FORECASTING ARTIFICIAL EARTH SATELLITE POPULATIONS

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Introduction

In this project, we investigate four time series models for predicting the population of Earth-orbiting satellites. Since 1957's launch of Sputnik 1, space access has grown steadily more accessible as more nations and private actors have gained access to launch capability. Today, even a small team of high school students can assemble and launch a space satellite on a reasonable budget.

Servicing the orbiting hardware population includes launch, tracking, and communications. Understanding the demand for space access is necessary for establishing the business case for providing service, as well as future tracking of space debris and other on-orbit risks.

Using publicly available data from the Joint Force Space Component Commander's Space-Track system, we construct four time series models for estimating the on-orbit population of four different orbit classifications. These models are used to predict populations for ten year periods, going forward.

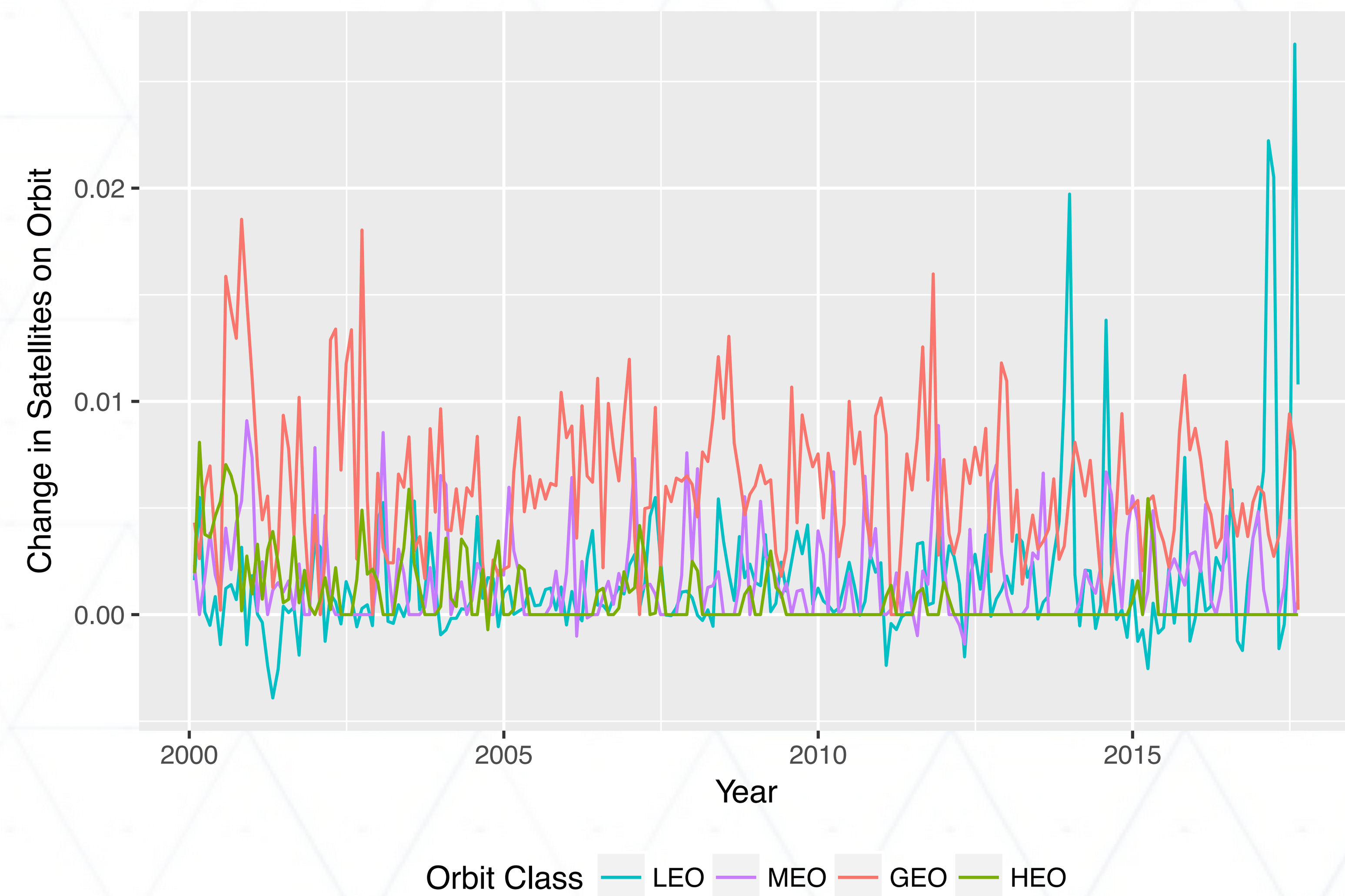

Figure 1. Change in Satellites on Orbit by Orbit Class

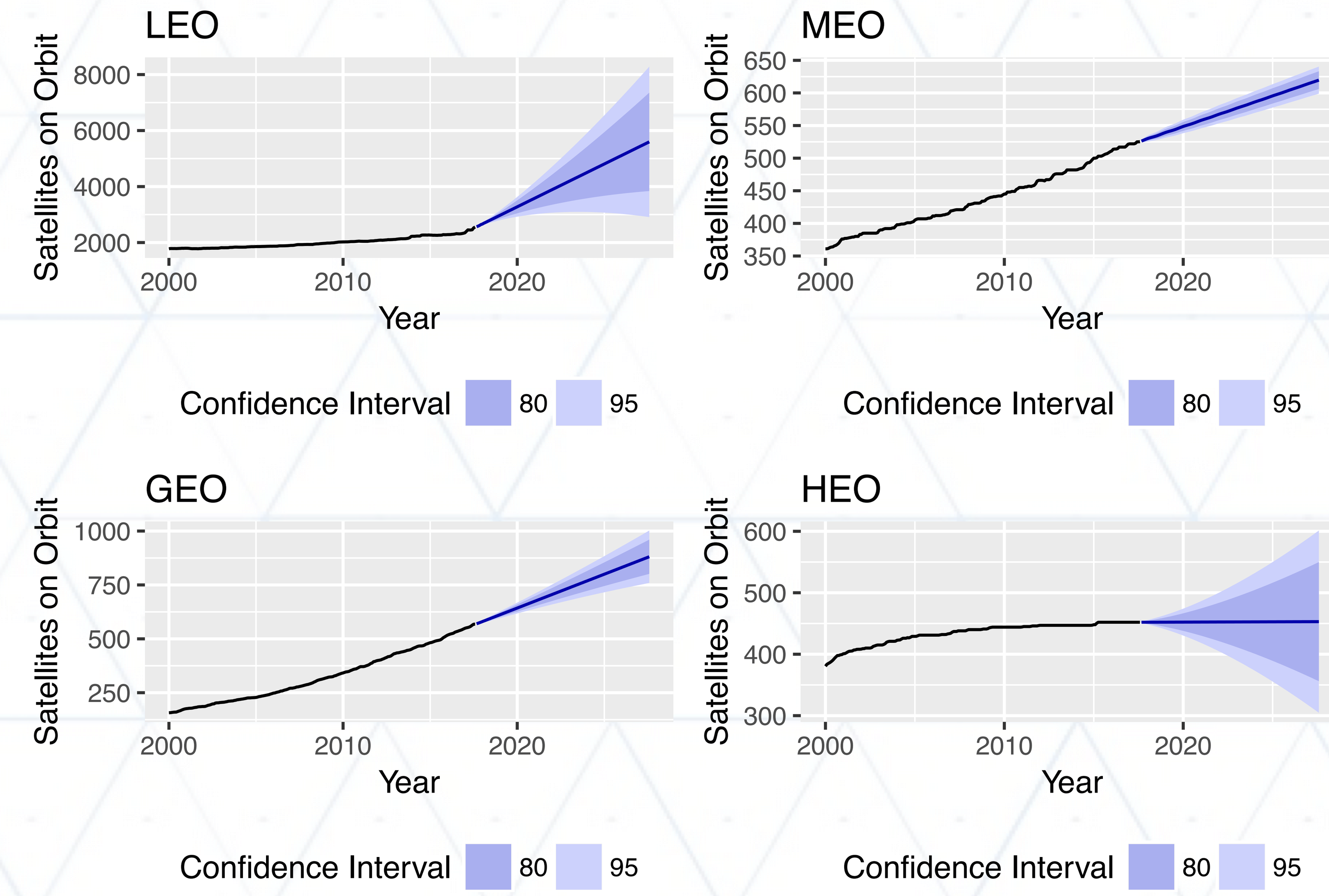

Figure 2. Forecast of LEO Satellite Population

Data and Model

This analysis uses data available from the Space Track website, maintained by the United States Strategic Command's Joint Functional Component Command for Space ("`satcat`"). The data contains a catalog of all space launches starting with the Soviet launch of Sputnik. The period of analysis runs from January 1, 2000 through August 19, 2017. The data catalog is principally used to describe orbital parameters for predicting satellite location. However, the data provided is a complete catalog of all known orbital launches.

The `LAUNCH` field of this dataset describes the data of launch for the object and the `DECAY` field describes the date of decay for the object. The `satcat` dataset uses `DECAY` to describe the date the satellite deorbited. The `PERIOD` field provides the orbital period in minutes.

