Moments of Inertia

Uninhabited Aerial Vehicle (UAV)
Dryden Remotely Operated Integrated Drone (DROID)

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Agenda

- Personal Background
- Research
  - Importance
  - Measure, Weight, CG
  - Design Hardware and Test
  - Machining
  - Hangar
  - Safety Mitigations
  - Critical Design Review (CDR)
  - Tech Brief
  - Test
  - Analyze Data
- Lessons Learned
- Future Plans
- Questions
Personal Background

- CSUN Applied Mathematics Master Student
- CA Mathematics Council Member
- CSUN Mathematics Club Member
- National Science Foundation Scholarship Recipient
- NASA Intern
Research
The mass properties of an object are simply the proportionality constants between applied force and the resulting acceleration:

\[ f = m \ddot{x} \]

\[ T = J \alpha \]

This is Newton’s 2nd law for 1 Degree of Freedom (DOF) translation and rotation, respectively.

When expanded to 6 DOF:

Mass:
\[
\begin{bmatrix}
F_x \\
F_y \\
F_z \\
M_x \\
M_y \\
M_z
\end{bmatrix}
= 
\begin{bmatrix}
m & 0 & 0 \\
0 & m & 0 \\
0 & 0 & m \\
mZ_{CG} & -mZ_{CG} & mY_{CG} \\
-mZ_{CG} & mY_{CG} & mX_{CG} \\
-mY_{CG} & mX_{CG} & 0
\end{bmatrix}
\begin{bmatrix}
x \\
y \\
z \\
\dot{x} \\
\dot{y} \\
\dot{z}
\end{bmatrix}
\]

CG information:
\[
\begin{bmatrix}
\ddot{x} \\
\ddot{y} \\
\ddot{z}
\end{bmatrix}
\]

Inertia Tensor:
\[
\begin{bmatrix}
I_{xx} & -I_{xy} & I_{xz} \\
-I_{yx} & I_{yy} & -I_{yz} \\
-I_{zx} & -I_{yz} & I_{zz}
\end{bmatrix}
\]

6 DOF acceleration:
Importance

The inertial characteristics have direct consequences on:

- Aerodynamics!
- Propulsion!
- Structures!
- Control!
Measure and Weight

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Design

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Manufacturing

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Safety

- Human Hazard Analysis
- Loss of Asset/Mission Hazard Analysis
Approvals

- Critical Design Review (CDR)
- Tech Brief
Data Analysis

- Time Constraints
- Basic Geometric Shapes
- MATLAB
- Error
Lessons Learned

- Dryden vs. Disneyland
- Learning
- Team Effort
- Double check all work
- Stress Testing
- Use steel instead of aluminum
Future Plans

- GSIRP at NASA Headquarters
- Graduate
- Work for NASA
Questions?

Mark, Chris, Aaron, Lesli, Stephanie, Alex, and Helida!
All photos provided by: NASA photographer, Thomas P. Tschida and INSPIRE Team!

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BACK-UP: Inertia Calculations

\[ I_{Pod} = \left( \frac{g}{16\pi^2} \right) \left( \frac{d^2}{l} \right) T^2 \left( W_{Pod} + W_{Rig} \right) - I_{Rig} \]

Where,

- \( I \) = Yaw Mass Moment of Inertia, [lb-in\(^2\)]
- \( g \) = gravity, [in/sec\(^2\)]
- \( d \) = Distance Between Cables, [in]
- \( l \) = Cable Length, [in]
- \( T \) = Period of Oscillation, [sec]
- \( W \) = Weight, [lb]

Reference:
NACA TN No.351