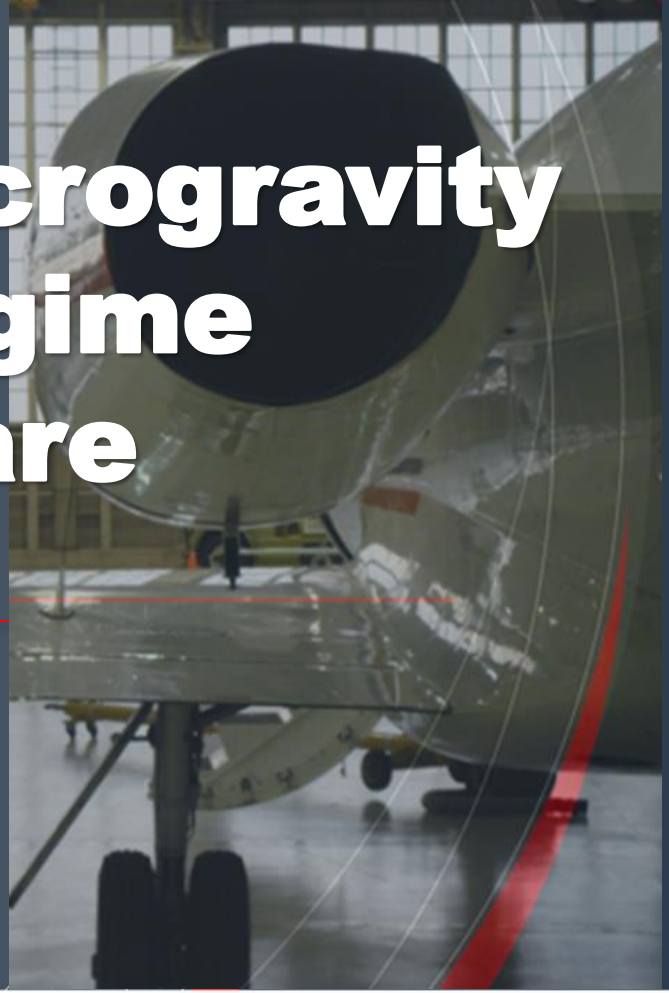
NRC·CNRC

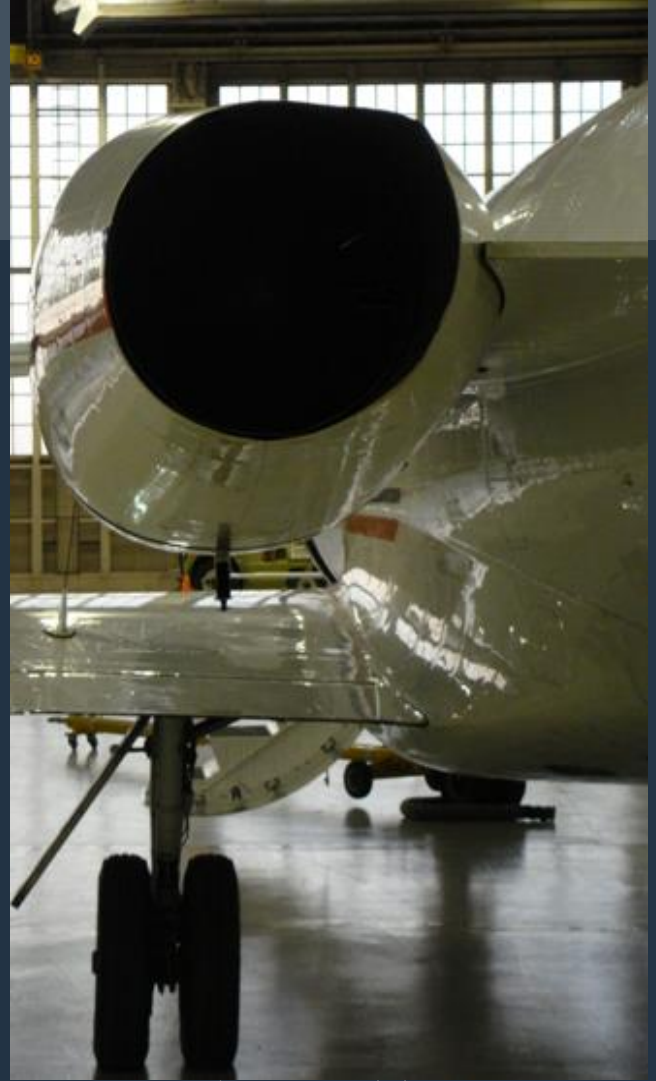
Development of Microgravity Flight Sciences Regime Recognition Software



NRC Flight Research Laboratory:

M. Alexander, T. Zaidi, A. Brown

15 June 2021



Marc Alexander,
Research Officer, Flight Sciences
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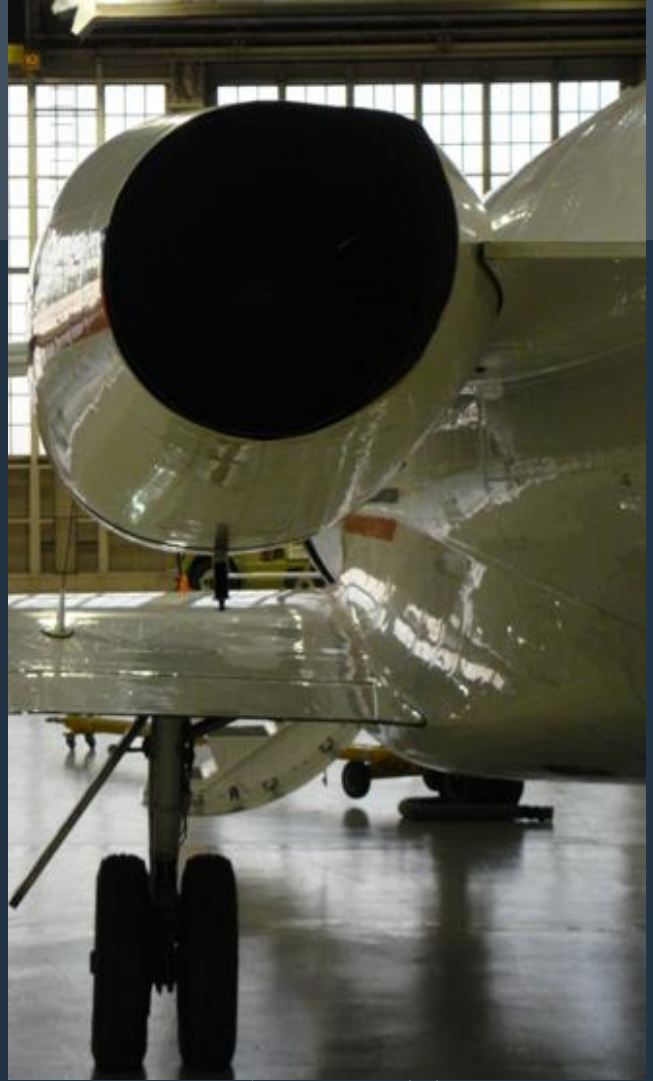
Overview

- Domain Overview: Parabolic Flight
  - Research, Flight Dynamic Complexity, Test Aircraft
- MGFSSIM Development: Parabolic Flight Data Analytics
  - Requirements, Parabolic Flight Discretization
  - NRC FA-20 Data Correlation (Implementation, Calibration, Correction)
- Case Study: NRC FA-20 Sample Sortie
  - Case overview, Input Setting, Run verification,
- Results
  - Case Data Review
  - Sample Analytics: Standard Deviation, Regression, Phase Classification
- Conclusions and Closing Remarks