A new monthly dataset is created from this data. The monthly dataset contains `LAUNCHES`, `DECAYS`, and `POP`, on the last day of each month, that is the arithmetic mean of the daily values for that month. This dataset includes values for each of four orbit classes: low-earth, medium-earth, high-earth, and geosynchronous.

The `auto.arima` function described by Hyndman and Khandakar (20008) will fit ARIMA(p, d, q) models with fixed values of p, d, and q, up to a maximum value of each, or a maximum combined value of p and q, returning the "best" fit according to the Akaike information criterion (AIC) measurement. We use the `auto.arima` function on each of the orbit classifications datasets fitting the best ARIMA(p, d, q) model with a combined value of p and q of 10 or less.

Results

	LEO	MEO	GEO	HEO
ar1	-1.02***	1.70***	0.29***	
ar2	-0.41*	-0.97***		
ma1	0.50**	-1.52***	-0.96***	-0.52***
ma2	-0.58***	0.66**		-0.29***
ma3	-0.73***	0.14		
ma4	0.01			
ma5	0.39***			
drift		0.78***		
AIC	1436.08	575.93	614.86	299.57
BIC	1462.86	599.40	624.90	309.61
log-likelihood	-710.04	-280.97	-304.43	-146.79

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Discussion

We are seeing an increase in the private use of space (Genta, 2014). This increase will likely require the development of infrastructure, both public and private, to support that use. Some of this infrastructure will be Earth-bound while other infrastructure will be placed into space, itself needing infrastructure to support it. It will range from elementary object tracking through to space communications support.

These models provide guidance for prospective demand for space access going forward. Using these models, we can estimate how many new satellites will be on orbit year over year. While each of these may require different types and manner of infrastructure support, both public and private entities may use these models to estimate demand for infrastructure. From this demand, these entities can make better decisions on how and where to invest capital for space infrastructure support.

References

- Hyndman, R., & Khandakar, Y. (2008). Automatic time series forecasting: The forecast package for R. *Journal of Statistical Software, Articles*, 27 (3), 1–22.
- Genta, G. (2014). Private space exploration: A new way for starting a spacefaring society? *Acta Astronautica*, 104(2), 480-486.