



# Streamlining Pre-Launch Support for Missions with Highly Variable Trajectories

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# Agenda

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# Introduction

- ***The Flight Dynamics Facility (FDF) located in the NASA Goddard Space Flight Center (GSFC) supports a variety of Human Space Flight (HSF) and Launch Vehicle (LV) missions***
  - FDF provides acquisition data vectors to the Space Network (SN) White Sands Complex (WSC) to control Tracking and Data Relay Satellites (TDRSs) to point to an asset for data collection
- ***WSC processes and uplinks FDF data to a scheduled TDRS to maintain communications throughout required support***
  - Launch support on a TDRS S-band Single Access antenna (SSA) does not have auto-track ability, highlighting importance for accurate pointing data from FDF



Simplified Space Network Interface

# Background

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- ***Certain missions use Right Ascension of the Ascending Node (RAAN), or yaw, steering to target specific orbit planes***
  - These are considered variable trajectory missions
- ***Due to current legacy criteria, variable trajectory missions require a lot of attention from FDF and WSC analysts***
  - Current criteria is Range < 35 kilometers (km) between two trajectory profiles
  - Possible to spend more than 175 hours to generate and deliver acquisition data to WSC for more than 100 trajectories per launch
  - WSC receives and categorizes all maneuver sequences for each trajectory case and manually inputs each vector component for all cases
    - 100 cases yields approximately 700 vectors, or a total of 4,900 vector components
- ***Revisiting legacy analysis methods/criteria might reduce number of trajectories actually needed for successful mission support***
  - Legacy criteria is more conservative than current mission support requirements

# Research Question

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- ***Generating and delivering large amounts of data increases chances of human error, requiring more effort to find and resolve issue(s)***
- ***Research would suggest an updated criteria that meets current mission support requirements would decrease trajectories needed***
  - Half-beamwidth < 0.90 degrees (deg) [1]
  - Differenced Doppler Offset < 4.1 kilohertz (kHz)

