Interactive Mission Model for NASA Communication Network Analysis

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Goals

(1) Create a centralized database of current NASA network users and expected future users

(2) Develop an interactive and extensible model of NASA network users that can be used for future mission planning and network loading analysis

(3) Evaluate and improve the current model of use case characterization in terms of communications requirements and orbit parameters.

Background

The evolution of NASA's communication networks is guided by the needs of future users, and the ability to model those users would provide great foresight into how the networks must change in the future. Each user can be grouped into a **use case**, which describes the user's service needs, characteristics, and constraints. When assessing a communications architecture, the goal is to evaluate how well it can support the needs of each use case. User needs and the number of users per use case will evolve over time, and in turn the requirements for the communications architecture will change. Current use case projections do not behave as expected, showing a dip in the mid-term (~10 years ahead) that is known to be artificial. Improved projections requires revisiting the use case model and re-characterizing use cases. However, the current mission models are not equipped for such analysis, relying on numerous data sources containing inconsistent information. The next-level mission model would be flexible, extensible, and enable other types of analysis.

Table 1: Examples of user scenarios included in the use case model*

- HSF: LEO Ops
- HSF: Cis-Lunar Crewed Mission
- LEO Science (Low Volume)
- LEO Science (High Volume)
- GEO: Science & Weather
- Cis-Lunar - Robotic
- Deep Space Science
- Deep Space Science Surface
- Weather Observations (LEO)
- Mission Commanding and Telemetry
- Launch Vehicle Support (ELV)
- HSF: LEO Ops-Servicing
- HSF: Exploring other Worlds Mars
- LEO Science (Moderate Volume)
- LEO Science (Ultra-High Volume)
- Highly Elliptical Orbit Science
- Sun-Earth Lagrange-High Rate Science
- Deep Space Science: High Volume
- Deep Space Launch Critcial Event
- Satellite Constellations
- Launch and Early Orbit Phase (LEOP)

