

UH-60

Real-Time Flight Simulation Data

Zielonka 2019

Copyright © 2019 Merak M. Cel. All rights reserved.

Author: Marek M. Cel

Revision: 4

Date: 2019-09-08

This work is licensed under a

Creative Commons CC0 1.0 Universal Public Domain Dedication

Statement of Purpose

The laws of most jurisdictions throughout the world automatically confer exclusive Copyright and Related Rights (defined below) upon the creator and subsequent owner(s) (each and all, an "owner") of an original work of authorship and/or a database (each, a "Work").

Certain owners wish to permanently relinquish those rights to a Work for the purpose of contributing to a commons of creative, cultural and scientific works ("Commons") that the public can reliably and without fear of later claims of infringement build upon, modify, incorporate in other works, reuse and redistribute as freely as possible in any form whatsoever and for any purposes, including without limitation commercial purposes. These owners may contribute to the Commons to promote the ideal of a free culture and the further production of creative, cultural and scientific works, or to gain reputation or greater distribution for their Work in part through the use and efforts of others.

For these and/or other purposes and motivations, and without any expectation of additional consideration or compensation, the person associating CC0 with a Work (the "Affirmer"), to the extent that he or she is an owner of Copyright and Related Rights in the Work, voluntarily elects to apply CC0 to the Work and publicly distribute the Work under its terms, with knowledge of his or her Copyright and Related Rights in the Work and the meaning and intended legal effect of CC0 on those rights.

1. Copyright and Related Rights. A Work made available under CC0 may be protected by copyright and related or neighboring rights ("Copyright and Related Rights"). Copyright and Related Rights include, but are not limited to, the following:

- i. the right to reproduce, adapt, distribute, perform, display, communicate, and translate a Work;
- ii. moral rights retained by the original author(s) and/or performer(s);
- iii. publicity and privacy rights pertaining to a person's image or likeness depicted in a Work;
- iv. rights protecting against unfair competition in regards to a Work, subject to the limitations in paragraph 4(a), below;

- v. rights protecting the extraction, dissemination, use and reuse of data in a Work;
- vi. database rights (such as those arising under Directive 96/9/EC of the European Parliament and of the Council of 11 March 1996 on the legal protection of databases, and under any national implementation thereof, including any amended or successor version of such directive); and
- vii. other similar, equivalent or corresponding rights throughout the world based on applicable law or treaty, and any national implementations thereof.

2. Waiver. To the greatest extent permitted by, but not in contravention of, applicable law, Affirmer hereby overtly, fully, permanently, irrevocably and unconditionally waives, abandons, and surrenders all of Affirmer's Copyright and Related Rights and associated claims and causes of action, whether now known or unknown (including existing as well as future claims and causes of action), in the Work (i) in all territories worldwide, (ii) for the maximum duration provided by applicable law or treaty (including future time extensions), (iii) in any current or future medium and for any number of copies, and (iv) for any purpose whatsoever, including without limitation commercial, advertising or promotional purposes (the "Waiver"). Affirmer makes the Waiver for the benefit of each member of the public at large and to the detriment of Affirmer's heirs and successors, fully intending that such Waiver shall not be subject to revocation, rescission, cancellation, termination, or any other legal or equitable action to disrupt the quiet enjoyment of the Work by the public as contemplated by Affirmer's express Statement of Purpose.