## ***Research Question***

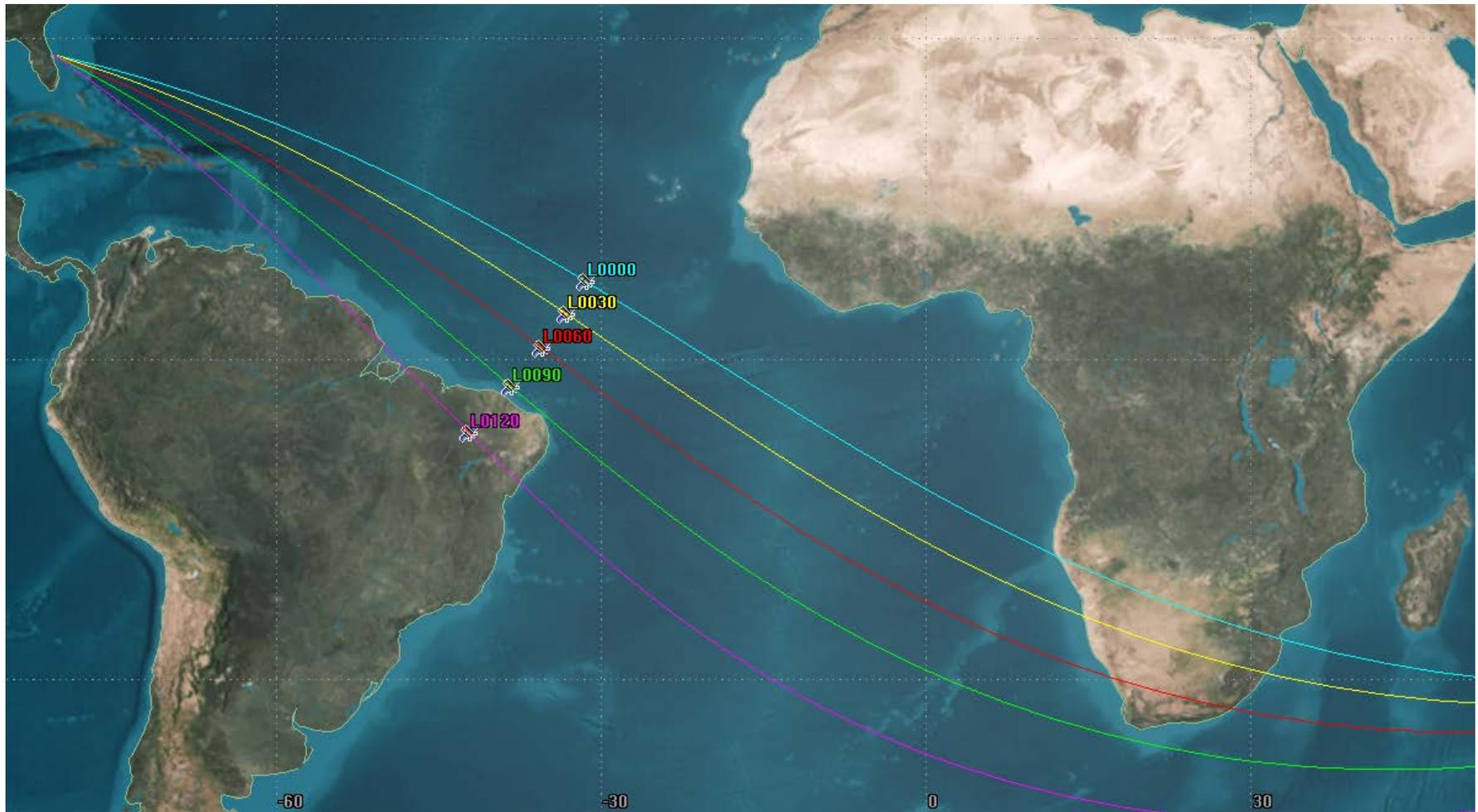
***Can FDF reduce the number of trajectory cases needed for support, with no impact to mission safety? If so, then by how much?***

# Data Sources

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- ***AGI's STK Astrogator was used to generate fictitious variable trajectories across a two-hour launch window***
  - Due to some data being considered proprietary, this additional step to generate the data was necessary to be able to discuss results with outside entities
  - Generated trajectories for a two-hour launch window with a 1-minute step size for total of 121 trajectories

# Data Sources



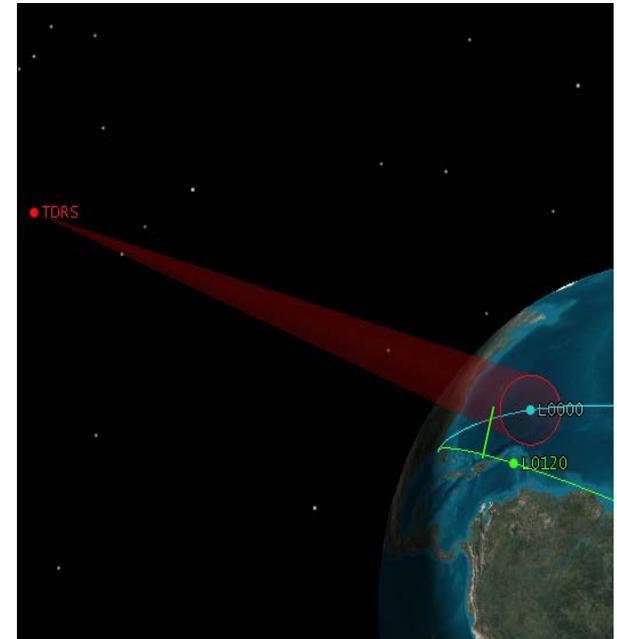
Variable Trajectories Across Two-Hour Launch Window Sampled at 30 Minutes

- ***Range (Legacy Criteria)***

- Distance calculated between two trajectories
- Range < 35 km for variable trajectory cases

