National Aeronautics and Space Administration

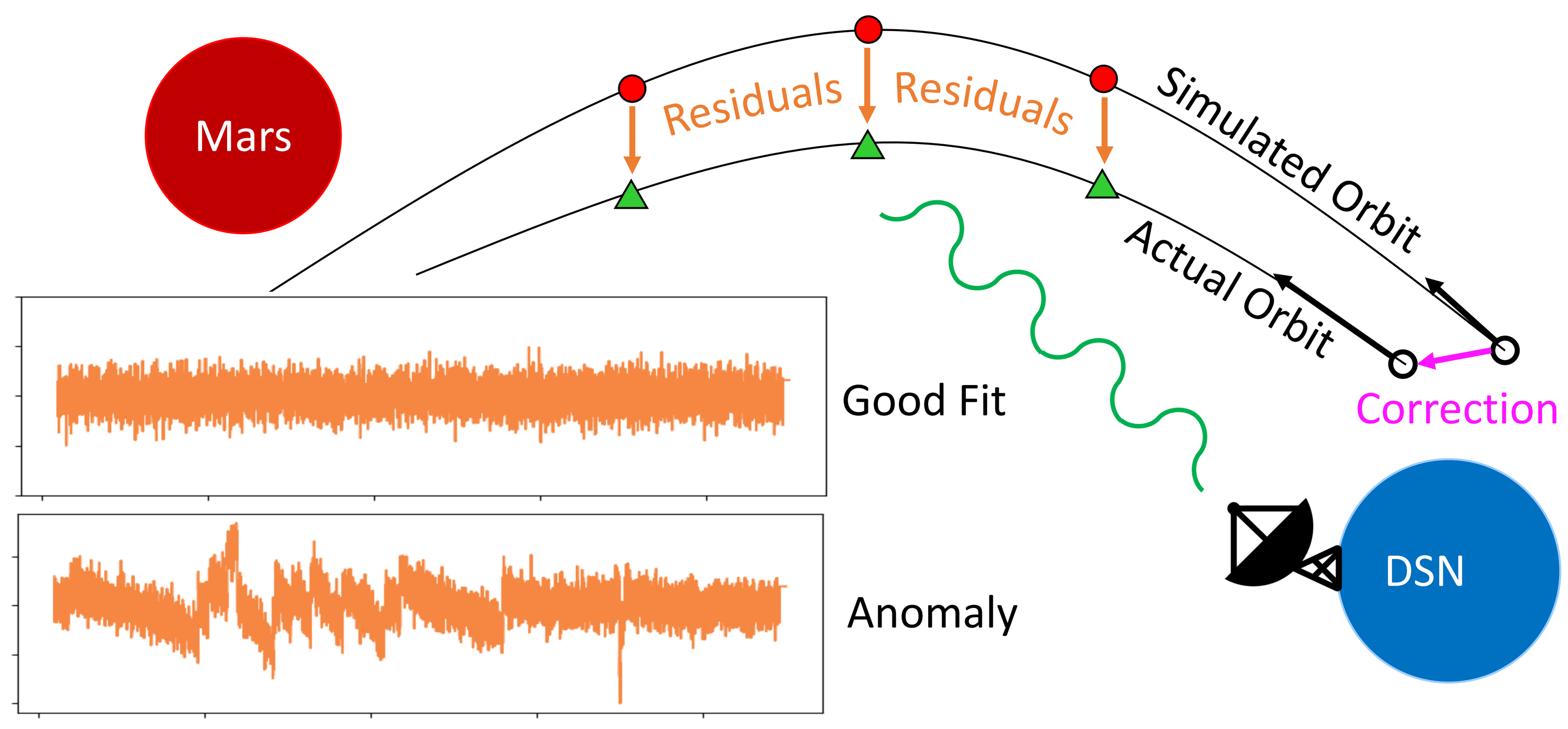
Postdoc Research

Diagnosing Deep Space Navigation Anomalies with Deep Learning

Author: Justin R. Mansell, JPL Postdoctoral Fellow (392A)
Brian M. Kennedy (392A) and Eric D. Gustafson (392A)

Background

- To find where a spacecraft is in space and design correction maneuvers, Navigators in JPL's MDNav section build comprehensive simulations of trajectory dynamics and radio signals collected by the Deep Space Network
- "Orbit Determination" involves iterating on parameters in the simulation until the simulated observations are consistent with the actual DSN signals
- **If the simulated trajectory cannot be made consistent with the DSN observations, something is wrong**:
    - The simulation may be missing or misrepresenting forces acting on the spacecraft
    - The conversion of the simulated trajectory into simulated observations could be flawed
- Given the complexity of the simulations, getting to the root cause in time for a critical spacecraft event is a difficult task
- Unresolved navigation anomalies can have **catastrophic consequences**; Mars Climate Orbiter was lost due to an incorrect model of thruster firings