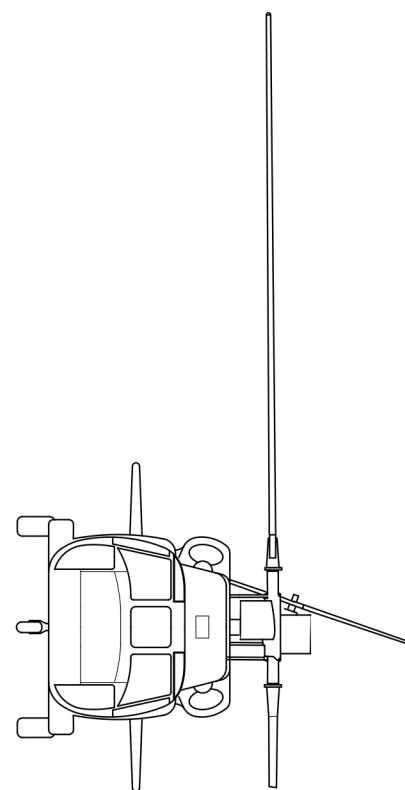
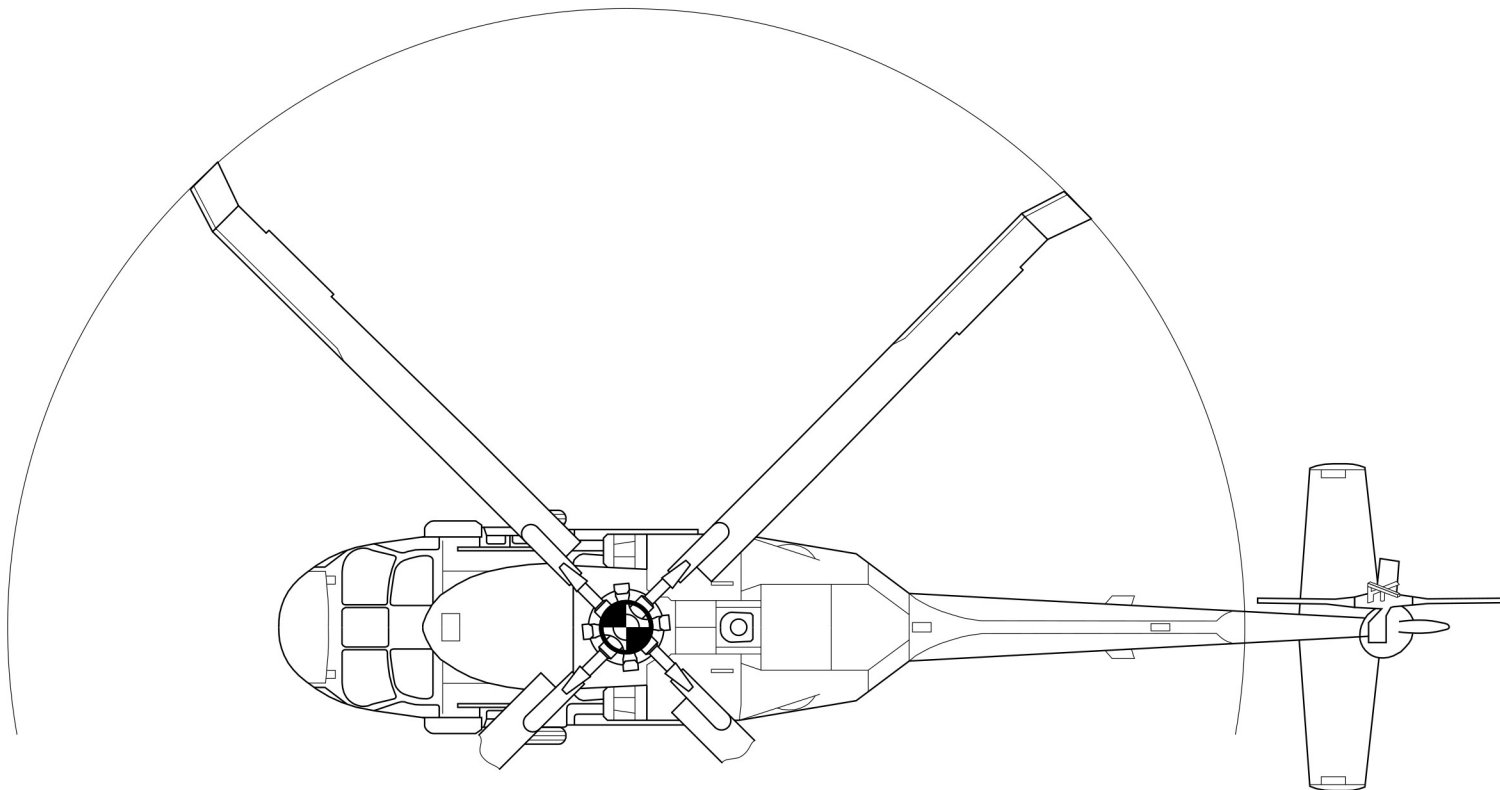
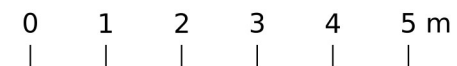
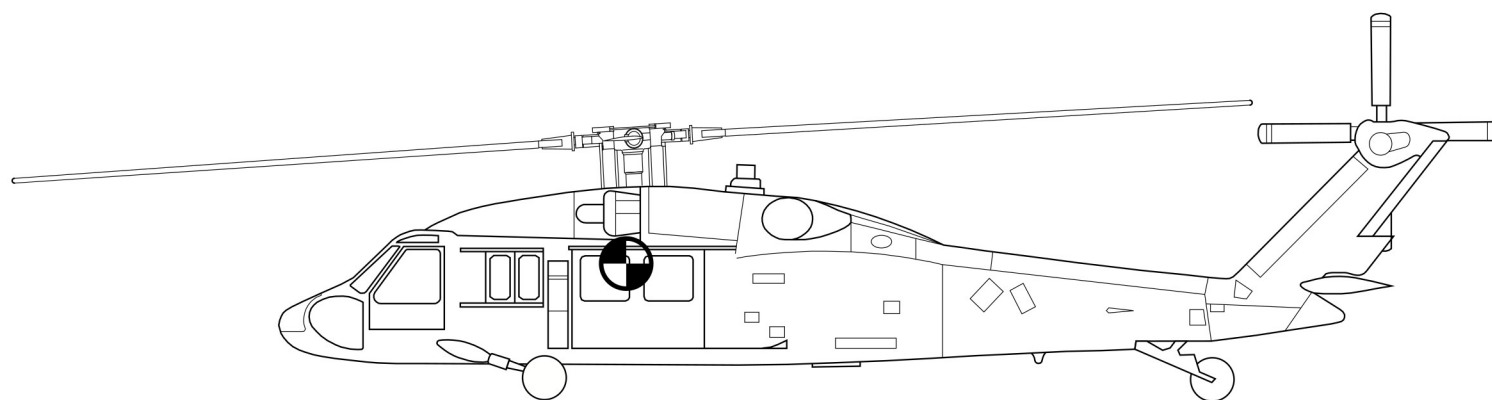
3. Public License Fallback. Should any part of the Waiver for any reason be judged legally invalid or ineffective under applicable law, then the Waiver shall be preserved to the maximum extent permitted taking into account Affirmer's express Statement of Purpose. In addition, to the extent the Waiver is so judged Affirmer hereby grants to each affected person a royalty-free, non transferable, non sublicensable, non exclusive, irrevocable and unconditional license to exercise Affirmer's Copyright and Related Rights in the Work (i) in all territories worldwide, (ii) for the maximum duration provided by applicable law or treaty (including future time extensions), (iii) in any current or future medium and for any number of copies, and (iv) for any purpose whatsoever, including without limitation commercial, advertising or promotional purposes (the "License"). The License shall be deemed effective as of the date CC0 was applied by Affirmer to the Work. Should any part of the License for any reason be judged legally invalid or ineffective under applicable law, such partial invalidity or ineffectiveness shall not invalidate the remainder of the License, and in such case Affirmer hereby affirms that he or she will not (i) exercise any of his or her remaining Copyright and Related Rights in the Work or (ii) assert any associated claims and causes of action with respect to the Work, in either case contrary to Affirmer's express Statement of Purpose.