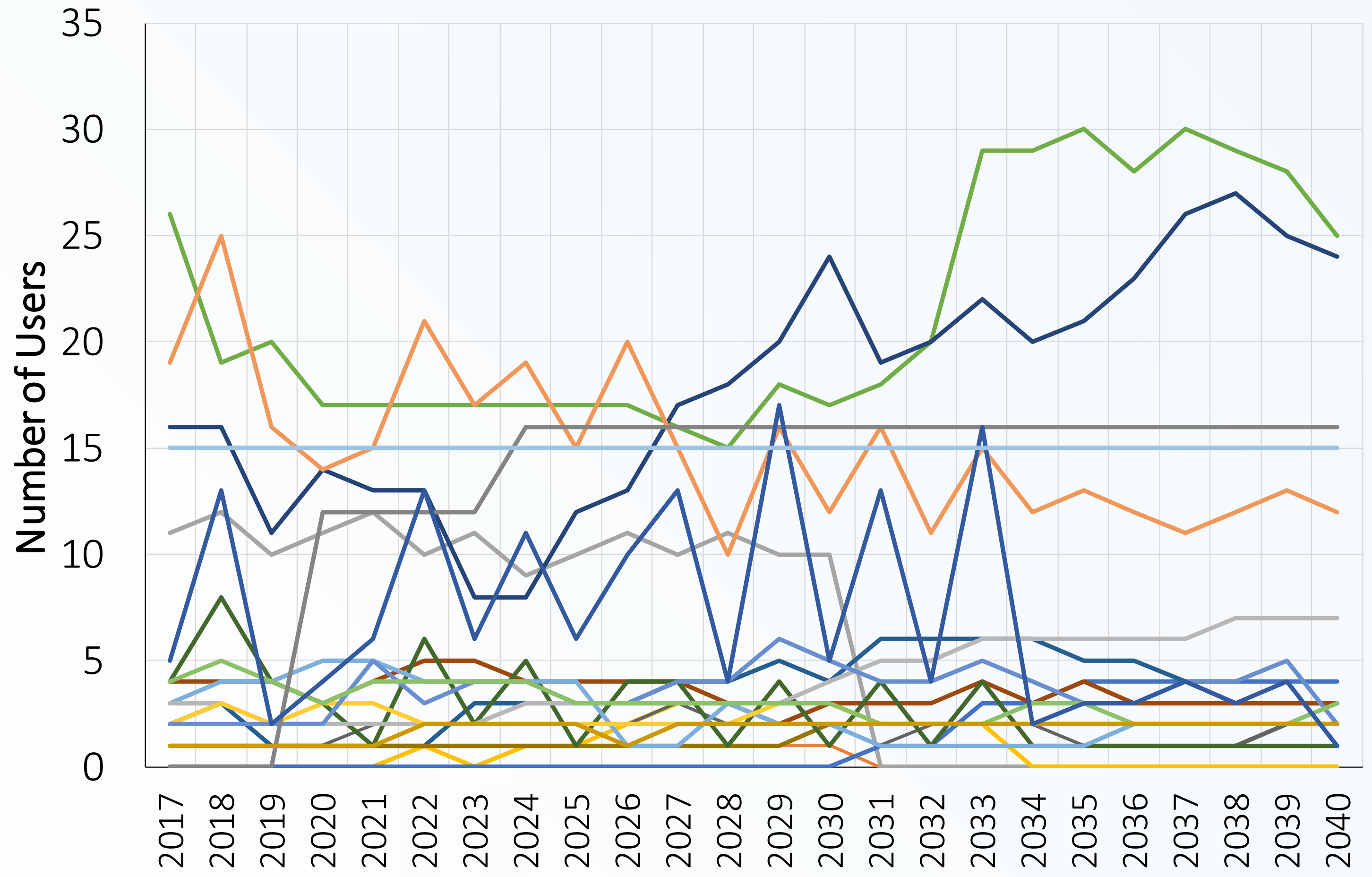


Figure 1: Current use case projections do not match the expected trend*

**Note: Some use cases have been excluded for legibility.*

Creating a Central Database

Three data sources are used to compile the database: the SCMM, ESCMM, and SCENIC. A MATLAB table is used as the data format as it is easy to manipulate. A set of identifiers unique to each user—SCMM IDs, NORAD IDs, and HORIZONS IDs—are used to cross-reference between the data sources. For each mission, information from all data sources are compared based on a source hierarchy and the data that is deemed most accurate is stored in the database, and the name of the data source is stored in a reference table.

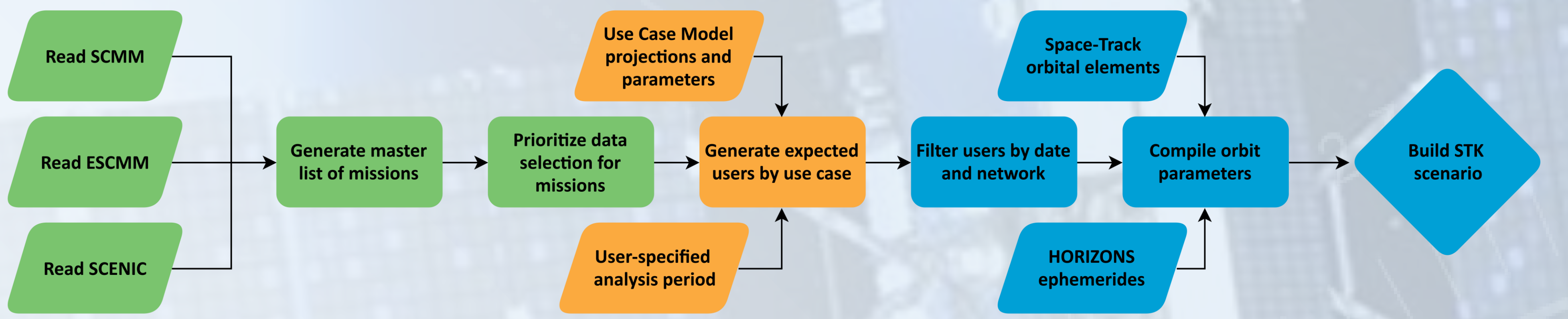


Figure 2: This flowchart shows the major operations of the code that builds the database then creates a mission model.

