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| --- |
| Team 2 |
| Simulation Experiment |
| AENG 411-37 Aerospace Laboratory |
|  |
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# Introduction

The Cooper Harper Rating Scale is used to evaluate a test aircraft's handling performance. It is a scale from 1 to 10 where 1 is the best and 10 is the worst.

Short Period motion usually lasts for only a few seconds. It is a rapid pitching about the center of gravity and since it is so short it can be considered an angle of attack change.

Phugoid motion or long period motion sees a significant change in airspeed, pitch angle, and altitude, but not angle of attack. Since the motion is so slow the pilot will usually correct for it before it's noticed.

Dutch roll combines roll and yaw motion. It is described as a yaw/roll to the right, then a recovery towards equilibrium. A row/yaw to the left then occurs, which then goes towards equilibrium. The motion will continue until it either settles or the pilot corrects for it.

# Design of Test

## Objective

Use the flight-simulator to analyze the performance of the Kingair aircraft.

## Test Apparatus and Function

* AE flight-simulator
* X-Plane 10

# Test Procedure

1. The Windows Operating System version of X-Plane 10 was loaded in the AE department flight simulator.
2. X-Plane was set up to record flight data to an external text file.
3. The Kingair aircraft was selected and loaded.
4. The Kingair was flown to 5,000 feet and trimmed.
5. The three dynamic maneuvers were executed. Time data for each maneuver was recorded.

# Test Results

See the Graphs appendix for all data plots.

See the Tables appendix for data. Note that the Phugoid data table was excluded because it was over 2000 lines long.

Table 1: Short Period Period, Damping Ratio, and Cooper Harper Scale

|  |  |  |
| --- | --- | --- |
| **Oscillatory Period** | 2.5 | seconds |
| **d** | 1.844447 |  |
| **Damping Ratio** | 0.293553 |  |
| **Cooper Harper Scale** | 2 | Good, negligible deficiencies |

Table 2: Phugoid Period, Damping Ratio, and Cooper Harper Scale

|  |  |  |
| --- | --- | --- |
| **Oscillatory Period** | 50 | seconds |
| **d** | 1.014074 |  |
| **Damping Ratio** | 0.161395 |  |
| **Cooper Harper Scale** | 2 | Good, negligible deficiencies |

Table 3: Dutch Roll Period, Damping Ratio, and Cooper Harper Scale

|  |  |  |
| --- | --- | --- |
| **Oscillatory Period** | 3 | seconds |
| **d** | 1.304993 |  |
| **Damping Ratio** | 0.207696 |  |
| **Cooper Harper Scale** | 2 | Good, negligible deficiencies |

# Discussion of Results

The KingAir is a small passenger aircraft, thus longitudinal static stability and dynamic stability are highly desirable traits. To determine how stable the KingAir is, several maneuvers were performed and the data was recorded.

The Short Period graphs (Figures 2, 3, and 4) show that the plane rapidly returns to equilibrium after being disturbed from trimmed level flight.

The Phugoid or long period oscillation graphs (Figures 5, 6, and 7) show that the plane takes a significant amount of time to return to equilibrium, but has relatively small amplitude compared to the other maneuvers.

The Dutch Roll plots (Figures 8, 9, and 10) show that when the plane is rolled it tends to return to equilibrium rather quickly, with only a few significant oscillations

For a passenger aircraft, the KingAir scored a 2 in all three categories on the Cooper Harper Scale based on its remarkably stable behavior when encountering upsets in flight.

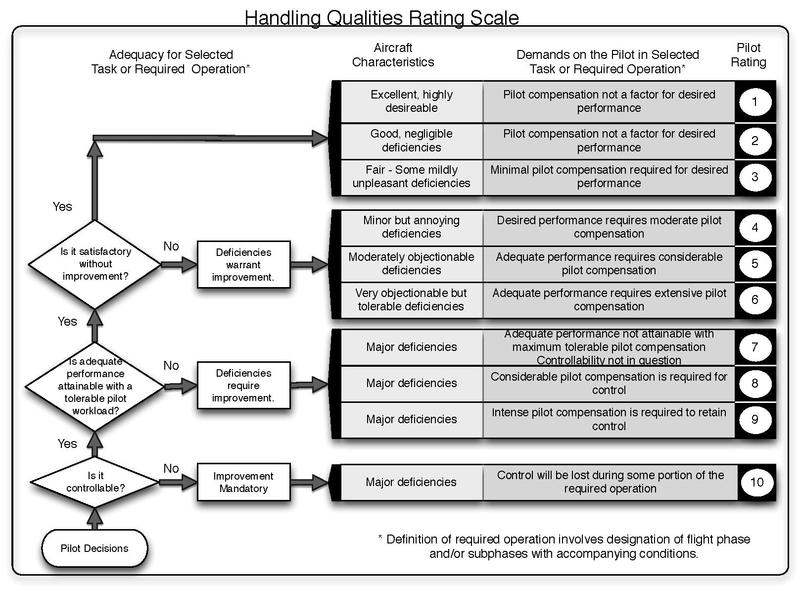


Figure 1: Cooper Harper Scale

# Conclusion

The experiment was successful in determining that the KingAir aircraft is statically and dynamically stable. When instabilities are introduced by rapid commands from the control column, in all three maneuver cases (Short Period, Phugoid, and Dutch Roll), the amplitude of the resulting oscillations decreased rapidly with time as evidenced by the plots located in the appendix.

