Incorporating Fast Fourier Transforms into Solar Array Lifetime Predictions

Jann Grovogui

The Aerospace Corporation, 2310 E. El Segundo Ave, El Segundo, CA 90245, USA

Motivation

Several factors can limit the ability to predict satellite solar array degradation:

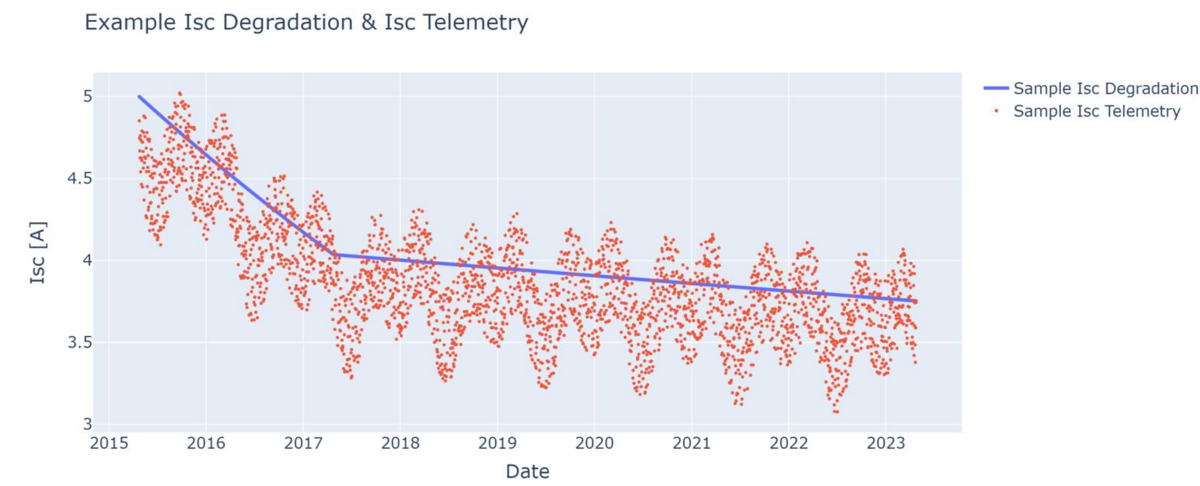
1. Degradation may be obscured by large periodic fluctuations due to a variety of unknown factors
2. Analysts may not be the original solar array designer/manufacturer, and may not have access to solar array design documentation
3. Analyst may have limited access to telemetry, potentially due to clearance limitations

Is there a way to perform solar array lifetime predictions in light of these challenges?

Sample Data

To demonstrate how FFTs can be used, a sample dataset with known degradation and periodicity was generated. This data set has:

- Two-Part Linear Degradation
- Two Sources of Periodicity:
  1. Earth Sun Distance
  2. Angle of Inclination
- Random Noise

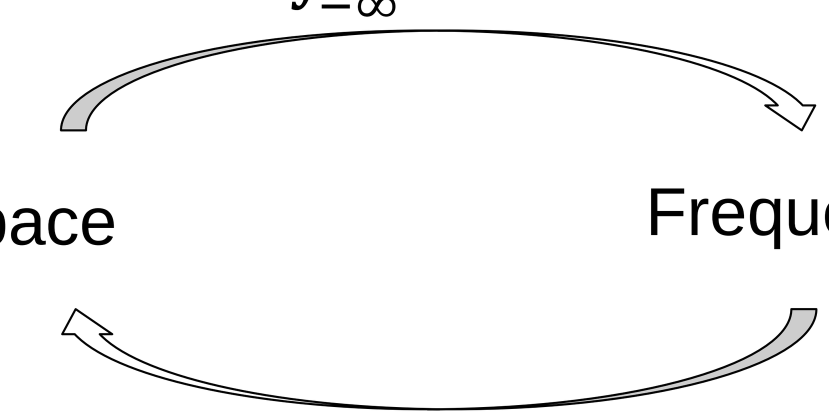


Fourier Transforms

The Fast Fourier Transformation (FFT) algorithm is used to convert time based signals into frequency space for ease of filtering &processing.