4. Limitations and Disclaimers.

- a. No trademark or patent rights held by Affirmer are waived, abandoned, surrendered, licensed or otherwise affected by this document.
- b. Affirmer offers the Work as-is and makes no representations or warranties of any kind concerning the Work, express, implied, statutory or otherwise, including without limitation warranties of title, merchantability, fitness for a particular purpose, non infringement, or the absence of latent or other defects, accuracy, or the present or absence of errors, whether or not discoverable, all to the greatest extent permissible under applicable law.
- c. Affirmer disclaims responsibility for clearing rights of other persons that may apply to the Work or any use thereof, including without limitation any person's Copyright and Related Rights in the Work. Further, Affirmer disclaims responsibility for obtaining any necessary consents, permissions or other rights required for any use of the Work.
- d. Affirmer understands and acknowledges that Creative Commons is not a party to this document and has no duty or obligation with respect to this CC0 or use of the Work.

Table of Contents

1. General Data.....	7
2. Aerodynamic Characteristics.....	9
3. Mass Data.....	16
Bibliography.....	18



1. General Data

Parameter	Value	Reference
Main rotor diameter	16.36 m	[1], [2]
Main rotor blade chord	0.53 m	[1], [3]
Main rotor blade airfoil	SC 1095	[3]
Main rotor solidity	0.0826	[3]
Main rotor shaft inclination angle	3.0°	[3]
Main rotor nominal rotation speed	258 RPM	[3]
Main rotor hinge offset	0.38 m	[3]
Main rotor blade tip loss factor	0.97	[3]
Main rotor lift curve slope	5.73 1/rad	[4]
Main rotor maximum thrust coefficient	0.1846	[4]
Main rotor single blade weight	116.5 kg	[3]
Main rotor single blade moment of inertia about flapping hinge	2 058.8 kg·m ²	[3]
Main rotor hub stationline	8.67 m	[5]
Main rotor hub waterline	8.00 m	[5]
Tail rotor diameter	3.35 m	[1], [2]
Tail rotor blade chord	0.25 m	[3]
Tail rotor blade airfoil	SC 1095	[3]
Tail rotor solidity	0.1875	[3]
Tail rotor cant angle	20.0°	[2]
Tail rotor nominal rotation speed	1 190 RPM	[3]
Tail rotor blade tip loss factor	0.92	[3]
Tail rotor blade section lift curve slope	5.73 1/rad	[3]
Tail rotor stationline	18.59 m	[5]
Tail rotor waterline	8.25 m	[5]
Fuselage length	15.43 m	[2]
Fuselage width	2.36 m	[2]
Fuselage aerodynamic reference point stationline	8.78 m	[4]
Fuselage aerodynamic reference point waterline	5.94 m	[4]
Cockpit floor waterline	5.46 m	[5]
Cabin floor waterline	5.25 m	[5]

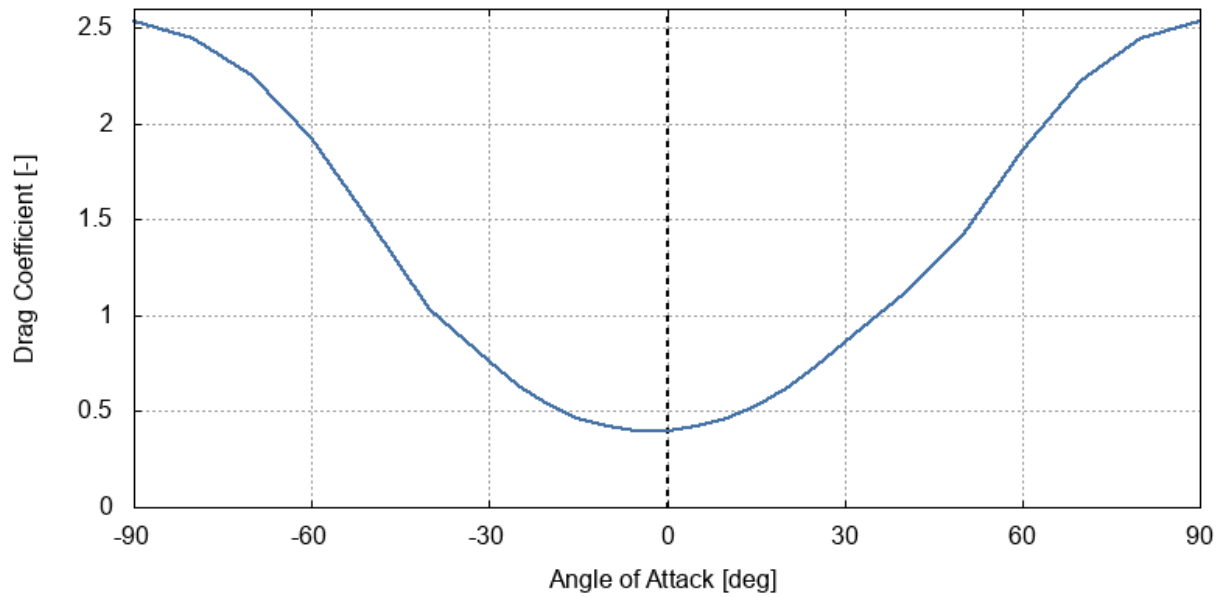
UH-60 - Real-Time Flight Simulation Data

Parameter	Value	Reference
Horizontal tail area	4.18 m ²	[1], [3]
Horizontal tail airfoil	NACA 0014	[3]
Horizontal tail stationline	17.79 m	[4]
Horizontal tail waterline	6.20 m	[4]
Horizontal tail deflection limit	up 30°, down 35°	[2]
Vertical tail area	3.00 m ²	[1], [3]
Vertical tail airfoil	NACA 0021	[3]
Vertical tail stationline	17.65 m	[4]
Vertical tail waterline	6.93 m	[4]
Lateral cyclic output at rotor	±8.0°	[3]
Longitudinal cyclic output at rotor	aft 16.5°, forward -12.3°	[3]
Pedals	left 29.9°, right 0.1°	[3]
Collective	low 9.9°, high 25.9°	[3]
Empty weight	5 118 kg	[1]
Internal fuel tanks capacity	1 361 l	[1], [2]
Internal fuel tanks stationline	10.69 m	[2]
Center of mass stationline (for 7,258 kg)	9.09 m	[3]
Center of mass waterline (for 7,258 kg)	6.38 m	[3]
Moment of inertia I _x (for 7,258 kg)	7 406 kg·m ²	[3]
Moment of inertia I _y (for 7,258 kg)	53 513 kg·m ²	[3]
Moment of inertia I _z (for 7,258 kg)	50 012 kg·m ²	[3]
Cross product of inertia I _{xz} (for 7,258 kg)	2 134 kg·m ²	[3]
Engine manufacturer	General Electric	[1]
Engine model	T700-GE-700	[1], [2]
Engine maximum power output	1 163 kW	[1]
Engine weight	207 kg	[6]
Engine specific fuel consumption at maximum continuous power	279.2 g/(kW·h)	[6]