Domain Overview: Parabolic Flight Sciences



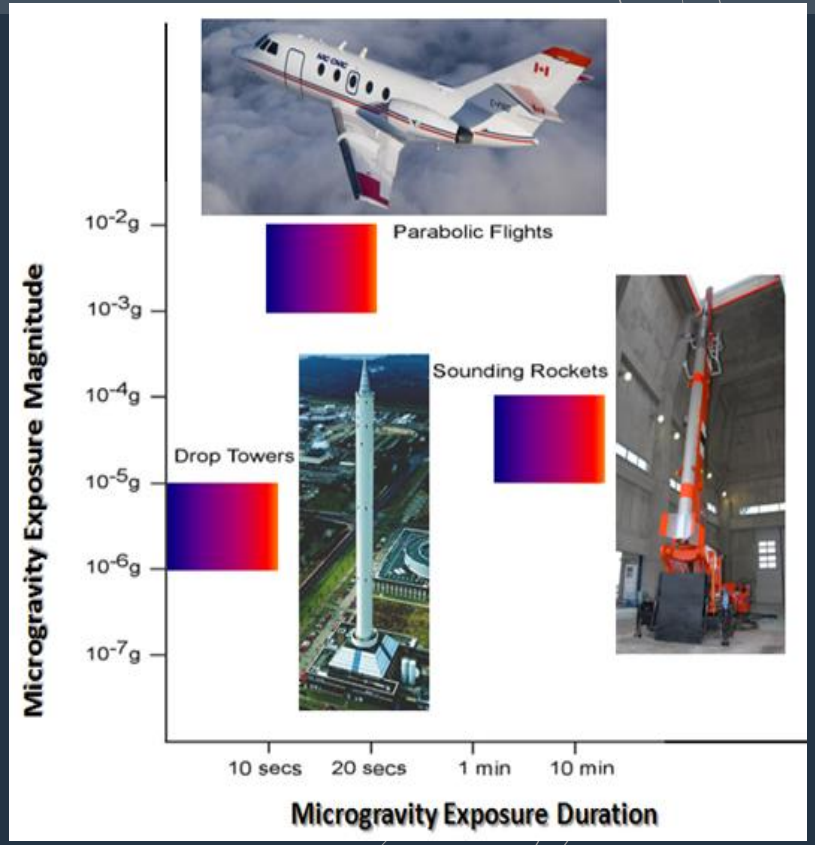
NRC Microgravity Flight Research

Research Domain:

- Manufacturing Technologies,
- Life Sciences,
- Energy and Environmental Sciences,
- Natural Sciences,
- Aerospace Systems
- Human Performance

Complexities:

- Aircraft configuration & structures
- Piloting techniques
- Weather
- Operations
- Human Factors



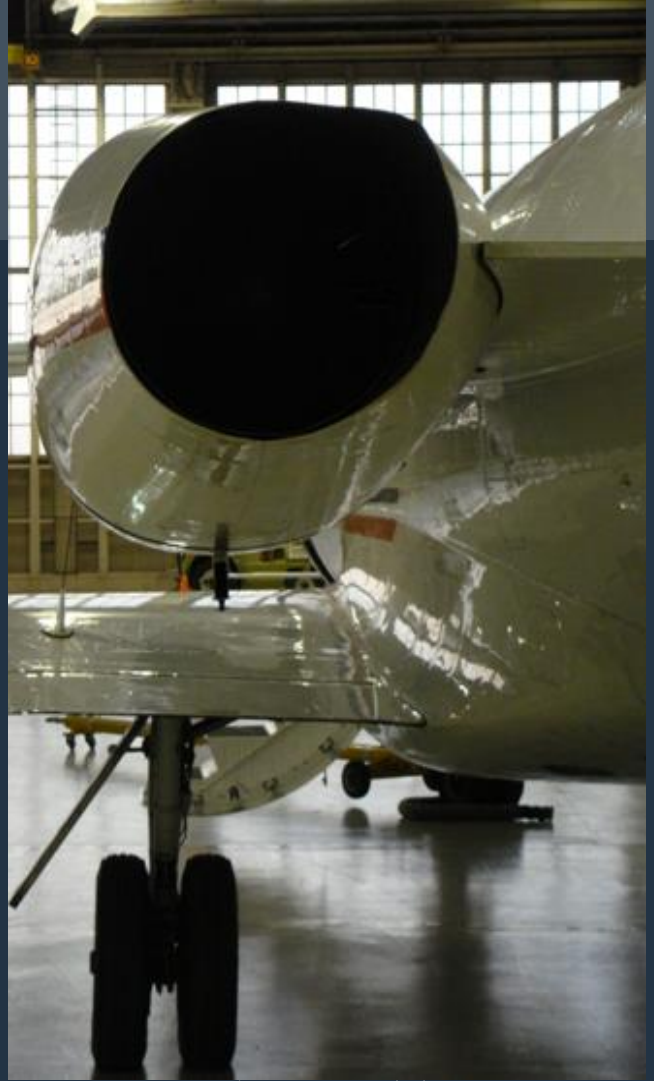
Test Aircraft: NRC Falcon 20 (C-FIGD):

- Dassault Aviation Falcon-20, DND-RCAF
- 2 x GE CF-700-2D2 Turbofans
- Hmax = 42k feet, Mmax = 0.88
- MG Experimentation: 1992 to present
- Payload: N experiments per flight,
  - t = 20 sec (g = 0) per parabola,
  - N = 30 to 40 parabolas per 1.5-hour flight

Test Aircraft: NRC CT-133 (CF-SKH):

- Canadair CT-133 Silver-Star fighter-trainer
- MG Experimentation: 1988 to 1992
- 1 x Rolls-Royce Nene 10 turbojet
- Hmax = 46k feet, Mmax = 0.86
- Payload: One experiment per flight,
- Performance:
  - t = 25 (g = 0) per parabola,
  - N = 12 to 16 parabolas per 2-hour flight.

MGFSSIM Development: Parabolic Flight Data Analytics



MGFSSIM: Discretization Gates

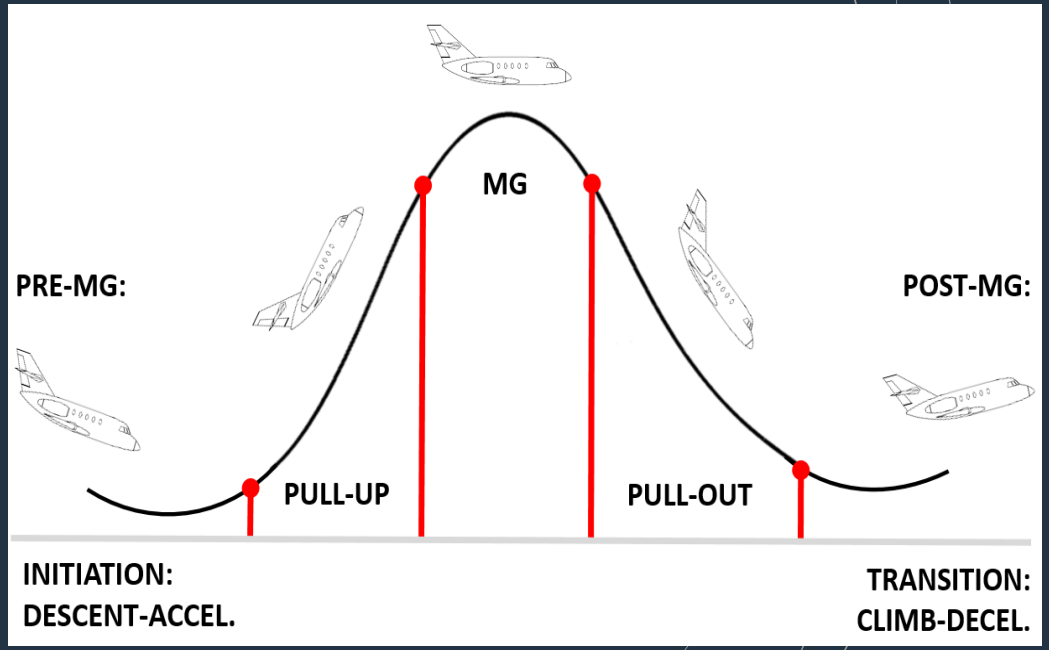
i. Pre-Microgravity:
SLF for t = 30 sec. preceding pull-up.