- ***Beamwidth (Criteria to investigate)***

- The angular separation between two trajectories as observed from the perspective of the TDRS SSA antenna
- Half-beamwidth < 0.90 degrees (for TDRS SSA) [1]



TDRS SSA Beamwidth

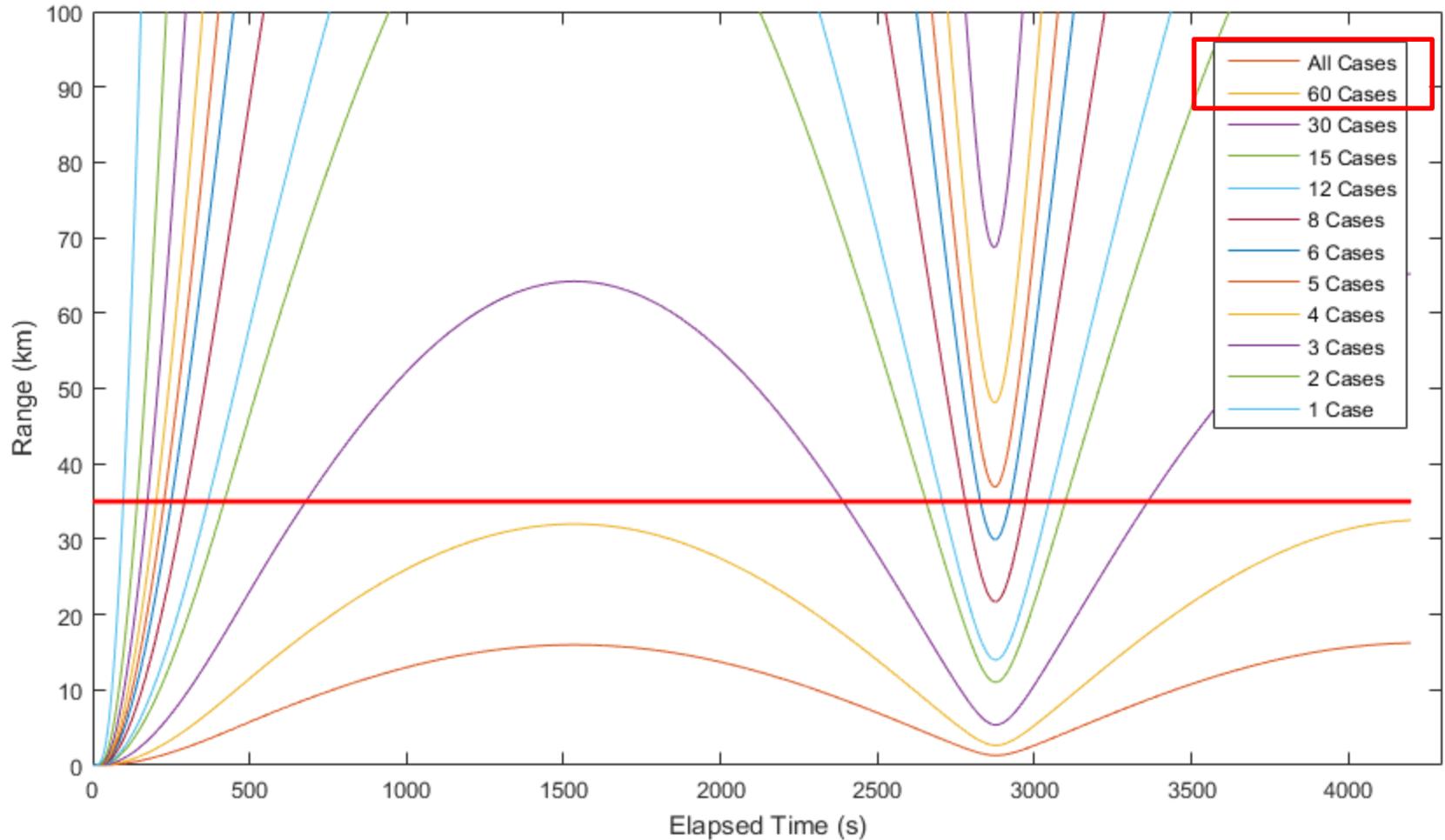
- ***Differenced Doppler Offset (Criteria to investigate)***