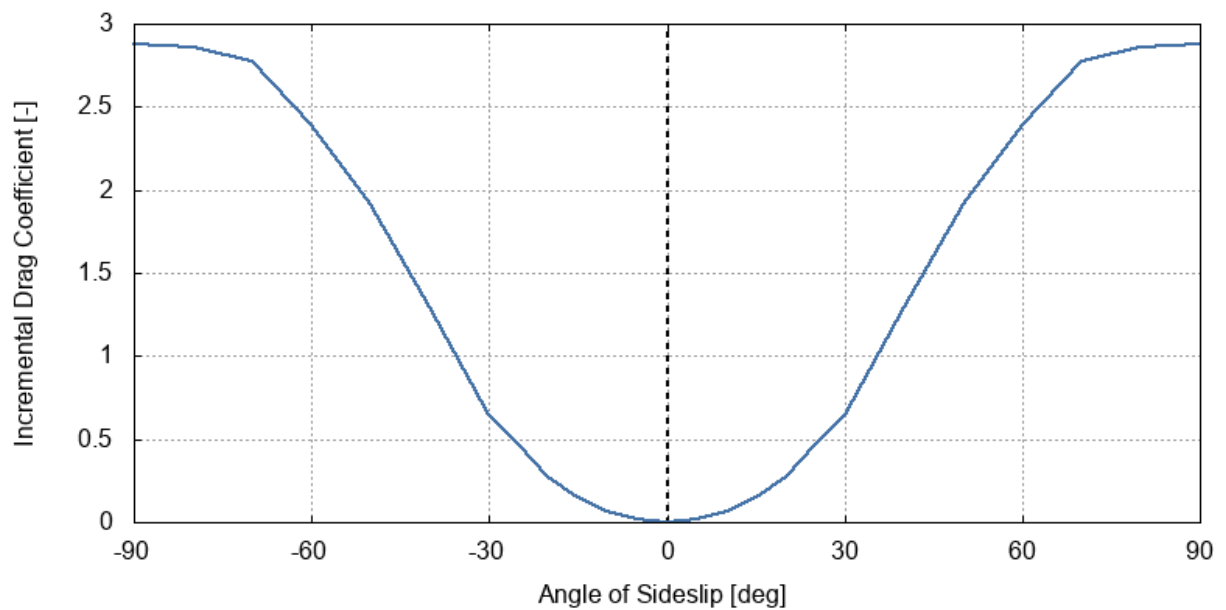
UH-60 data

2. Aerodynamic Characteristics

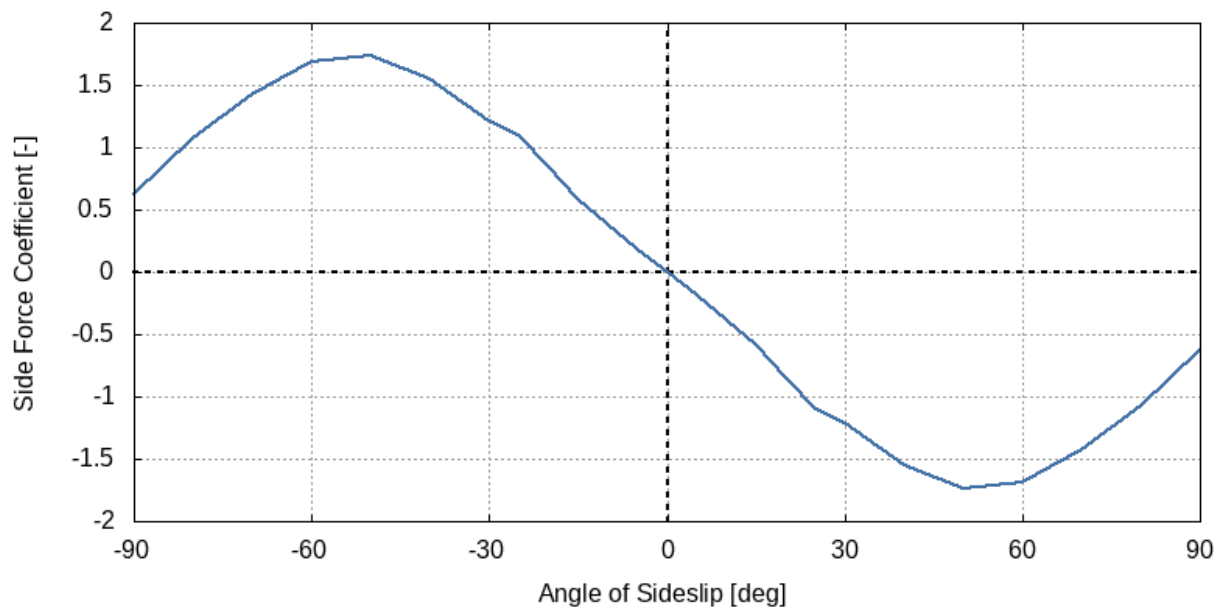
Aerodynamic characteristics are given in [3].