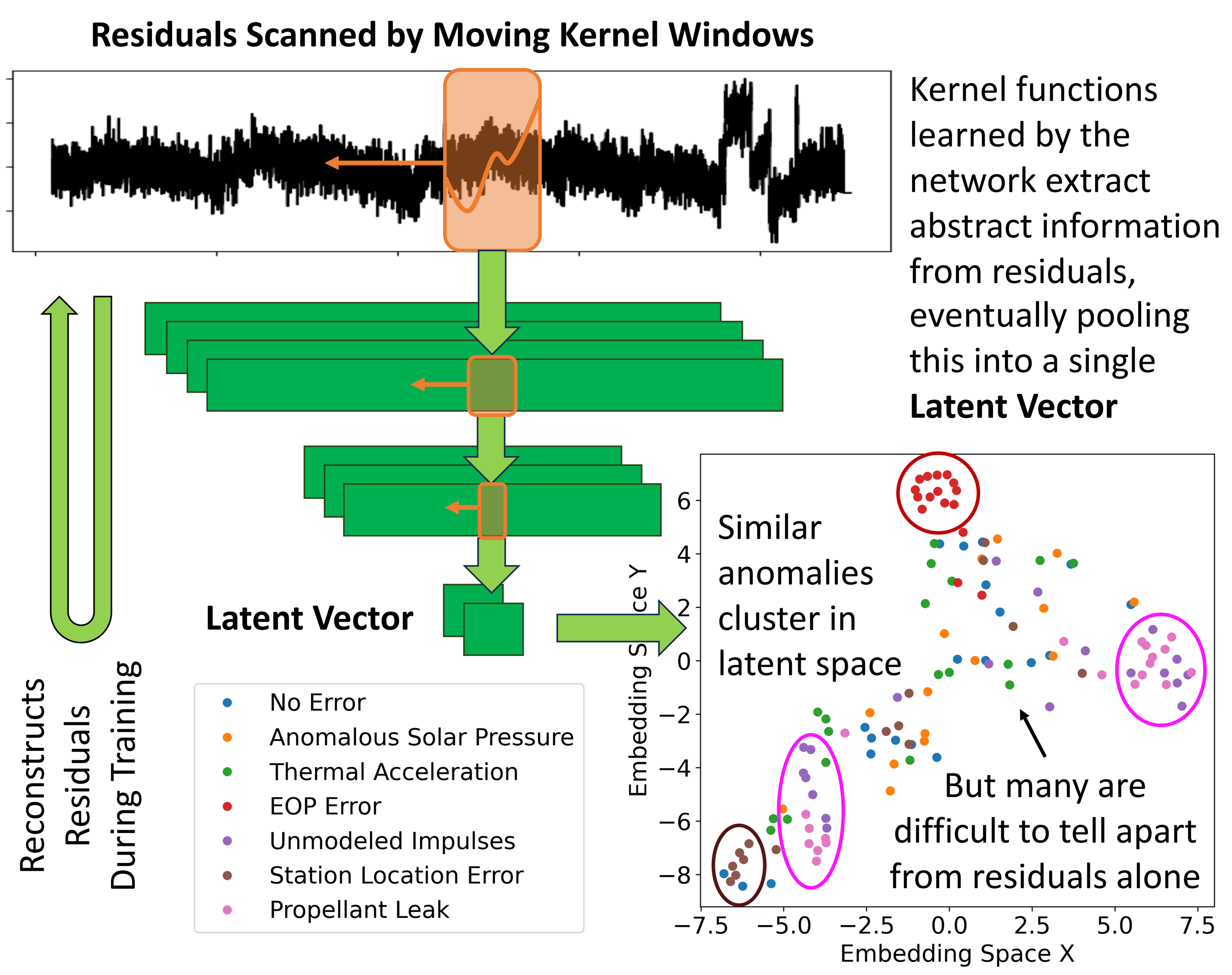
Objectives

Can deep learning improve detection and diagnosis of anomalous navigation solutions for deep space missions?