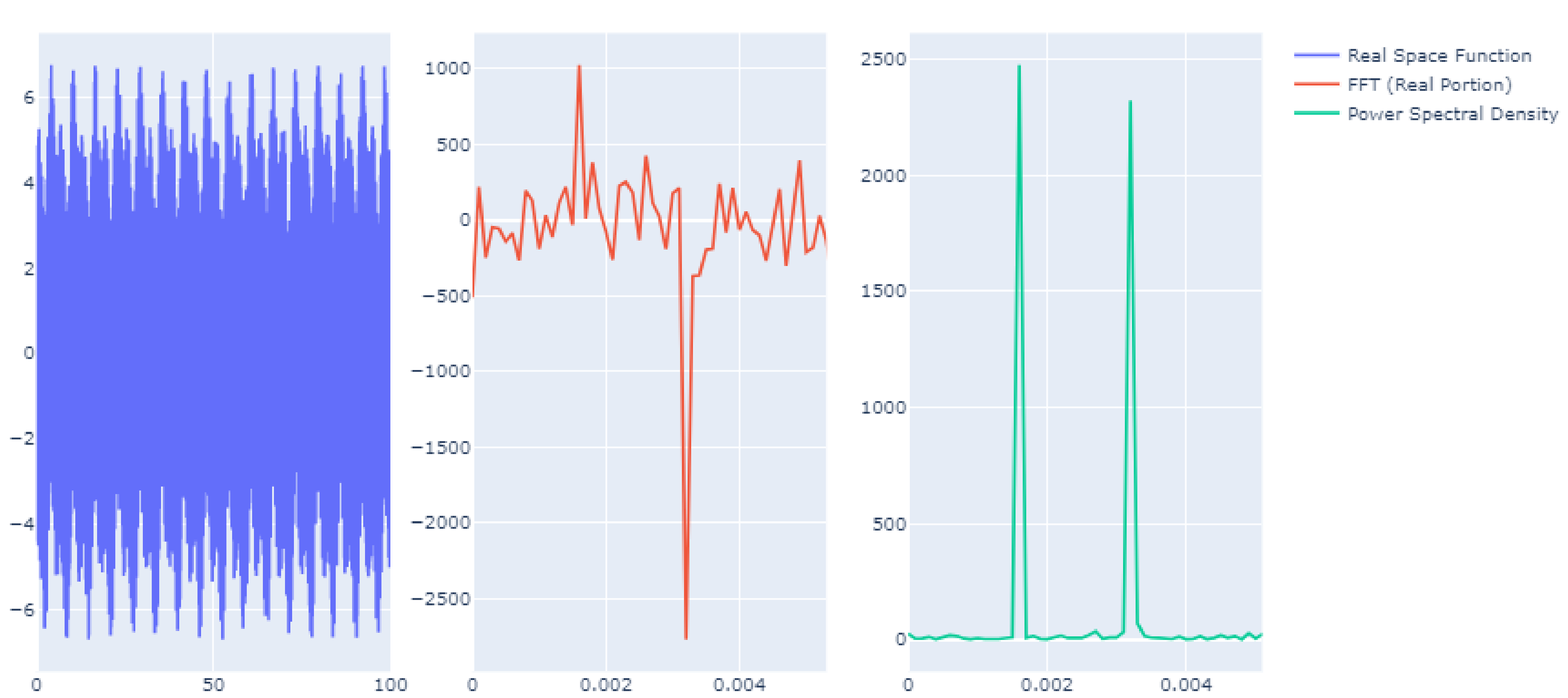
Fourier Transform

$$F(\nu) = \int_{-\infty}^{\infty} f(t)e^{-2\pi i\nu t}d\nu$$