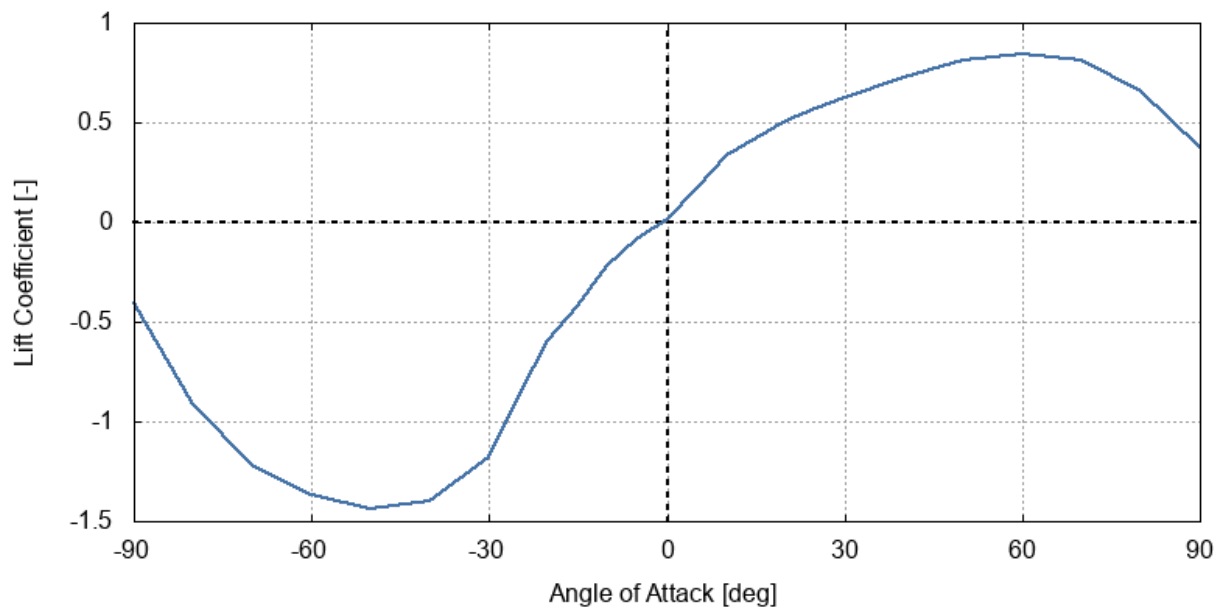
Fuselage drag coefficient due to angle of attack [3]



