen in Figure 1, though this is not easily seen in some such as pretreat tanks and filter inserts. This is likely either due to the limited use and the large capacity of the containers.

Conclusion and Future Work

So far, the linear regression models in Figure 5 do not appear to correlate with historical data trends. According to the historical data, linear regressions suggest that there are 15 people aboard that are consuming food! This indicates the need to recalculate or that the historical data is not accurate after all. Further data analysis is necessary to evaluate how the historical data matches with the current data. Another next step is to set up a logistic regression model to predict the general time before items should be restocked. Some scenarios that will be explored include varying the number of people aboard, adjusting rates of consumption, and duration in-between resupplies.

References

[1] Carter, D. L., Riggle, D., Walker, S., Andreychuk, P., Karaseva, G., Zheleznyakov, A., ... & Berrill, M. (2021, July). Operation of the urine collection and pretreatment system in the ISS US Segment waste & hygiene compartment (WHC). In 50th International Conference on Environmental Systems (No. ICES-2021-035).

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