

# **Robust and Interpretable Learning Techniques for Operator-Theoretic Modeling of Non-linear Dynamics**

by

Shaowu Pan

A dissertation submitted in partial fulfillment  
of the requirements for the degree of  
Doctor of Philosophy  
(Aerospace Engineering)  
in The University of Michigan  
2020

Doctoral Committee:

Associate Professor Karthik Duraisamy, Chair  
Professor Venkat Raman  
Assistant Professor Aaron Towne  
Assistant Professor Alex Gorodetsky  
Professor Nathan Kutz

© Shaowu Pan 2024

---

All Rights Reserved

For my parents.

## ACKNOWLEDGEMENTS

## TABLE OF CONTENTS

DEDICATION . . . . .	ii
ACKNOWLEDGEMENTS . . . . .	iii
LIST OF FIGURES . . . . .	v
LIST OF TABLES . . . . .	vi
LIST OF APPENDICES . . . . .	vii
ABSTRACT . . . . .	viii
CHAPTER	
I. Introduction . . . . .	1
1.1 High Dimensional Non-linear Dynamical Systems . . . . .	1
APPENDICES . . . . .	3
BIBLIOGRAPHY . . . . .	5

## LIST OF FIGURES

### Figure

- |     |   |   |
|-----|---|---|
| 1.1 | Left: Aerion SBJ designed by jet builder Aerion Supersonic that expects to fly silent supersonic planes by 2024, unlocking a \$40 billion market (?). Right: Human launch of SpaceX's Falcon 9 rocket raises the company value to \$44 billion (?). . . . . | 2 |
|-----|---|---|

## LIST OF TABLES

Table

## LIST OF APPENDICES

### Appendix

A.	Appendix . . . . .	4
----	--------------------	---



# ABSTRACT

Operator theoretic learning and decomposition of non-linear dynamics

by

Shaowu Pan

Chair: Associate Professor Karthik Duraisamy

abstract

# CHAPTER I

## Introduction

We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too.

---

*John F. Kennedy Moon Speech,  
Rice Stadium (1962)*

### 1.1 High Dimensional Non-linear Dynamical Systems

The need for faster, more efficient and versatile air transport vehicles continues to drive challenging design problems in Aerospace engineering. As examples, the desire to reduce travel time from New York City to London by half has led to silent super-

sonic commercial aircraft initiated by *Aerion Supersonic*, while *SpaceX* is developing vehicles for space exploration as shown in fig. 1.1.

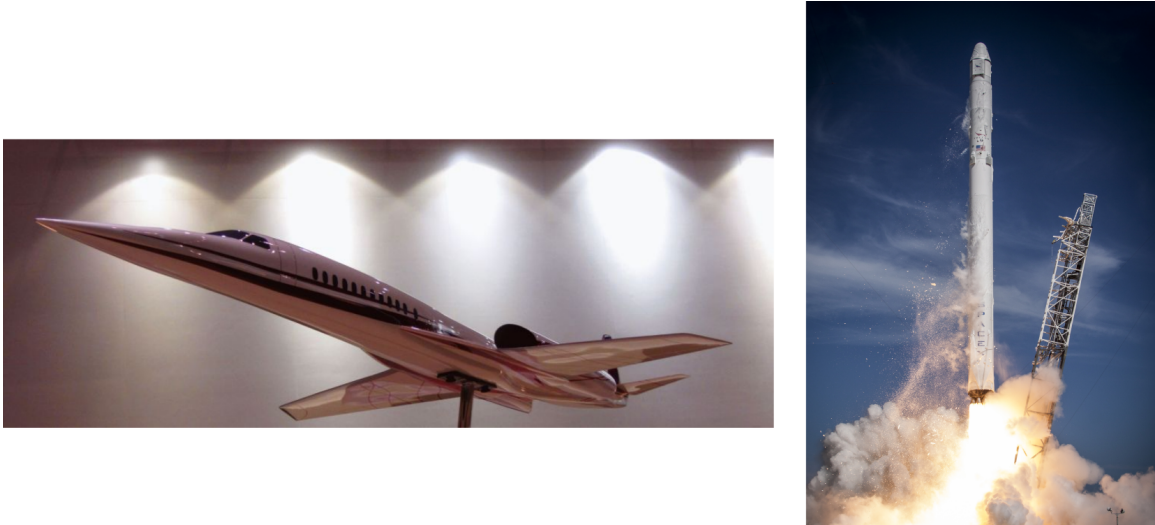


Figure 1.1: Left: Aerion SBJ designed by jet builder Aerion Supersonic that expects to fly silent supersonic planes by 2024, unlocking a \$40 billion market (?). Right: Human launch of SpaceX's Falcon 9 rocket raises the company value to \$44 billion (?).

## APPENDICES

## APPENDIX A

### Appendix

## **BIBLIOGRAPHY**