For the Short Period, the damping ratio was determined to be 0.2935. The Phugoid damping ratio was 0.1614. The Dutch Roll damping ratio was 0.2077. All three are underdamped.

Because of the KingAir’s tendency to return to equilibrium despite the upsets, it rated a 2 on the Cooper Harper Scale.

# Appendices

## Graphs

### Short Period

Figure 2

Figure 3

Figure 4

### Phugoid

Figure 5

Figure 6

Figure 7

### Dutch Roll

Figure 8

Figure 9

Figure 10

## Tables

Table 4: Short Period Data

|  |  |  |  |
| --- | --- | --- | --- |
| **Total Time** | **Pitch Angle (degrees)** | **Angle of Attack (degrees)** | **Vertical Load Factor** |
| 345.04657 | 0.013 | -0.78636 | 1.01736 |
| 345.1427 | 0.02169 | -0.78562 | 1.01288 |
| 345.24768 | 0.06799 | -0.73634 | 0.97046 |
| 345.34235 | 0.30159 | -0.48743 | 0.98442 |
| 345.43762 | 0.92194 | 0.09916 | 1.1666 |
| 345.54367 | 2.14897 | 1.09901 | 1.66173 |
| 345.64291 | 3.63785 | 2.12173 | 2.16708 |
| 345.73972 | 5.21887 | 3.01713 | 2.61104 |
| 345.83542 | 6.76394 | 3.69858 | 2.9574 |
| 345.93088 | 8.11348 | 4.03363 | 3.2275 |
| 346.02582 | 9.00039 | 3.84849 | 3.23635 |
| 346.12195 | 9.2726 | 3.10971 | 2.93996 |
| 346.2189 | 8.93847 | 1.97113 | 2.40089 |
| 346.29205 | 8.37327 | 0.98342 | 1.94646 |
| 346.41589 | 6.93382 | -0.79291 | 1.16564 |
| 346.51569 | 5.45076 | -2.18262 | 0.50837 |
| 346.61584 | 3.8532 | -3.36781 | -0.07454 |
| 346.7157 | 2.33463 | -4.22658 | -0.48927 |
| 346.82187 | 0.93735 | -4.74294 | -0.76034 |
| 346.92648 | -0.09793 | -4.81483 | -0.85801 |
| 347.03116 | -0.64723 | -4.40905 | -0.7461 |
| 347.12726 | -0.62291 | -3.61422 | -0.43471 |
| 347.22357 | -0.10861 | -2.53742 | 0.08596 |
| 347.32156 | 0.69826 | -1.44165 | 0.66703 |
| 347.42136 | 1.51128 | -0.59146 | 1.09898 |
| 347.52042 | 2.15715 | -0.06487 | 1.32745 |
| 347.62097 | 2.64793 | 0.2217 | 1.45112 |
| 347.72171 | 2.97364 | 0.29879 | 1.50552 |
| 347.81998 | 3.10229 | 0.18365 | 1.46172 |
| 347.91559 | 3.06094 | -0.05171 | 1.34285 |
| 348.00775 | 2.9207 | -0.31856 | 1.21476 |
| 348.11139 | 2.70654 | -0.60483 | 1.07472 |
| 348.21115 | 2.48613 | -0.83255 | 0.964 |
| 348.31107 | 2.28615 | -0.99275 | 0.88597 |
| 348.40878 | 2.13141 | -1.07962 | 0.84345 |
| 348.51315 | 2.0196 | -1.10485 | 0.83053 |
| 348.6073 | 1.96472 | -1.0819 | 0.84037 |
| 348.70297 | 1.94664 | -1.02964 | 0.86487 |
| 348.80237 | 1.95665 | -0.96122 | 0.89754 |
| 348.90604 | 1.98475 | -0.88968 | 0.93078 |
| 349.00964 | 2.01801 | -0.82949 | 0.95955 |
| 349.10583 | 2.04487 | -0.78921 | 0.97921 |
| 349.20404 | 2.06267 | -0.76506 | 0.99003 |
| 349.29959 | 2.06876 | -0.75629 | 0.99449 |
| 349.40497 | 2.0624 | -0.76007 | 0.99238 |
| 349.5097 | 2.0445 | -0.77293 | 0.98537 |
| 349.61356 | 2.01864 | -0.78971 | 0.97753 |
| 349.71057 | 1.99026 | -0.80552 | 0.96965 |
| 349.80612 | 1.96089 | -0.81894 | 0.96237 |
| 349.9133 | 1.92913 | -0.82946 | 0.95745 |
| 350.00803 | 1.90307 | -0.83485 | 0.95402 |
| 350.1048 | 1.87871 | -0.83723 | 0.95311 |
| 350.20654 | 1.8554 | -0.83696 | 0.95237 |
| 350.30719 | 1.83442 | -0.83492 | 0.95355 |
| 350.40445 | 1.81588 | -0.83156 | 0.95487 |
| 350.50974 | 1.79673 | -0.82793 | 0.95577 |
| 350.61371 | 1.77802 | -0.82473 | 0.95651 |
| 350.7106 | 1.76065 | -0.82225 | 0.95795 |
| 350.81625 | 1.74082 | -0.82075 | 0.95841 |
| 350.92117 | 1.72002 | -0.82043 | 0.9583 |