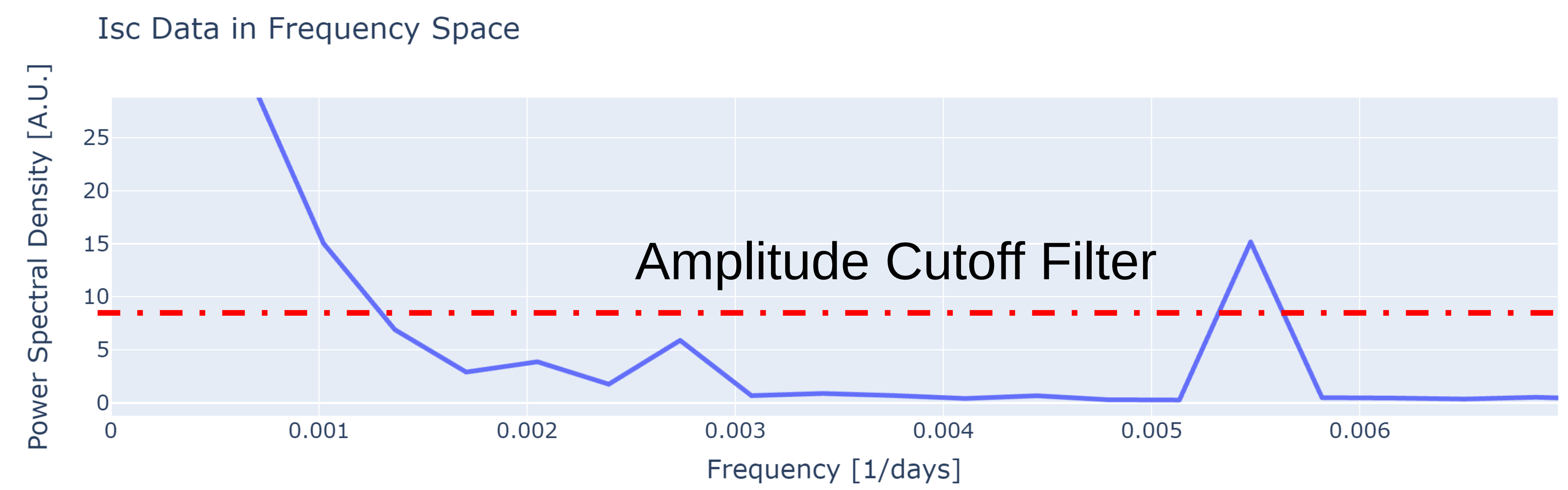
$$f(t) = \int_{-\infty}^{\infty} F(\nu)e^{2\pi i\nu t}dt$$