ii. Acceleration:
Pitch change (+40 deg to -40 deg) and user defined Az.

iii. Pull-Up:
Az exceeds a user defined threshold (pitch-up for parabola entry.)

iv. Pull-Out:
Az exceeds a user defined threshold (pitch-down for parabola exit.)

v. Deceleration:
Aircraft no longer pitched down; recovered t = 30 sec after pull-out.



MGFSSIM: Raw Data Correction

NRC FA-20 Raw Data File

Data Processing:

- Data Selection: INS States, Air Data, Controls, Propulsion, Time
- Controls: Calibrations
- Air Data: Simultaneous Calibration of Air Data Systems (SCADS), Pressure Error Correction (PEC)
- Propulsion: In-flight Propulsion System Identifications (IPSI)

(c. Elv, Ail, Flap, Rud, Stab)

↓

(c. ps, pd, alpha, beta, Mach)

↓

(Mach, EPR, Palt (c. Thrust))

↓

MGFSSIM: User Parameters

↓

MGFSSIM: Discretization

MGFSSIM: Raw Data Correction

MGFSSIM: Discretization → **MGFSSIM IN: User Parameters**

Data Processing:

- **User: Input Parameters**
- **Loop Closure (Discretization Gates): Search, Identification, Extraction, Sorting**
- **Results: Output Data**

Microgravity: Maximum Az limits

Maximum deviation: Mean Ax, Ay

Maximum roll angle excursion

Maximum heading angle excursion

Az (Start Pull-up, End Pull-Out)

↓

MGFSSIM OUT: MATLAB, EXCEL

Case Study:
NRC FA-20 Sample Sortie

Case Study: NRC FA-20 Sortie

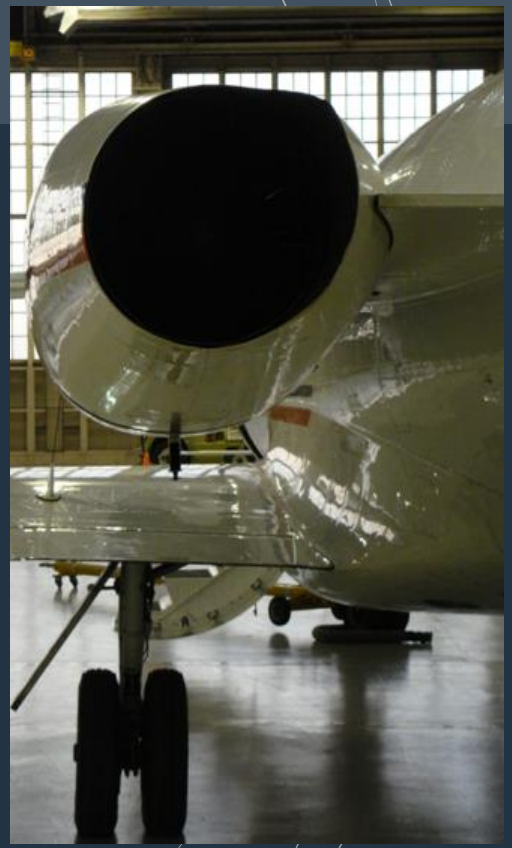
NRC FA-20 Microgravity Sortie (1990's) sample case study is selected consisting of:

a. Mission Duration: > 2 hours;

b. Microgravity Content: 23 Parabolas;

c. Engine Model: IPSI parameters from that era; and

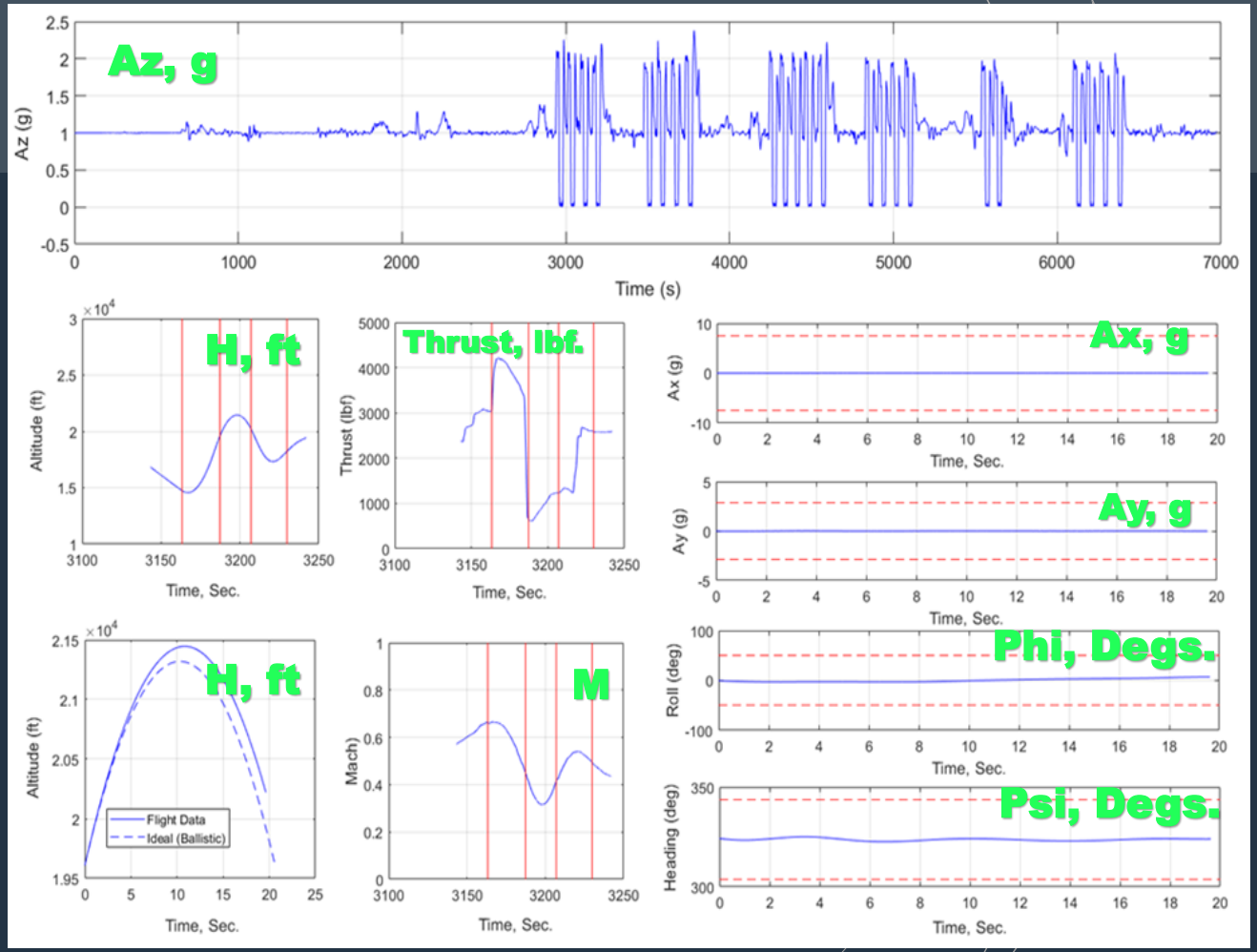
d. Air Data: PEC parameters from that era.