Table 5: Dutch Roll

|  |  |  |  |
| --- | --- | --- | --- |
| **Total Time** | **Angle of Sideslip (degrees)** | **Bank Angle (degrees)** | **Heading Angle (degrees)** |
| 685.08612 | -0.02173 | 0.00936 | 318.50214 |
| 685.17737 | -0.02661 | 0.03036 | 318.4971 |
| 685.2782 | -0.03034 | 0.05074 | 318.49332 |
| 685.375 | -0.03217 | 0.06766 | 318.49158 |
| 685.47278 | -0.03232 | 0.08325 | 318.4917 |
| 685.5686 | -0.03083 | 0.09635 | 318.49365 |
| 685.66486 | -0.02797 | 0.10826 | 318.49716 |
| 685.76147 | -0.0241 | 0.12013 | 318.50198 |
| 685.8573 | -0.01952 | 0.13291 | 318.50778 |
| 685.95618 | -0.01442 | 0.14695 | 318.5144 |
| 686.05298 | -0.00942 | 0.16226 | 318.52121 |
| 686.15131 | -0.00492 | 0.17918 | 318.52786 |
| 686.24823 | -0.00154 | 0.19766 | 318.53369 |
| 686.34485 | 0.00068 | 0.21759 | 318.53854 |
| 686.4422 | 0.0016 | 0.23878 | 318.54236 |
| 686.54114 | 0.00131 | 0.26117 | 318.5451 |
| 686.64026 | -0.0002 | 0.28412 | 318.54681 |
| 686.73767 | -0.00267 | 0.30645 | 318.54761 |
| 686.83478 | -0.00587 | 0.32809 | 318.54776 |
| 686.93201 | -0.00959 | 0.349 | 318.54745 |
| 687.02966 | -0.01358 | 0.36918 | 318.54694 |
| 687.12799 | -0.01758 | 0.38868 | 318.54648 |
| 687.23303 | -0.02152 | 0.40719 | 318.54636 |
| 687.32886 | -0.02462 | 0.42275 | 318.54675 |
| 687.4267 | -0.02705 | 0.43658 | 318.54797 |
| 687.5238 | -0.02798 | 0.44853 | 318.5506 |
| 687.62152 | -0.02516 | 0.45789 | 318.55643 |
| 687.71747 | -0.00021 | 0.46097 | 318.57956 |
| 687.81567 | 0.09981 | 0.44732 | 318.66931 |
| 687.91693 | 0.30995 | 0.42273 | 318.86978 |
| 688.02466 | 0.66324 | 0.41246 | 319.21719 |
| 688.12128 | 1.12257 | 0.44298 | 319.67535 |
| 688.21667 | 1.69865 | 0.55159 | 320.26743 |
| 688.31262 | 2.35516 | 0.7934 | 320.96289 |
| 688.4082 | 3.03962 | 1.21428 | 321.71149 |
| 688.50586 | 3.72126 | 1.86952 | 322.48615 |
| 688.60303 | 4.33102 | 2.7716 | 323.21652 |
| 688.70831 | 4.87017 | 4.03983 | 323.91467 |
| 688.80481 | 5.20802 | 5.45783 | 324.42499 |
| 688.90253 | 5.33629 | 7.12723 | 324.75305 |
| 689.00604 | 5.18688 | 9.10889 | 324.83258 |
| 689.10699 | 4.74075 | 11.18238 | 324.61514 |
| 689.20624 | 4.02877 | 13.26061 | 324.12085 |
| 689.30615 | 3.07436 | 15.28838 | 323.37222 |
| 689.40613 | 1.91587 | 17.15055 | 322.40594 |
| 689.50677 | 0.5881 | 18.75764 | 321.25778 |
| 689.60602 | -0.82218 | 19.98685 | 320.01276 |
| 689.70514 | -2.27541 | 20.78772 | 318.7149 |
| 689.80328 | -3.68617 | 21.09845 | 317.44348 |
| 689.90277 | -5.00129 | 20.87976 | 316.24475 |
| 690.00574 | -6.16379 | 20.07331 | 315.16724 |
| 690.10699 | -7.05119 | 18.72603 | 314.31546 |
| 690.2088 | -7.63772 | 16.86803 | 313.70499 |
| 690.3067 | -7.85805 | 14.66791 | 313.39716 |
