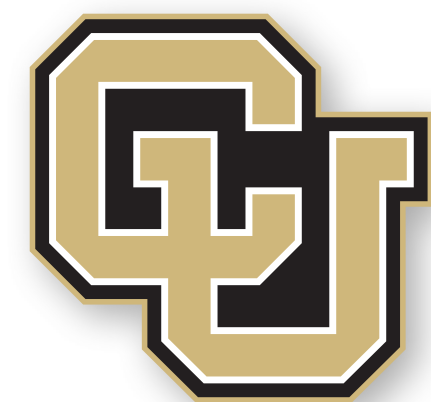


# Rigid Body Kinematics

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ASEN 5010

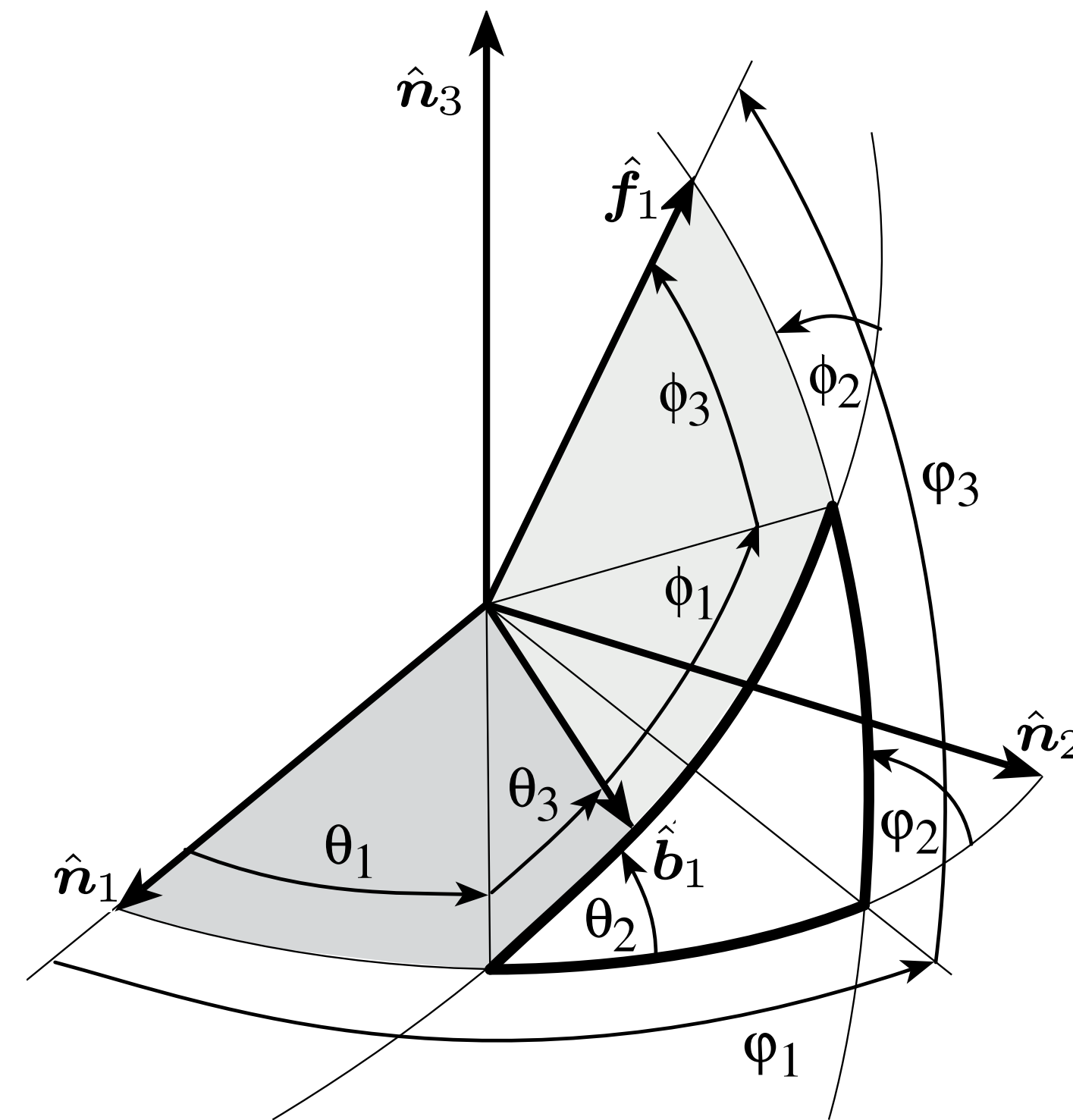
Prof. Hanspeter Schaub  
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Boulder