- Difference observed in Doppler calculation between two trajectories
  - Doppler calculation is between a trajectory and a TDRS
- Differenced Doppler Offset < 4.1 kHz (SN Legacy equipment, conservative)

- ***Data analysis with in-house tool for beamwidth, range, and differenced Doppler offset calculations***
  - In-house tool is a python-based GUI that integrates with Systems Tool Kit (STK) for automated analysis of many trajectories at once, decreasing workload on analysts and increasing efficiency
  - Results generated in a csv file that summarize statistical information across entirety of analysis
- ***Solving/testing for number of cases required for support with no impact to mission safety***
  - Will apply legacy criteria to determine number of cases needed (Control)
  - Will apply test criteria to determine number of cases needed (Test)

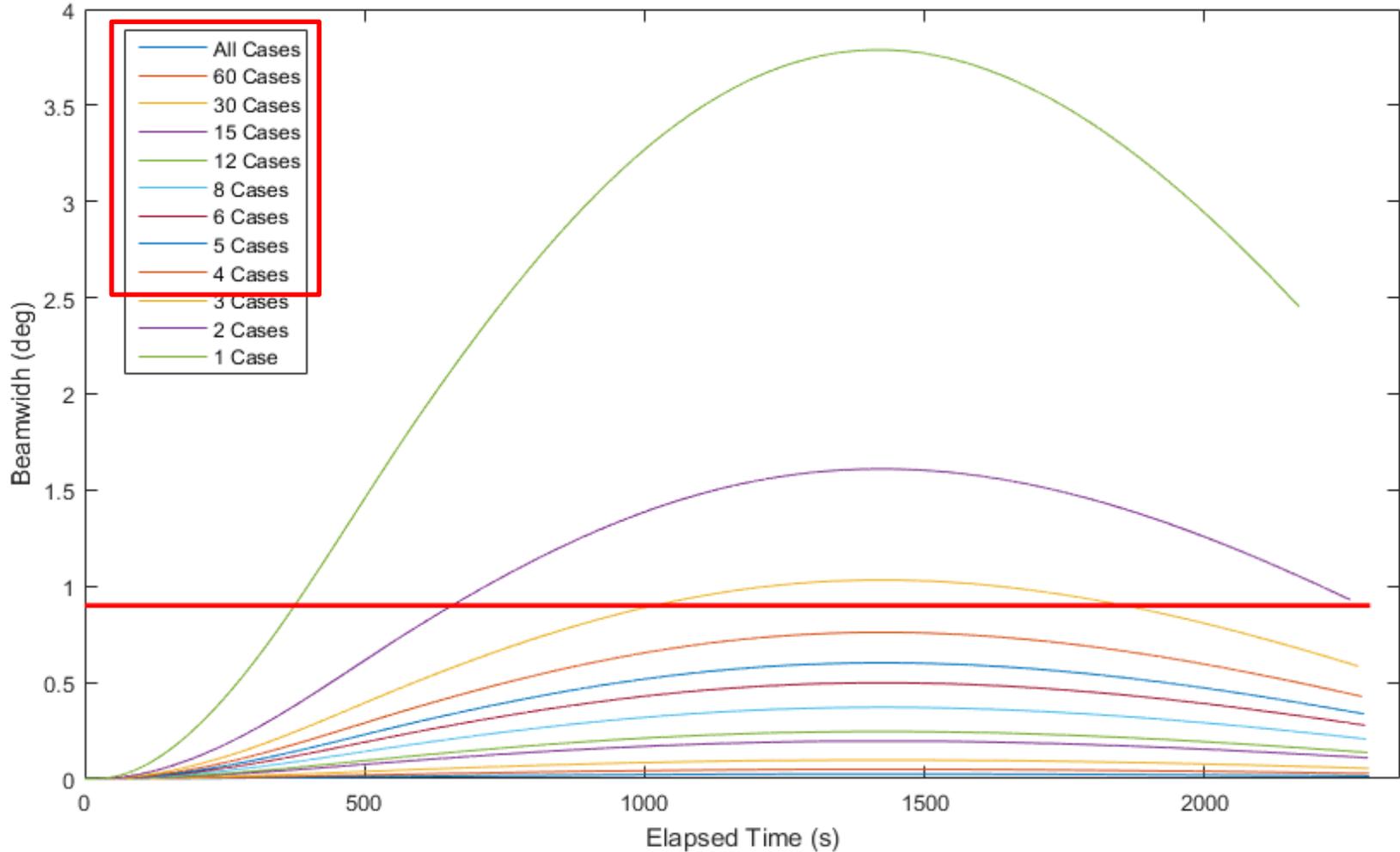
# Results

**Range Differences Compared Against Open of Window: 35 km Range Limit**



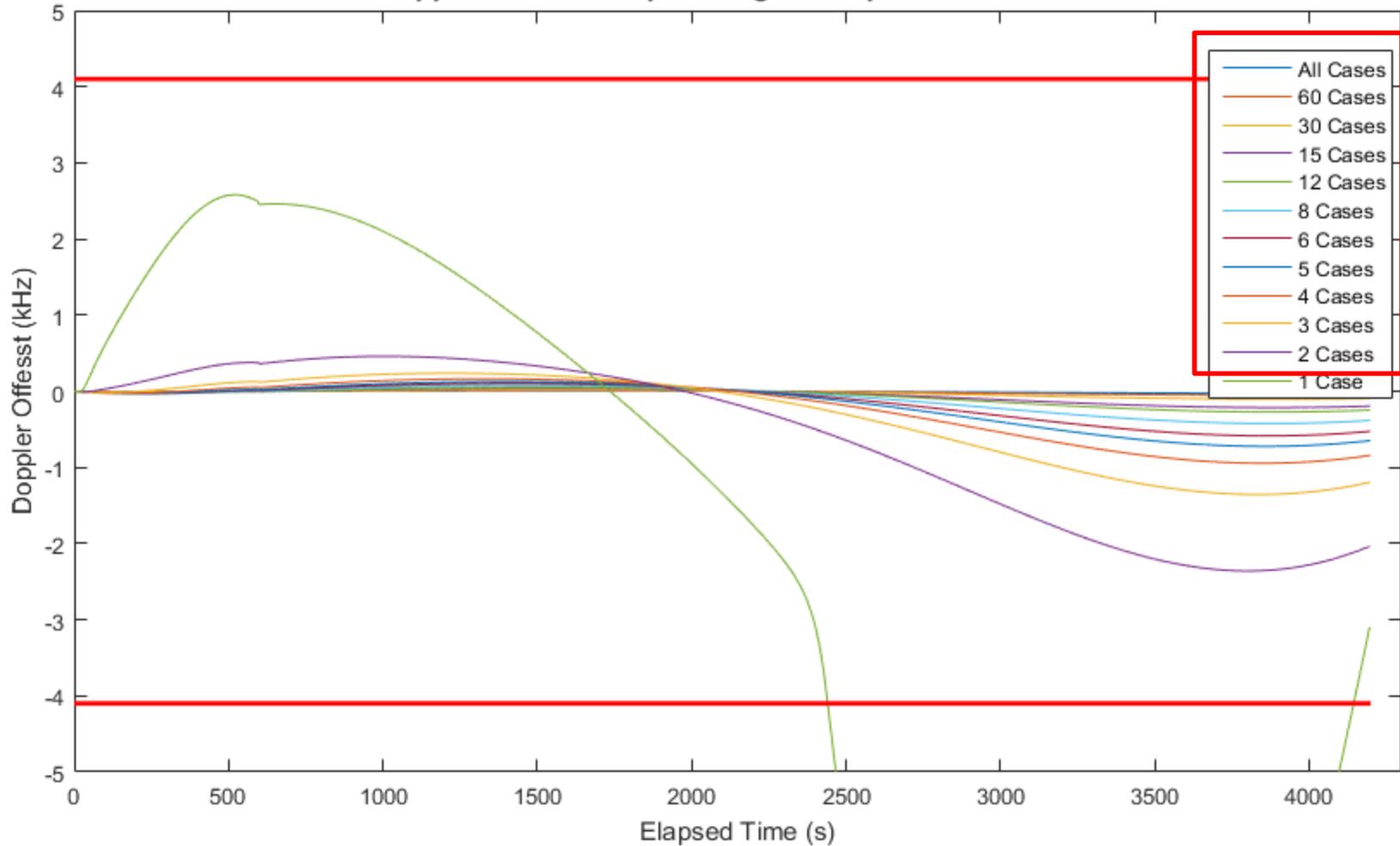
# Results

**Beamwidth Differences Compared Against Open of Window: 0.90 Degree Limit**



# Results

**Differenced Doppler Offset Compared Against Open of Window: 4.1 kHz Limit**



# Results

- Max values observed given number of trajectories used for support**