| 690.40509 | -7.69916 | 12.13432 | 313.41461 |
| 690.50555 | -7.14721 | 9.33205 | 313.79282 |
| 690.6051 | -6.2487 | 6.46683 | 314.51956 |
| 690.70422 | -5.07003 | 3.67248 | 315.55576 |
| 690.80292 | -3.6834 | 1.07182 | 316.84705 |
| 690.90039 | -2.19471 | -1.19926 | 318.29721 |
| 691.00012 | -0.66486 | -3.10551 | 319.84143 |
| 691.09906 | 0.76308 | -4.50697 | 321.32013 |
| 691.19415 | 1.98575 | -5.35697 | 322.60852 |
| 691.29614 | 3.07689 | -5.72548 | 323.77966 |
| 691.39655 | 3.87445 | -5.5599 | 324.66266 |
| 691.49902 | 4.3702 | -4.90376 | 325.25266 |
| 691.59772 | 4.53722 | -3.88686 | 325.51904 |
| 691.69708 | 4.40906 | -2.57894 | 325.49954 |
| 691.79736 | 4.00825 | -1.07446 | 325.21252 |
| 691.896 | 3.39414 | 0.47658 | 324.70563 |
| 691.99603 | 2.60538 | 2.01739 | 324.01074 |
| 692.09497 | 1.72315 | 3.41668 | 323.19876 |
| 692.19366 | 0.8051 | 4.61093 | 322.3244 |
| 692.2915 | -0.08562 | 5.54086 | 321.45172 |
| 692.39032 | -0.91255 | 6.18492 | 320.62146 |
| 692.48865 | -1.6219 | 6.51622 | 319.89282 |
| 692.58685 | -2.1839 | 6.54097 | 319.30099 |
| 692.68555 | -2.57829 | 6.27853 | 318.87015 |
| 692.784 | -2.79127 | 5.7662 | 318.61707 |
| 692.88269 | -2.82441 | 5.05028 | 318.54214 |
| 692.98285 | -2.68495 | 4.17515 | 318.63968 |
| 693.08319 | -2.39195 | 3.21122 | 318.89389 |
| 693.18353 | -1.97591 | 2.2271 | 319.27737 |
| 693.28326 | -1.47526 | 1.28855 | 319.75482 |
| 693.38263 | -0.92722 | 0.44635 | 320.29092 |
| 693.47333 | -0.41457 | -0.20532 | 320.80334 |
| 693.57794 | 0.1556 | -0.78504 | 321.38574 |
| 693.68054 | 0.66011 | -1.15462 | 321.91412 |
| 693.78113 | 1.07473 | -1.31782 | 322.36191 |
| 693.88062 | 1.38812 | -1.28997 | 322.71542 |
| 693.98004 | 1.59301 | -1.09062 | 322.96579 |
| 694.08124 | 1.68607 | -0.7375 | 323.10843 |
| 694.18115 | 1.66677 | -0.27367 | 323.13922 |
| 694.28052 | 1.54692 | 0.26506 | 323.06833 |
| 694.37891 | 1.34399 | 0.83518 | 322.91083 |
| 694.47839 | 1.07176 | 1.41187 | 322.67963 |
| 694.58051 | 0.74446 | 1.96715 | 322.3877 |
| 694.68103 | 0.39864 | 2.44638 | 322.069 |
| 694.78436 | 0.04276 | 2.84218 | 321.73273 |
| 694.88611 | -0.28594 | 3.11824 | 321.41541 |
| 694.98547 | -0.56847 | 3.27088 | 321.1373 |
| 695.08606 | -0.80115 | 3.30516 | 320.90347 |
| 695.18549 | -0.96861 | 3.2261 | 320.73062 |
| 695.28534 | -1.06884 | 3.04599 | 320.6221 |
| 695.38501 | -1.10014 | 2.78279 | 320.58105 |
| 695.48627 | -1.06478 | 2.45201 | 320.60638 |
| 695.59113 | -0.96441 | 2.06703 | 320.69757 |
| 695.69287 | -0.81618 | 1.67806 | 320.83926 |
| 695.79626 | -0.62761 | 1.29254 | 321.02466 |
| 695.89966 | -0.41521 | 0.93835 | 321.23804 |
| 695.99976 | -0.20191 | 0.64415 | 321.45673 |

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