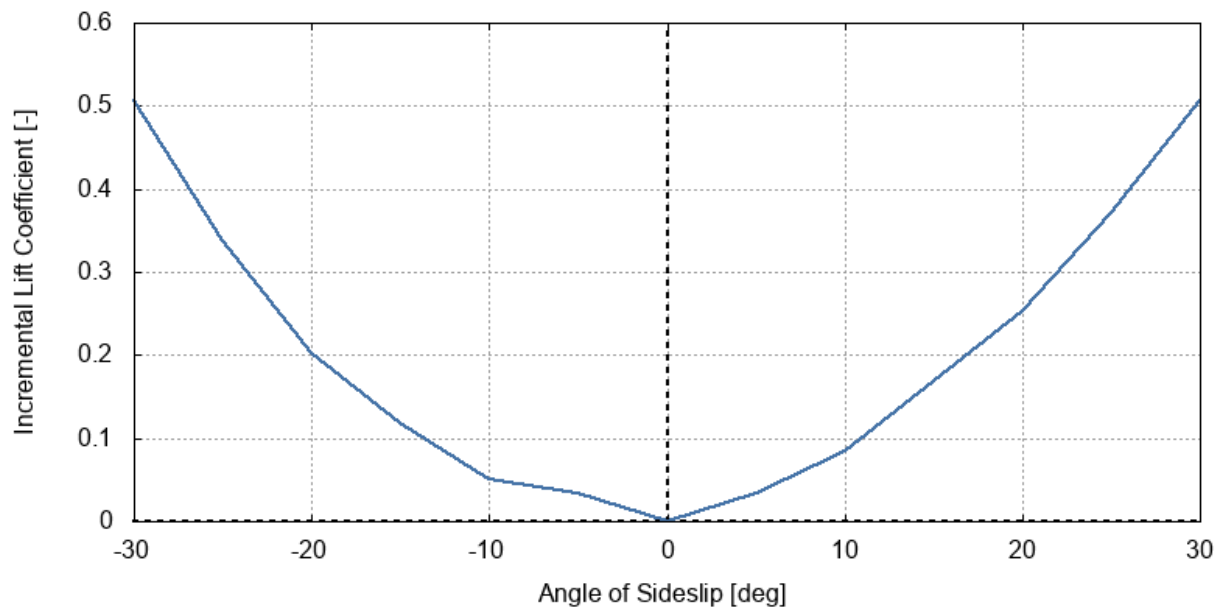
Incremental fuselage drag coefficient due to angle of sideslip [3]



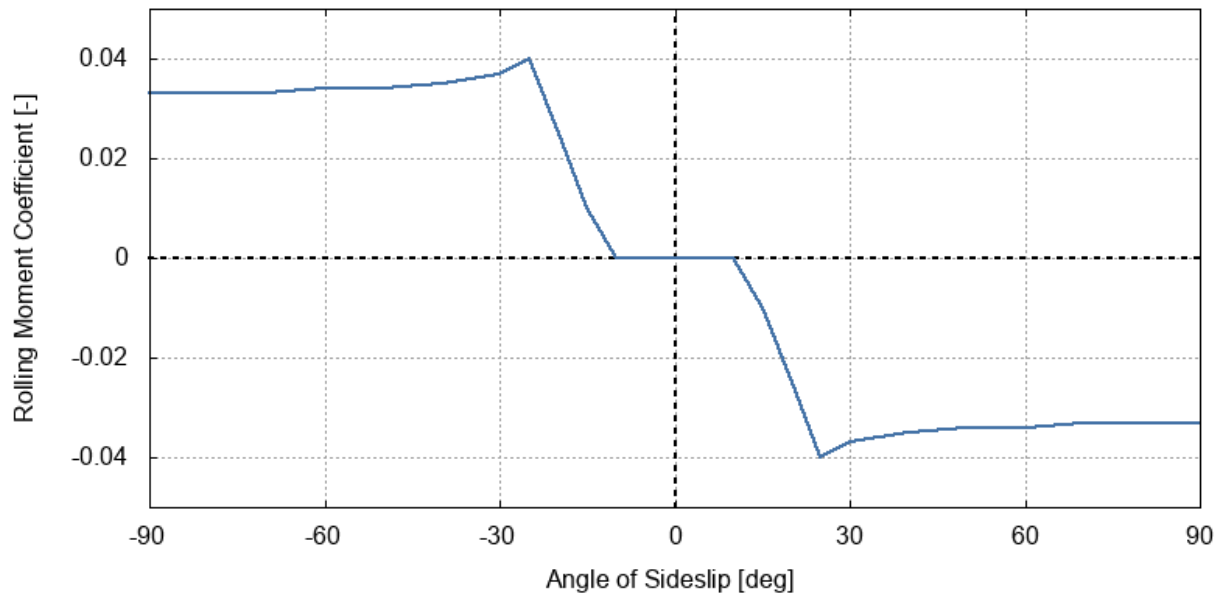
Fuselage side force coefficient due to angle of sideslip [3]