Cases Used	R_Max (km)	B_Max (deg)	Abs. D_Max (kHz)
1	2963.672	3.788	15.325
2	1096.813	1.610	2.36
3	698.963	1.032	1.356
4	<u>513.423</u>	<u>0.760</u>	<u>0.945</u>
5	405.867	0.602	0.723
6	335.621	0.498	0.586
8	249.364	0.371	0.423
12	164.736	0.245	0.272
15	131.321	0.195	0.215
30	65.204	0.097	0.104
60	<u>32.490</u>	<b>↑</b> <u>0.048</u>	<b>↑</b> <u>0.051</u>
120	16.218	0.024	0.025

# Discussion

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- ***Applying half-beamwidth and difference Doppler offset criteria allow the processing of fewer cases without impacting support***
  - Beamwidth and differenced Doppler offset criteria of 0.90 degrees and 4.1 kHz requires using only 4 trajectory cases
- ***Keeping the legacy range criteria requires more cases to process***
  - Range criteria of 35 km requires using 60 trajectory cases
- ***Reduction in cases used will also decrease the possibility of human error in processing, generating, or delivering acquisition data***

# Impact to Operations

- ***Assuming 3 maneuver sequences per launch, the analysis discussed here would have the following implications for the FDF***

Cases	Criteria	Process (hrs)	Products (hrs)	Delivery (hrs)	QA (hrs)	Total (hrs)
60	Legacy	45	51	6.9	2.1	<b>105</b>
4	Updated	3	3.4	0.4	0.2	<b>7.0</b>

- ***WSC would see similar results in their processing of FDF data***
  - For 60 trajectory cases, WSC would have to input a total of **2940** vector components vs **196** vector components for 4 trajectory cases
  - For 60 trajectory cases, WSC would have to manage a total of **180** maneuver sequences vs **12** maneuver sequences for 4 trajectory cases

- ***With updated criteria, effort is reduced by 93.3%!***

# Closing Remarks

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## ***Answering Research Question***

***It is shown that by applying an updated criteria to meet current mission requirements the FDF can reduce the number of cases needed for variable trajectory missions with no impact to mission safety***

- ***Future work should determine steps needed move towards these updated criteria***



# QUESTIONS



# References

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- 1. Phung, P. B., Guedeney, V. S., and Teles, J., “Tracking and Data Relay Satellite System (TDRSS) Range and Doppler Tracking System Observation Measurement and Modeling,” GSFC-E-DAA-TN52939, 1980-872-TDRSS, September 1980**

# Acknowledgements

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