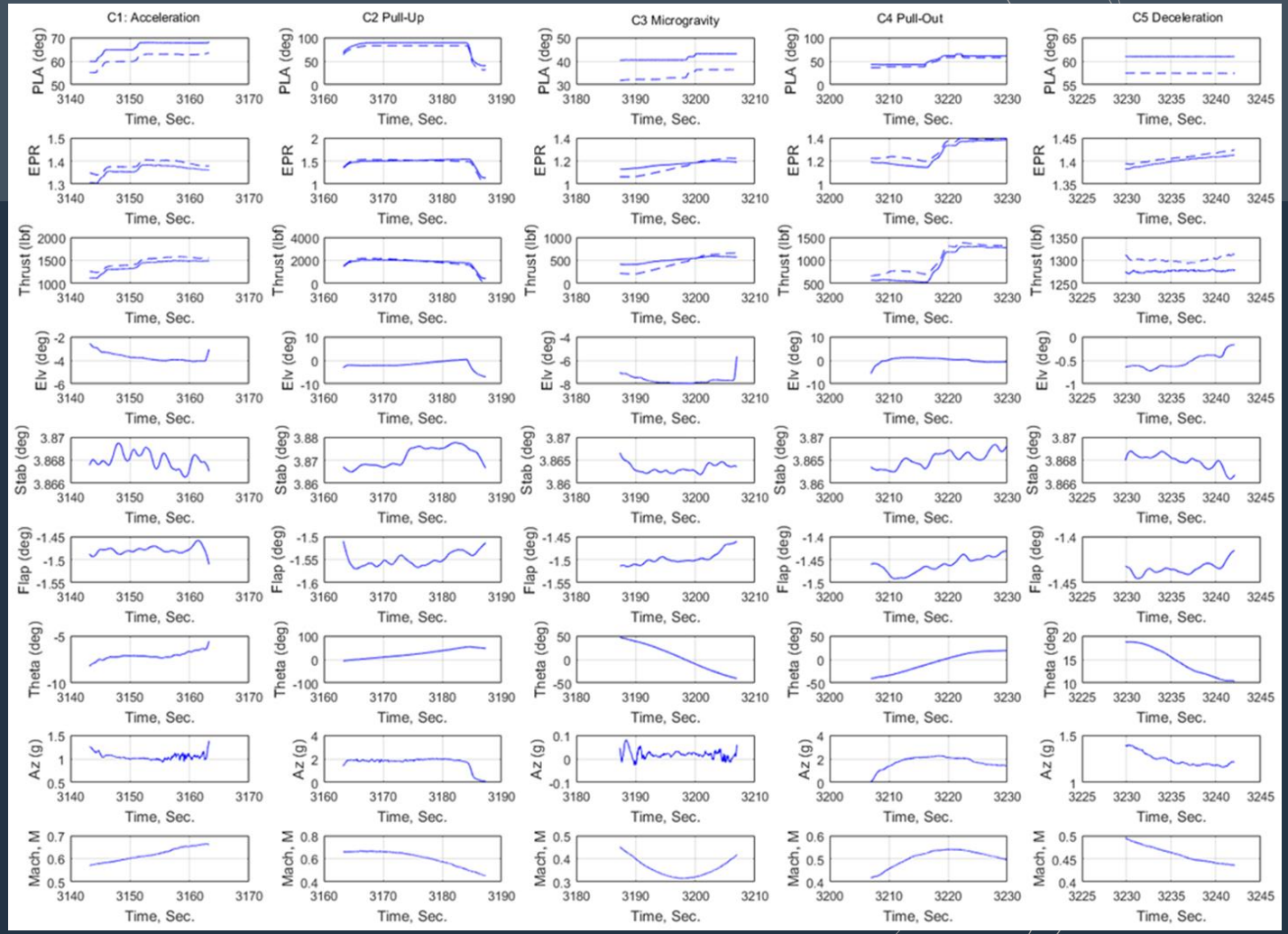
MGFSSIM: User Parameters

Input	Description	Value
Filename	Data Filename	N/A
Az tolerance in Microgravity Phase	Maximum ± g value expected. Variable used to define limits.	0.05
Tolerance (Az) (Pull-up start & Pull-Out end)	g-values (Pull-up start & Pull-Out end	1.4
Plotting method	Plots all parabolas (=2) Plots parabolas (microgravity Az = min/max (1)	1
Start-End Time	Time (sec.) period of analysis.	0 - 7000
Tolerance (Ax, Ay) %, Microgravity Phase	Variable defines max. deviation from mean Ax and Ay.	50000
Roll Tolerance deg, Microgravity Phase	Magnitude of max. Roll excursion from mean value.	50
Heading Tolerance deg, Microgravity Phase	Magnitude of the max. Heading excursion from the mean value	20

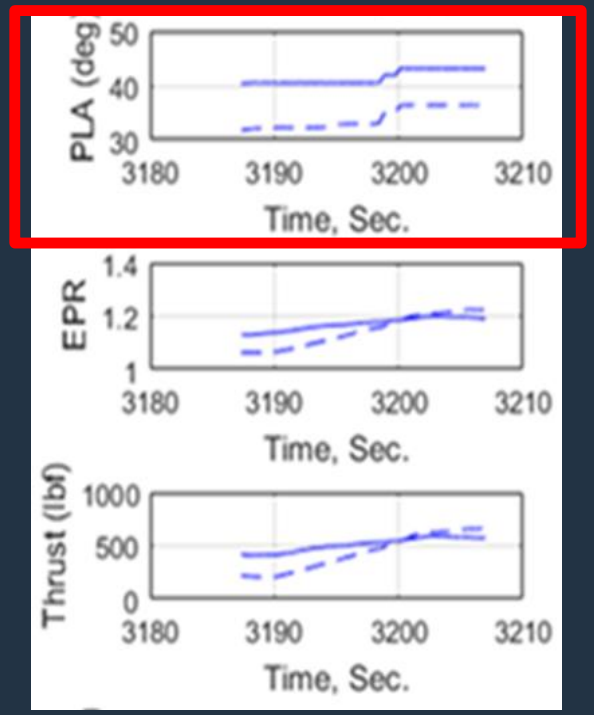
Run Verification:

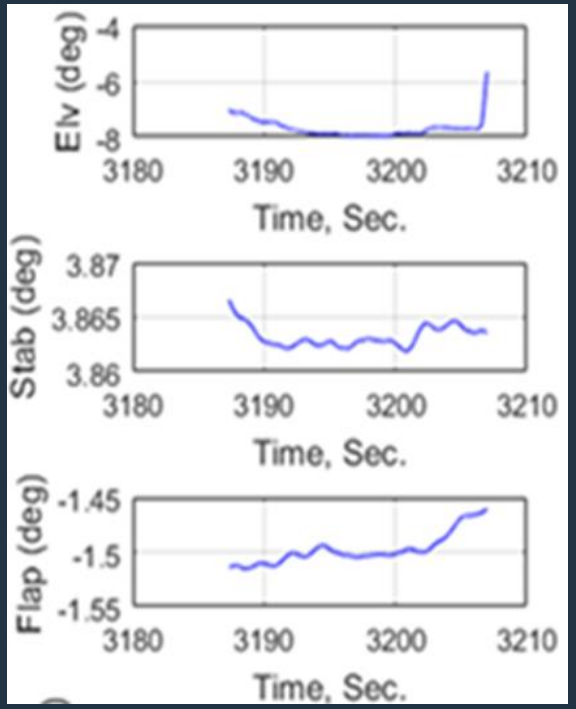


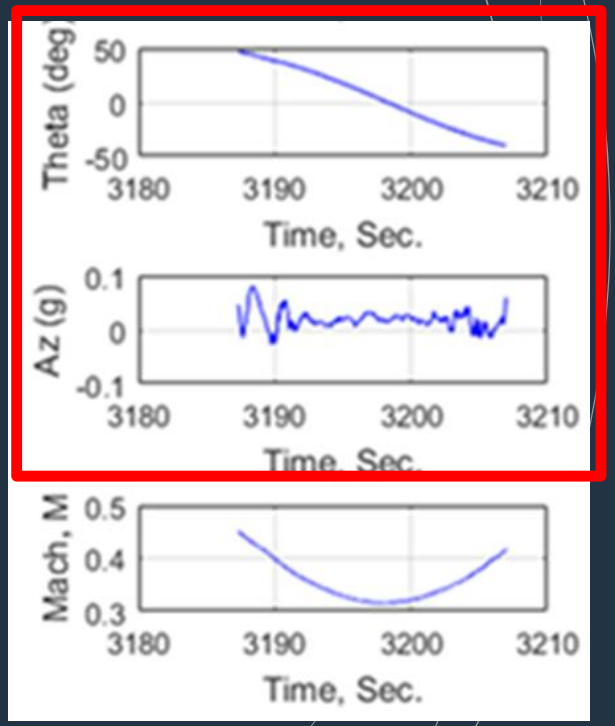
On-Axis Response:



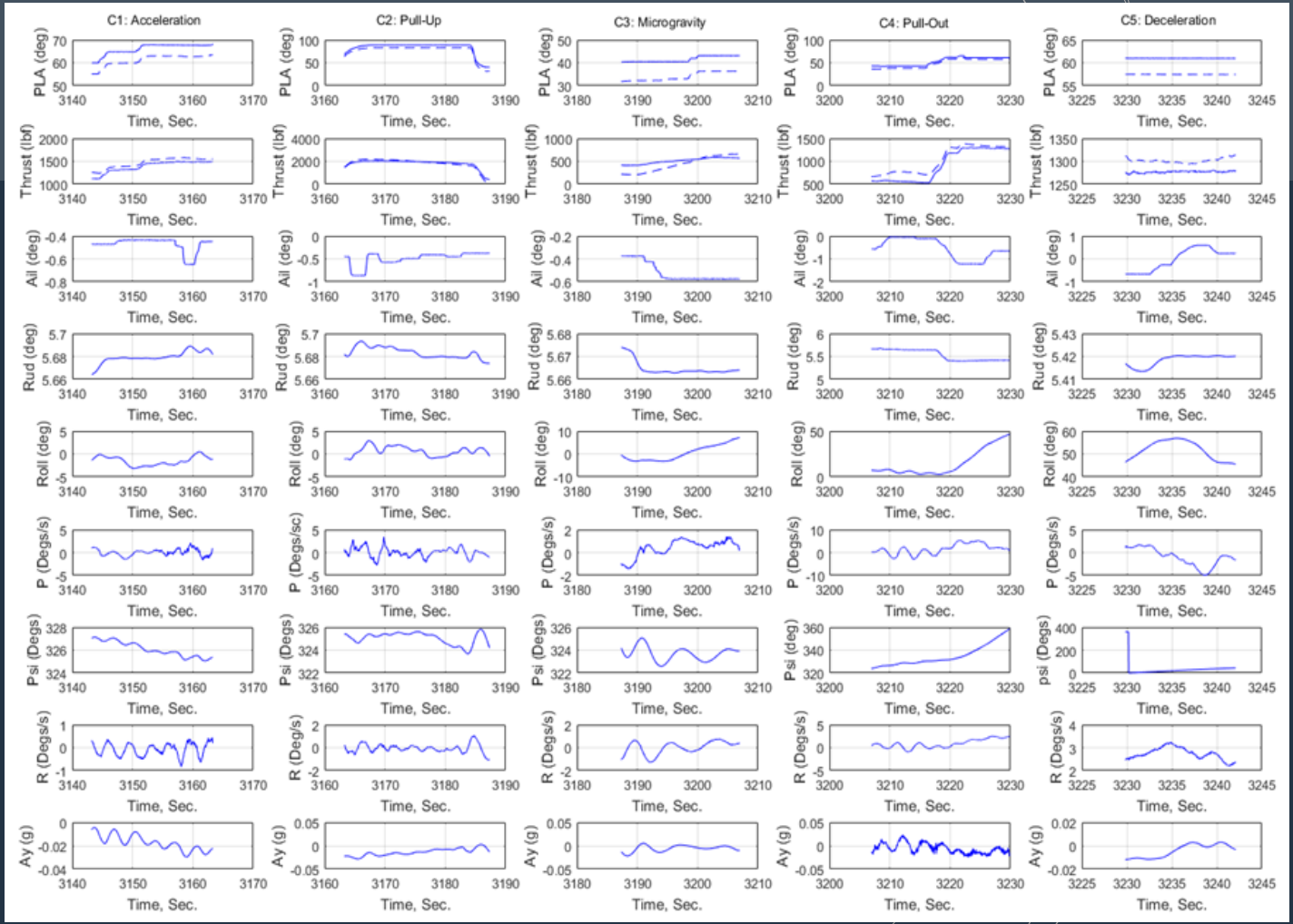
On-Axis Response: Microgravity Phase



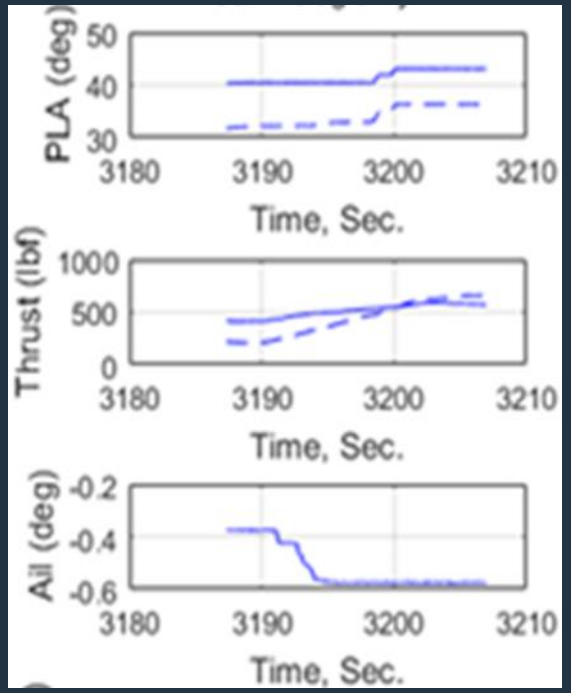


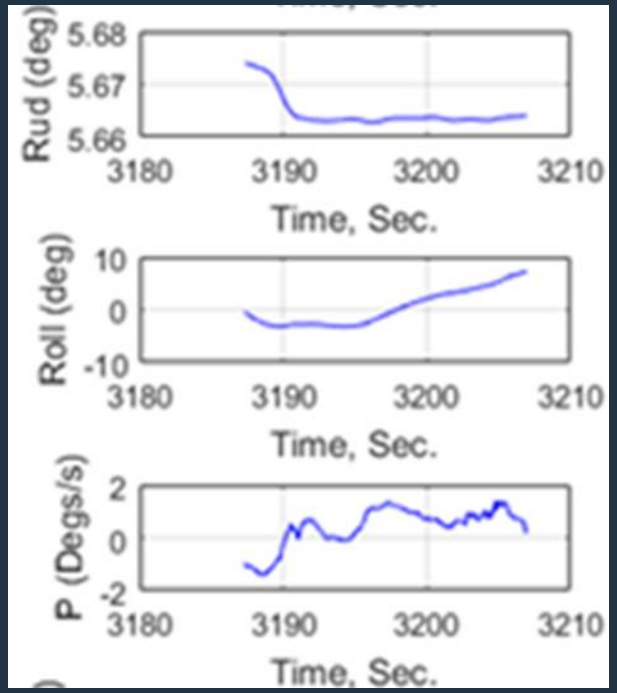


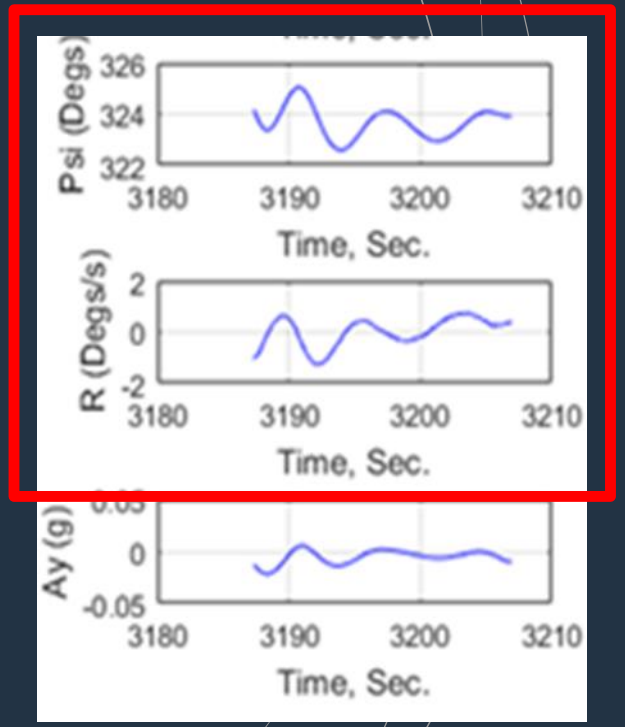
Off-Axis Response:



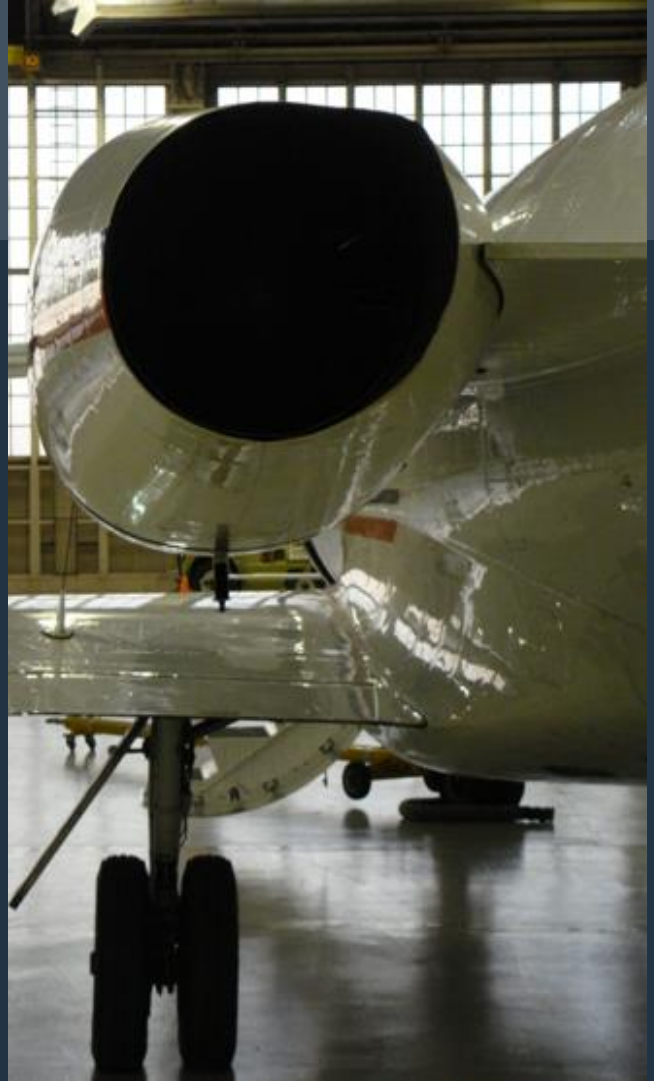
Off-Axis Response: Microgravity Phase



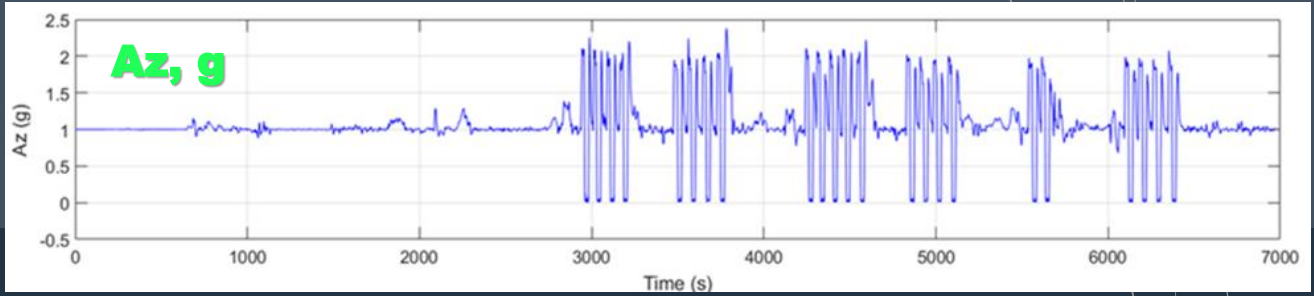




MGFSSIM: Sample Results

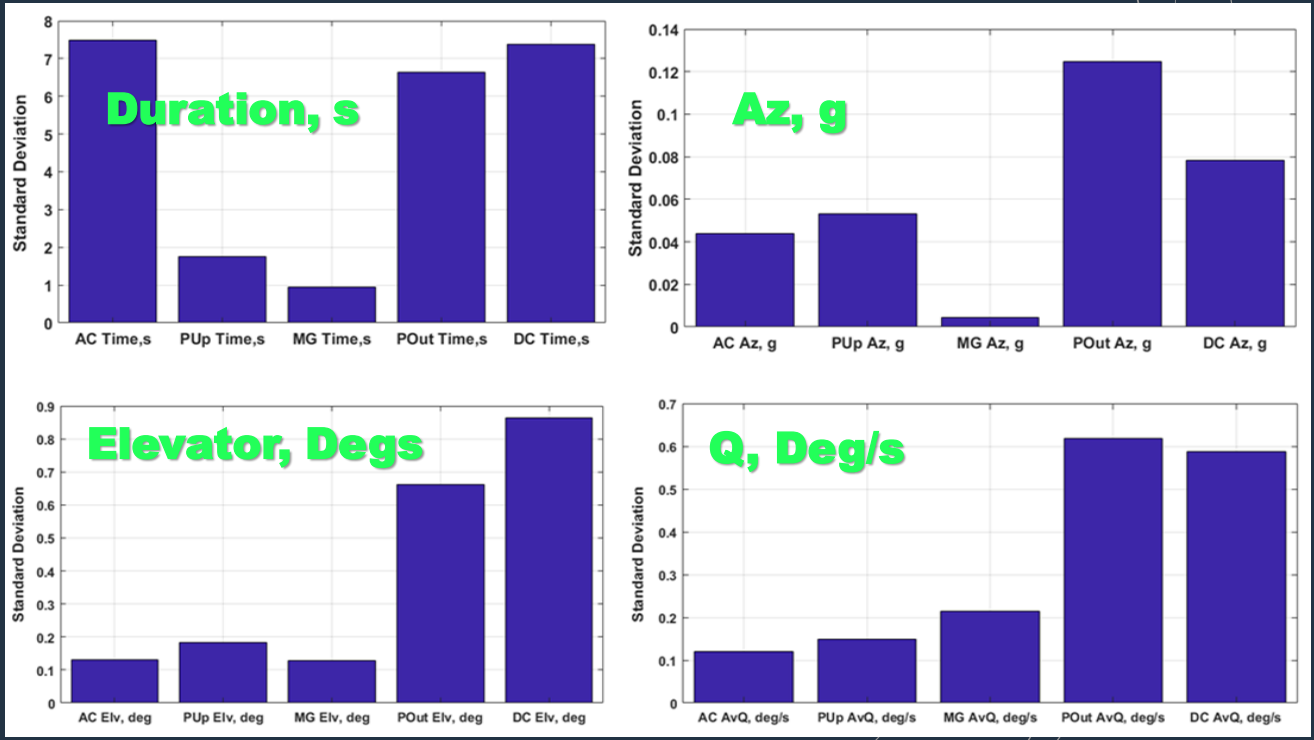


Influence of on-axis on microgravity quality:



Standard Deviation (23 Parabolas):

- Duration,
- Az,
- Elevator,
- Pitch Rate



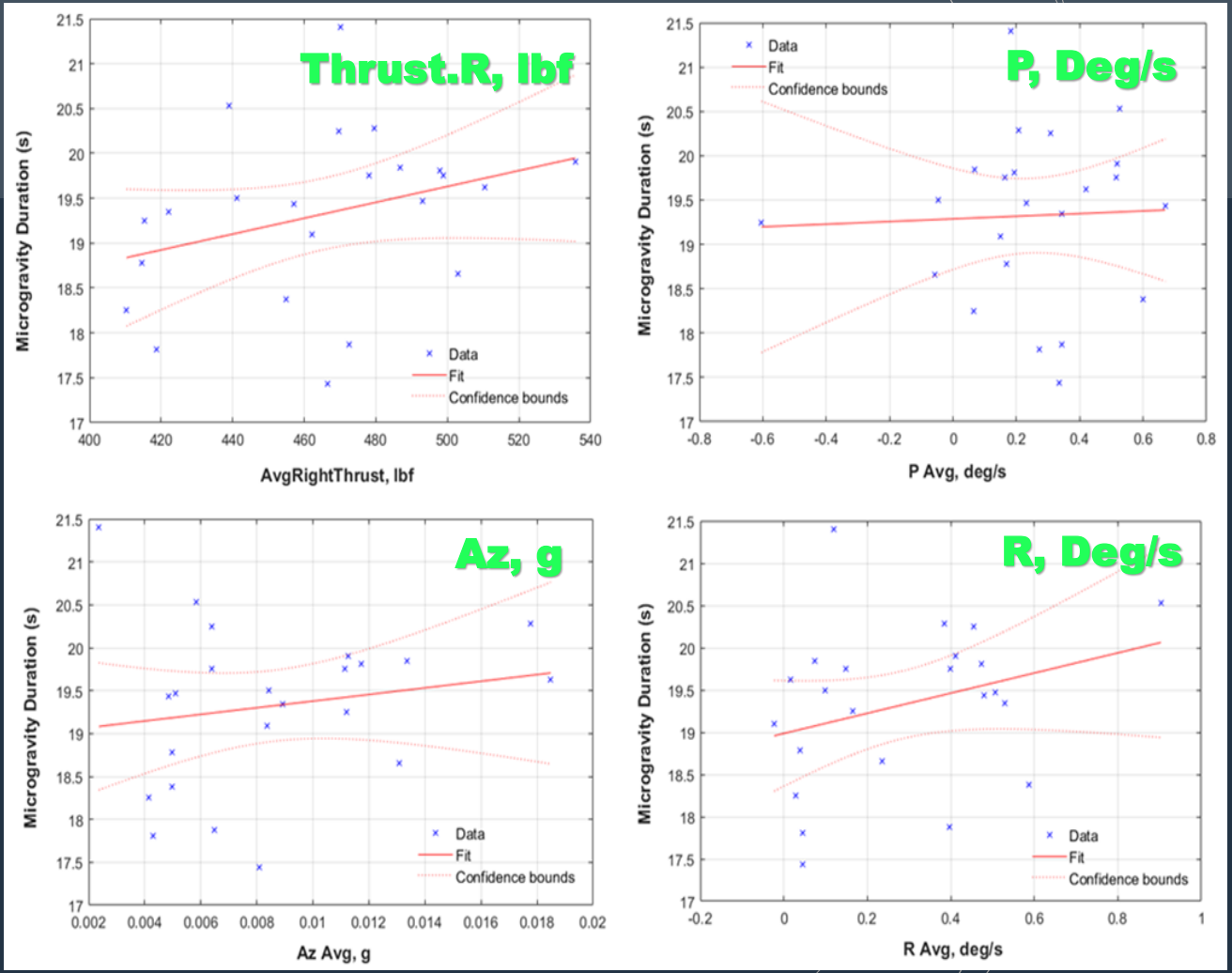
Influence of off-axis on microgravity phase durations:

Linear Regression (23 Parabolas):