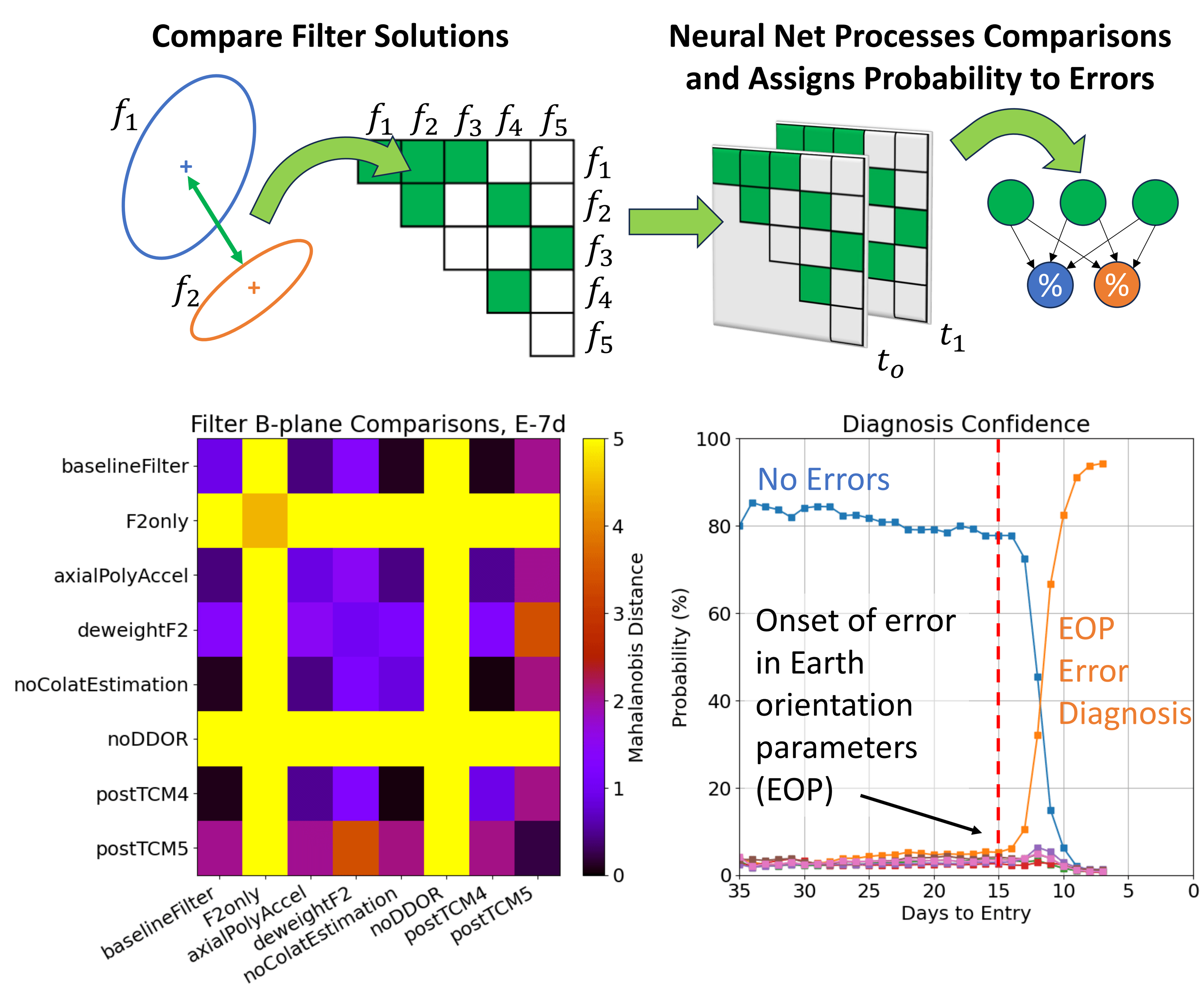
Approach and Results

- Starting from an approach navigation study for the Mars Sample Retrieval Lander, we modified the study to simulate a variety of mismodeling errors

Method #1: uses the errors to generate anomalous navigation residuals, then trains a **Convolutional Autoencoder** to detect patterns characteristic of each type of anomaly



Method #2: uses a catalog of trajectory models with different parameters for the dynamics and observations ("filters"). A **Long Short-Term Memory** network processes statistical comparisons and assigns confidence to each error.



Significance of Results/Benefits to NASA/JPL

- Either method could improve sensitivity to detecting navigation anomalies and increase the speed at which they can be diagnosed
- Deep learning can be useful in design too: elements of method #2 were recently used to assess the detectability of anomalies before the Sample Retrieval Lander's contingency maneuver

Future Work

- Method #1 does not require the types of errors to be known beforehand, but struggles to diagnose certain anomalies. In the next phase of research, we intend to combine the strengths of both methods by incorporating the latent vectors of the autoencoder as an additional input to the comparison neural network of method #2

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

Clearance Number: CL#00-0000
Poster Number: PRD-T-002

Publications and Acknowledgements:

The authors are preparing a journal article based on this work. The authors would additionally like to thank Daniel Lubey (392J), Tomas Martin-Mur (3920), Tim McElrath (3920), and Roby Wilson (3920) for their helpful comments and guidance.

Author Contact Information:

(818) 393-3073
justin.r.mansell@jpl.nasa.gov