Table 2: Information contained in database

Fields	Description
Mission	Mission name
SCMMID	Unique ID used in the SCMM
NORADID	Unique ID used to query TLEs
HORIZONID	Unique ID used to query ephemeris
NumberDL	Number of spacecraft downlinking
UseCase	Use case classification
Launch/End	Mission launch/end date
NEN/SN/DSN	NEN/SN/DSN support category
CentralBody	Central body used for orbit info
OrbitType	Orbit classification
Orbit	Container of orbit information
NEN/SN/DSN FL/RLService	NEN/SN/DSN forward/reverse link service
NEN/SN/DSN FL/RLFrequency	NEN/SN/DSN forward/reverse link freq.
NEN/SN/DSN FL/RLDataRate	NEN/SN/DSN forward/reverse data rate
DataVolume	Volume of data downlinked per day
Latency	Time period in which data needs to be transported

Building an Interactive Model

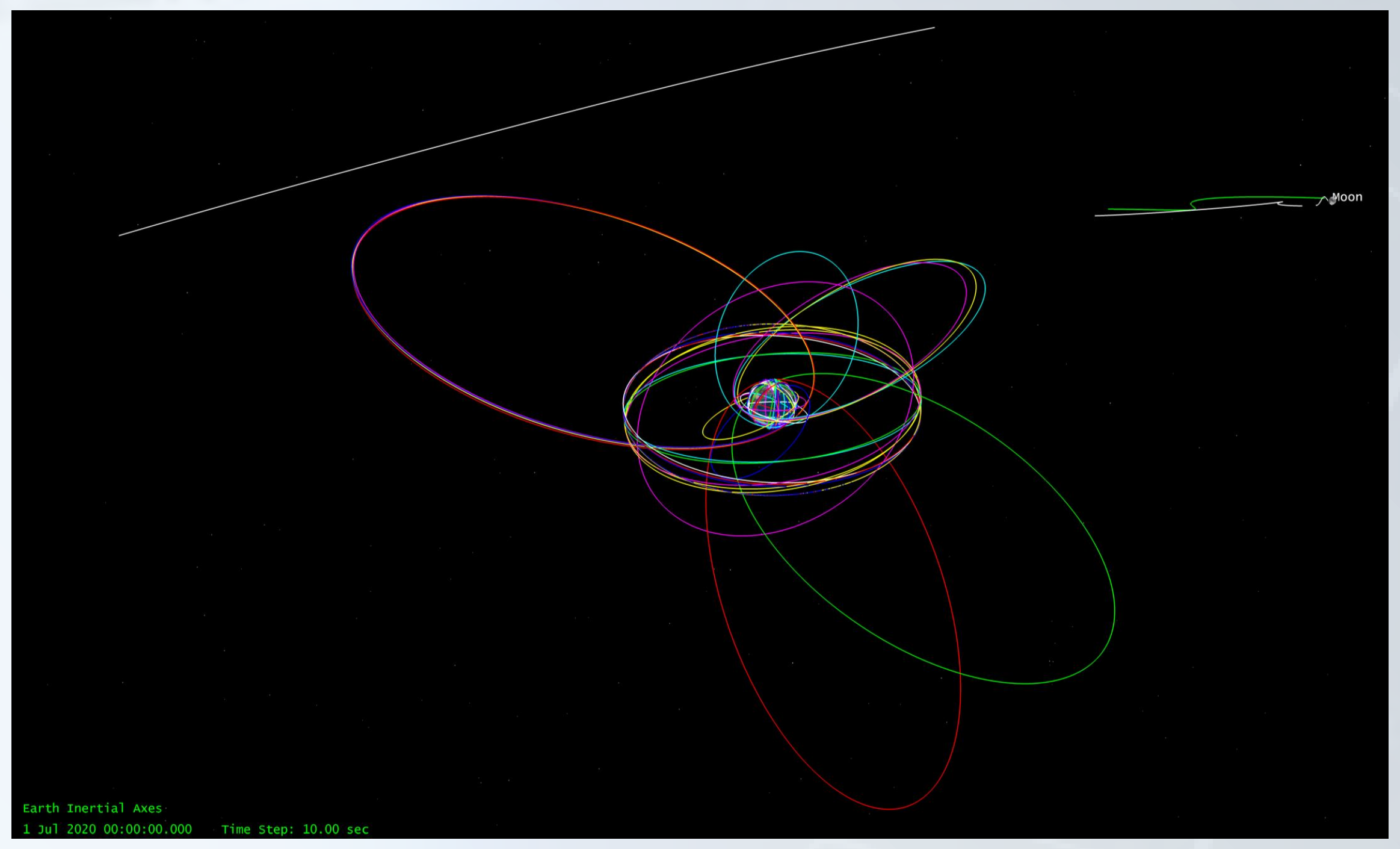


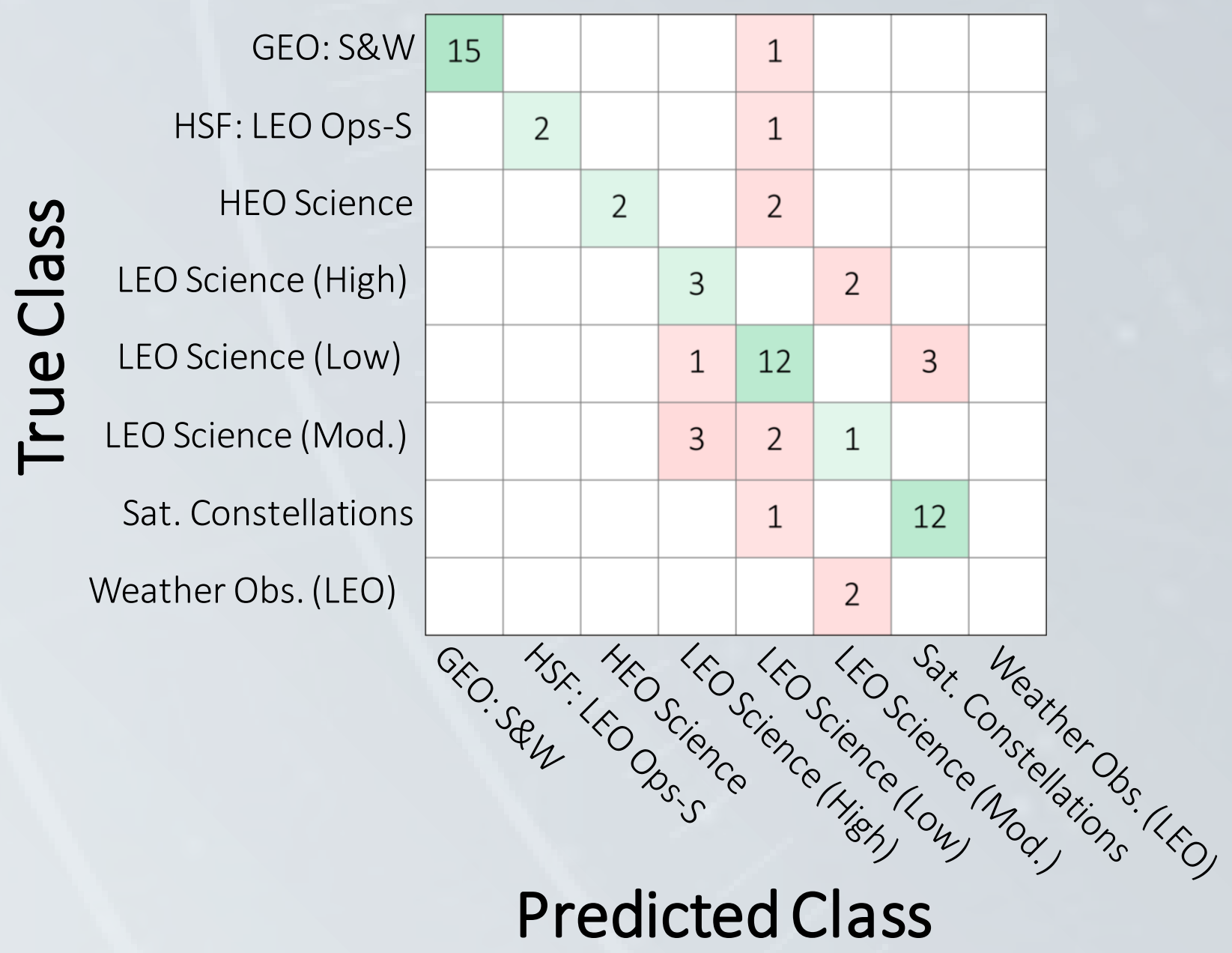
Figure 3: Mission model built for the year 2020