Inverse Fourier Transform

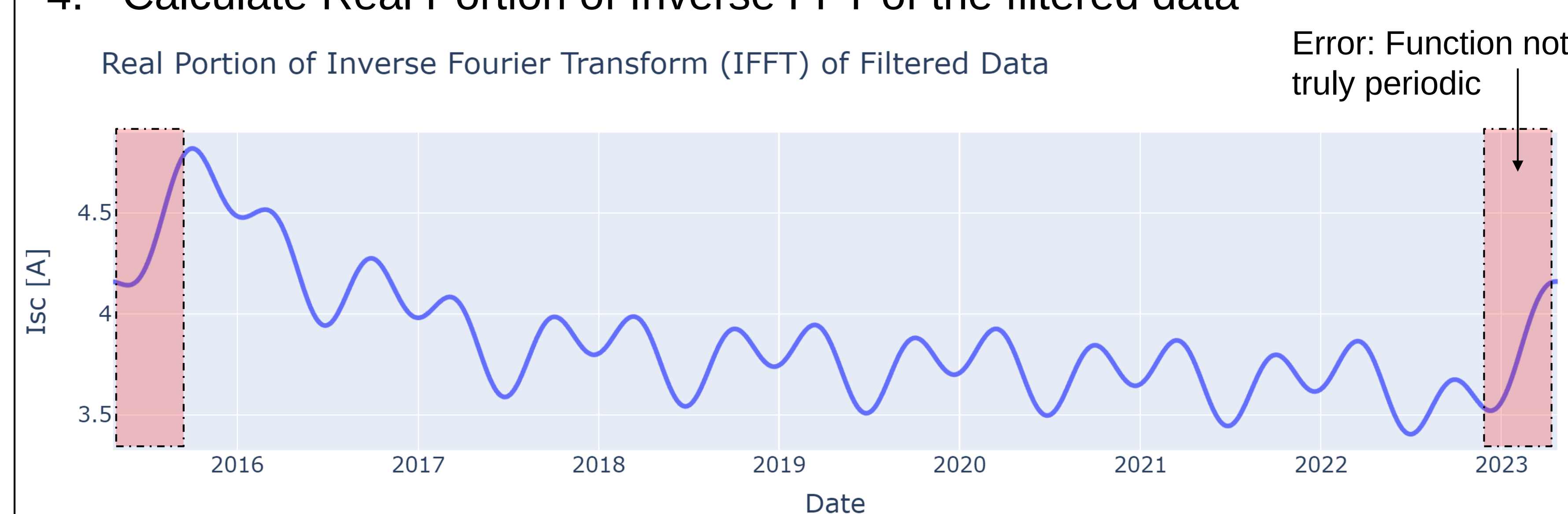


Procedures

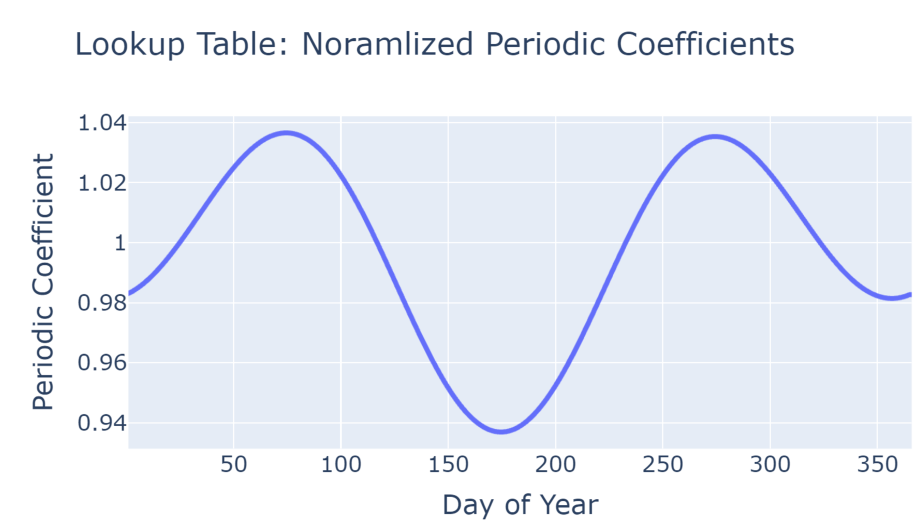
1. Convert Telemetry to frequency space using FFT
2. Calculate the Power Spectral Density (PSD)
   - PSD is the square of the FFT
3. Use an amplitude cutoff filter to select frequencies of interest