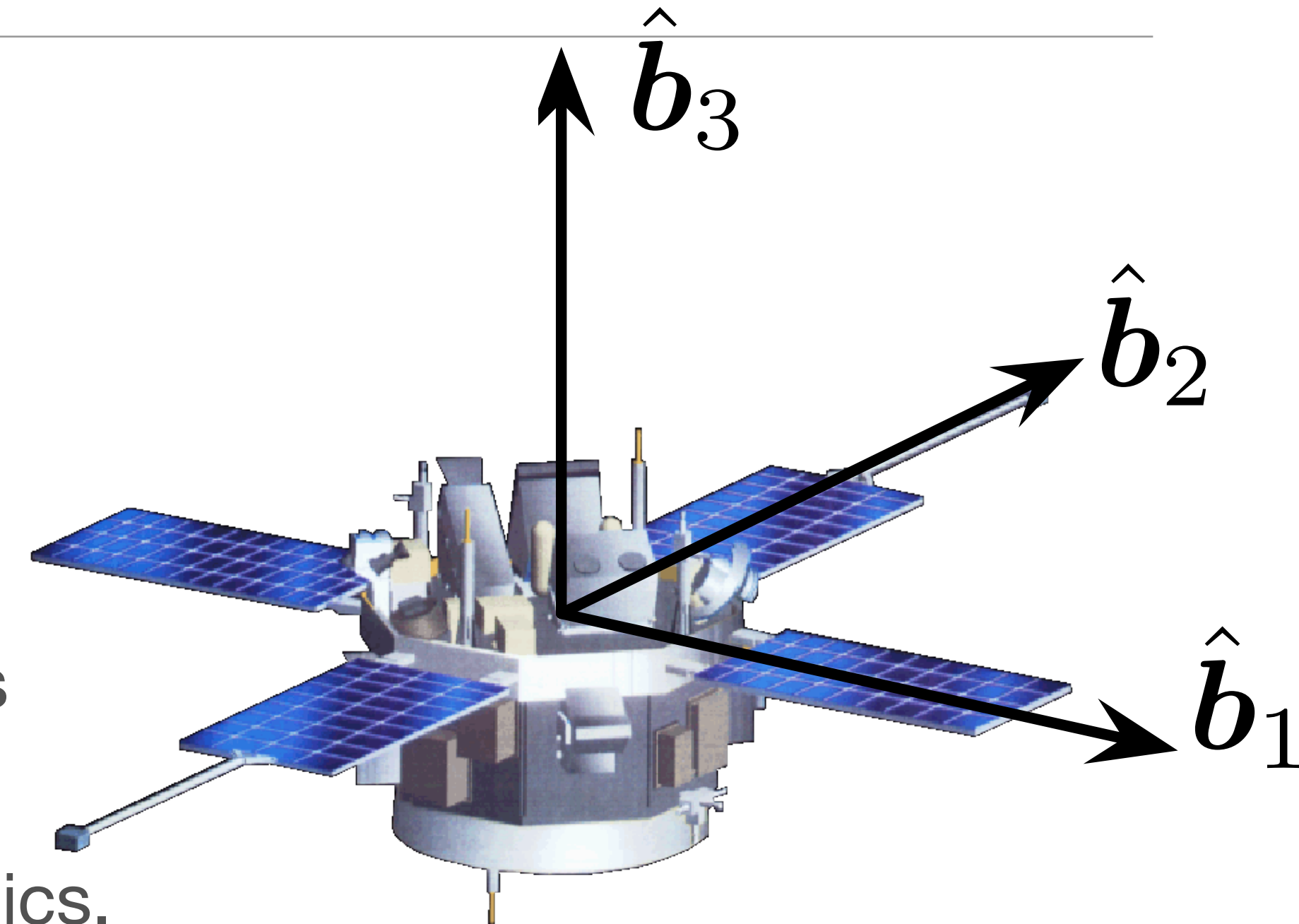
# Outline

- Direction Cosine Matrix
- Euler Angle Sets
- Principal Rotation Parameters
- Euler Parameters (Quaternions)
- Classical Rodrigues Parameters
- Modified Rodrigues Parameters
- Stereographic Orientation Parameters