1. Yaw Rate: Yaw Damper oscillation (Dutch Roll)

2. Right Engine Thrust. Roll, yaw, sideslip dynamics (i.e.; Dutch Roll,).

3. Roll Rate: Roll and Spiral mode dynamics.

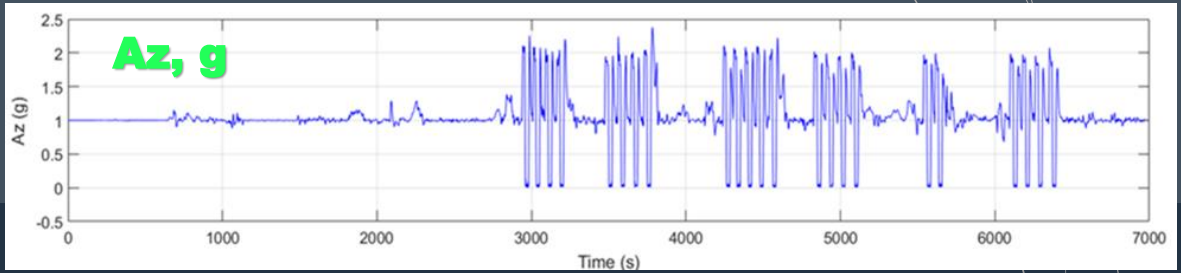


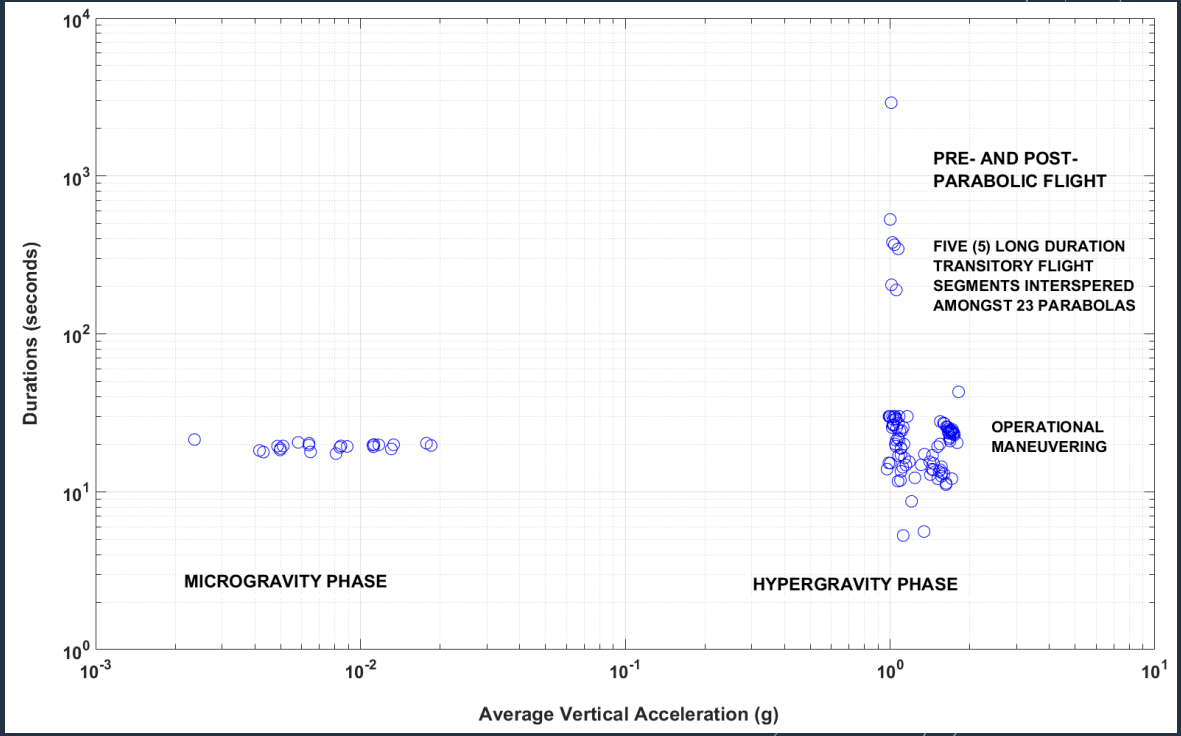
Phase Classification:

a. Mission Duration: > 2 hrs.

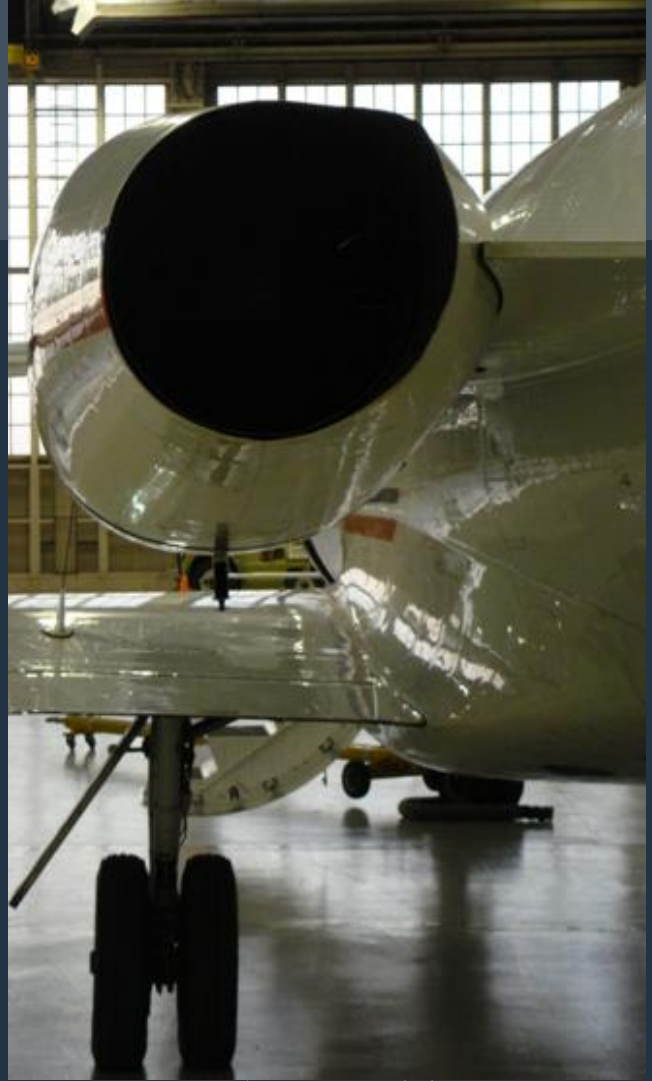
b. Microgravity Content:
   23 Parabolas

c. Hypergravity Content:
   - Pre-Parabolic
   - Operational Maneuvering
   - Transitory Flight
   - Post-Parabolic



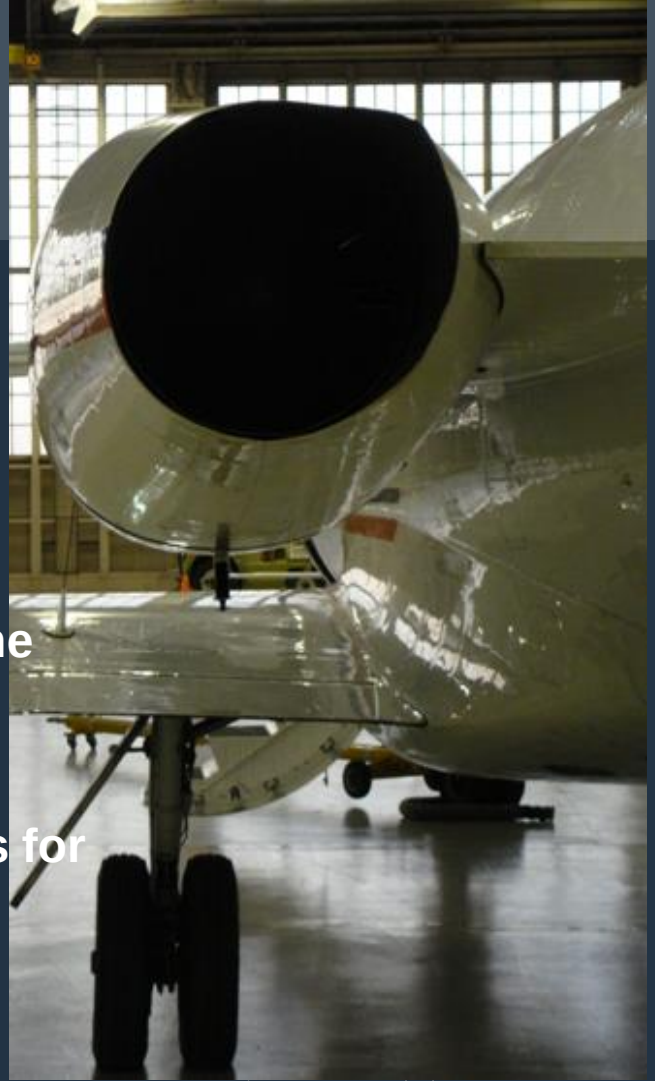


Conclusions and Closing Remarks



Conclusions

- MGFSSIM software enables user to analyze phases and parameters of parabolic flight missions,
- Facilitates a variety of analyses (such as Standard Deviation, Regression, Phase Classification) based on parabolic flight regime identification and discretization,
- Analytical areas may be performed in areas dynamics, control, propulsion, and operations for supporting research, mission execution, and aircraft life cycle management.



Questions?