4. Calculate Real Portion of Inverse FFT of the filtered data

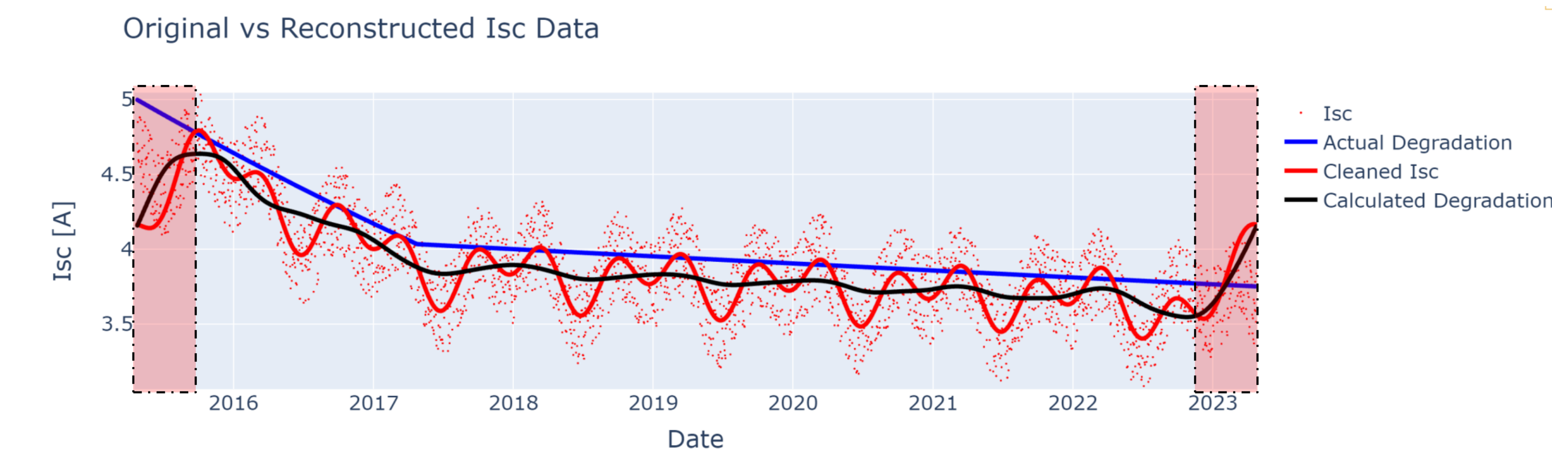


5. Calculate Annual Lookup Table with a Periodic Coefficient for each day of year. In this example, current values for each day were normalized against the median of the dataset.

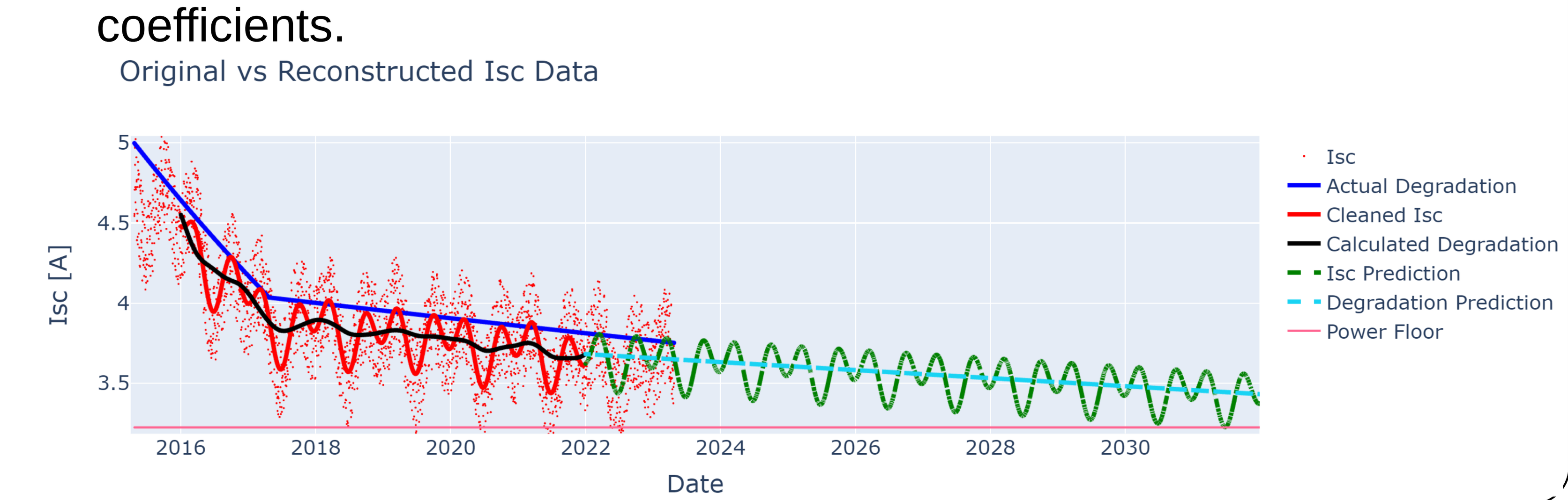


Day of Year	Periodic Coefficients
1	0.981737
2	0.982099
3	0.982499
...	...
364	0.981098
365	0.981375
366	0.981375

6. Divide IFFT by corresponding value in lookup table to obtain non-periodic degradation



7. Add Isc degradation prediction to (truncated) non-periodic degradation.
8. Multiply the resulting values by the corresponding periodic coefficients.



Summary

Accomplishments:

- (1) Periodicity & Degradation replicated with existing python libraries
- (2) Array size not needed, only average/relative current degradation
- (3) Only required current/power and timestamp
- FFTs were also used to filter out measurement noise
- Developed technique that is generally applicable to a variety of vehicles

Limitations:

- Not all periodicity was eliminated when dividing out periodic coefficients
- Can't accurately calculate normalized I_{sc} w/o oscillations (if BOL unknown)
- Performing FFTs on finite datasets results in error at the edges of data

Acknowledgements

I gratefully acknowledge Aerospace's Internal Research and Development (IRAD) program for funding this work.