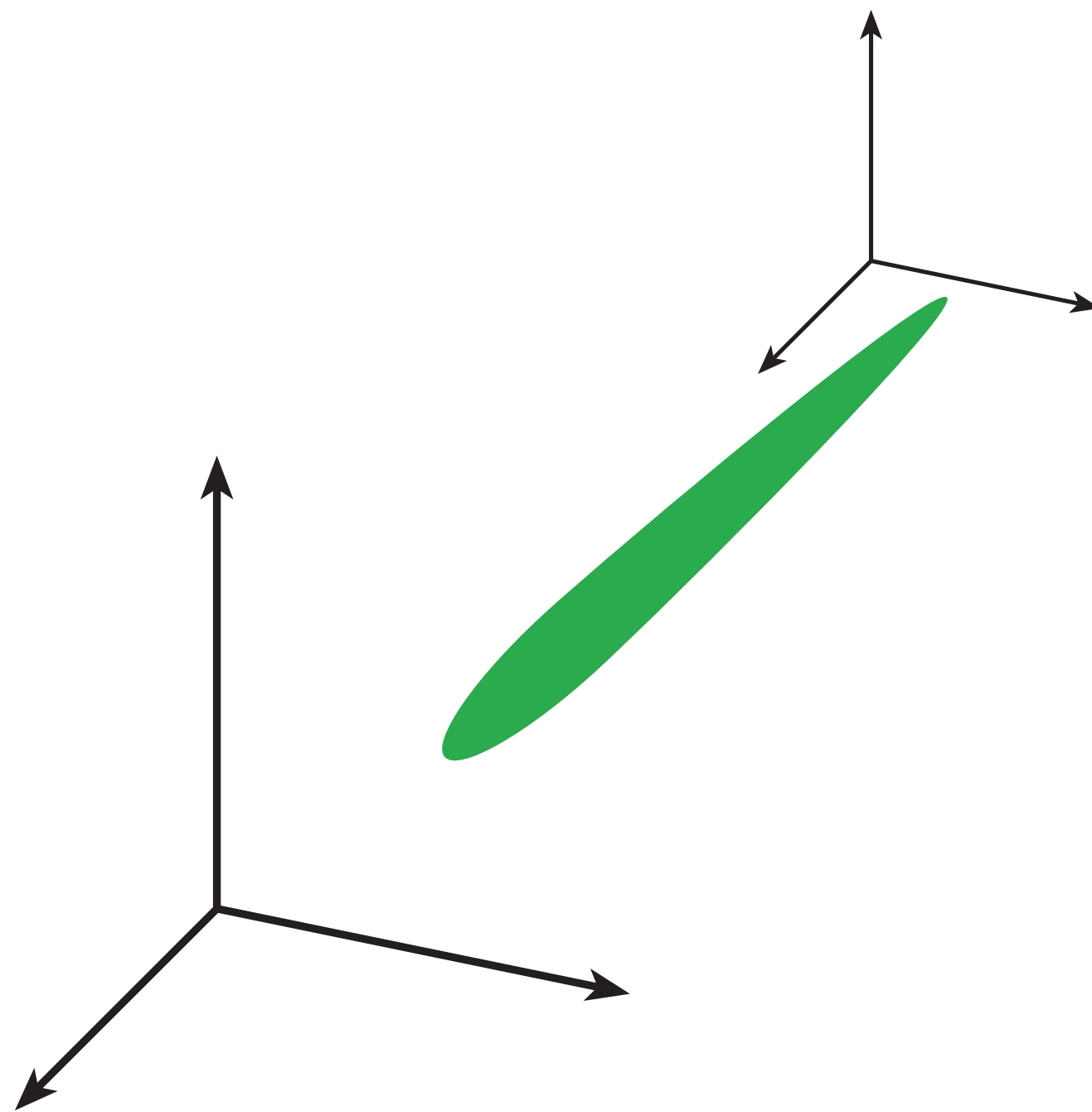
# Introduction

- Attitude coordinates are set of coordinates that describe of both a rigid body or a reference frame
- An infinite number of coordinate choices exists, same as with position coordinates
- A good choice in attitude coordinates can greatly simplify the mathematics of the problem solving process
- A bad choice in attitude coordinates can introduce singularities in the attitude description, as well as highly nonlinear mathematics.



# Relation to Position Coordinates

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Translational errors can grow infinitely large!



Attitude errors can grow to  $180^\circ$ !



## 4 “Truths” about Attitude Coordinates

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- A minimum of **three coordinates** is required to describe the relative angular displacement between two reference frames.
- Any minimal set of three coordinates will contain at least one geometrical orientation where the coordinates are **singular**, namely at least two coordinates are **undefined** or not unique.
- At or near such a geometric singularity, the corresponding **kinematic differential equations are also singular**.
- The geometric singularities and associated numerical difficulties can be avoided altogether through regularization. **Redundant sets of four or more coordinates exist that are universally valid.**