The central database includes all current and planned missions, however not all future missions are known. The use case model is a spreadsheet that contains projections for the number of users per use case through 2040. If the number of documented missions for a year is less than the number predicted for that year, the use case model will be used to generate orbital and communications parameters for the expected users and the remaining predicted uses.

The minimum information required to build a STK scenario is each user's orbit. Earth-orbiting spacecraft are modeled using their orbital elements. For current users these are retrieved from two-line elements (TLEs) hosted on Space-Track, whereas orbital elements were already defined for future users during random generation. Non-Earth-orbiting spacecraft are modeled using ephemeris: real ephemerides for current users with HORIZONS IDs are pulled from JPL's HORIZONS database, whereas ideal ephemerides were already created for future users during random generation. A library to create libration point orbits is used to generate ephemerides for such missions. Once all orbit information has been collected, a STK scenario will be created and each user will be inserted into the scenario. The result of this automated process is an interactive mission model that can be used for any analysis that can be performed in STK.

Use Case Characterization

An approach to resolve inaccuracies in the use case model is a generative adversarial network (GAN), which consists of a **generator** and a **discriminator**. The discriminator is trained to classify candidates, and the generator attempts to produce candidates that fool the discriminator. The result is that the generator will learn to map certain features to the classes recognized by the discriminator. In this case, the generator would include the algorithm and model data used to generate future users, and the discriminator would identify use cases based on orbit and communications parameters. The idea is that the same information that allows the, generator to learn could be used to modify the model data, so that after a long period of training the use case model would be tuned to better represent the use cases in terms of the features, thus accurately modeling the use cases.



True Class \ Predicted Class	GEO: S&W	HSF: LEO Ops-S	HEO Science	LEO Science (High)	LEO Science (Low)	LEO Science (Mod.)	Sat. Constellations	Weather Obs. (LEO)
GEO: S&W	15				1			
HSF: LEO Ops-S		2			1			
HEO Science			2		2			
LEO Science (High)				3		2		
LEO Science (Low)				1	12		3	
LEO Science (Mod.)				3	2	1		
Sat. Constellations					1		12	
Weather Obs. (LEO)						2		

Figure 4: A discriminator based on current users achieved 72.3% accuracy using orbital elements as input features

Conclusions

The database and mission model were successfully built for a number of analysis periods, which demonstrates the robustness of the of utilities developed to meet project goals—the most notable of which include the tools for retrieving and generating orbit data. Despite limited progress in developing the GAN to resolve inaccuracies in the use case model, the tests performed show promise for the approach. The results of this project are a solid base for future work on an enhanced interactive mission model for network analysis.

For more information, contact
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