Development of Microgravity Flight Sciences Regime Recognition Software

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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
- $H_{\text{max}} = 42k$ feet, $M_{\text{max}} = 0.88$
- MG Experimentation: 1992 to present
- Payload: N experiments per flight,
  - $t = 20 \text{ sec} (g = 0)$ 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

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)

NRC FA-20 Raw Data File ➔ (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

Data Processing:

User: Input Parameters

Loop Closure (Discretization Gates): Search, Identification, Extraction, Sorting

Results: Output Data

MGFSSIM IN: User Parameters

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

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

- $A_z, \ g$
- $H, \ ft$
- $\text{Thrust, lbf}$
- $A_x, \ g$
- $A_y, \ g$
- $\Phi, \ \text{Degs}$
- $\Psi, \ \text{Degs}$
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:


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?