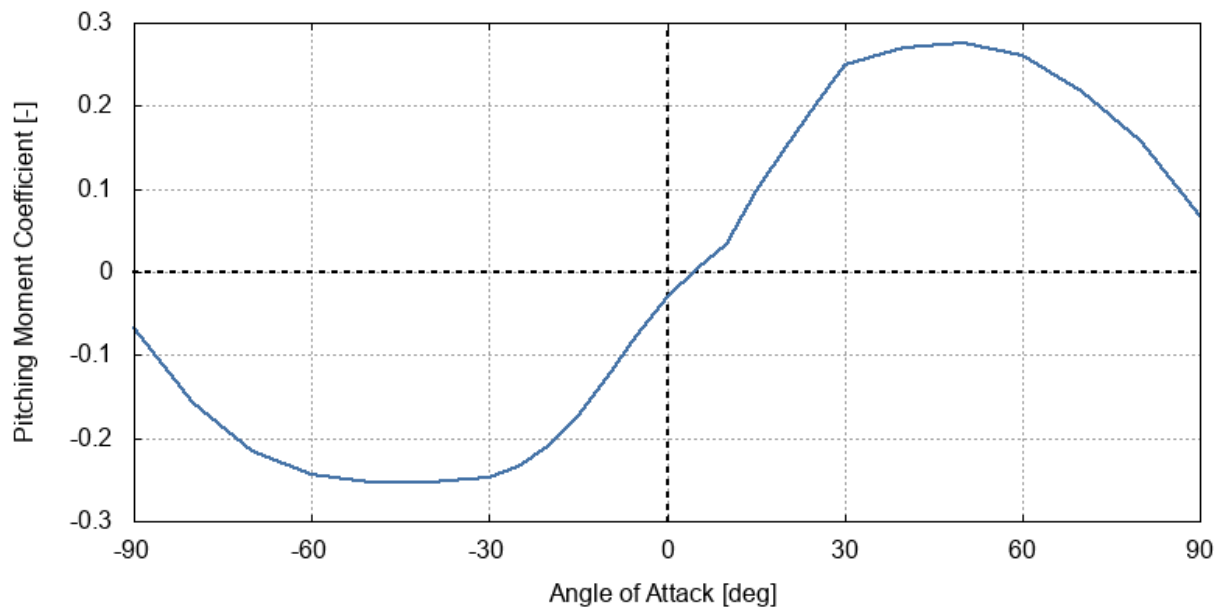
Fuselage lift coefficient due to angle of attack [3]



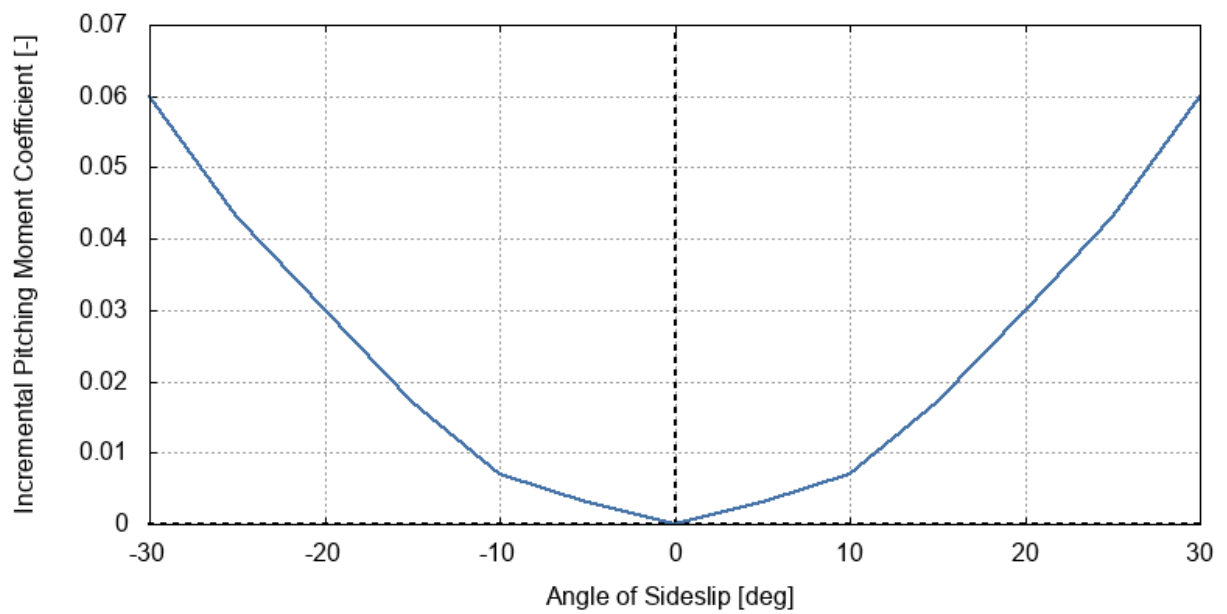
Incremental fuselage lift coefficient due to angle of sideslip [3]



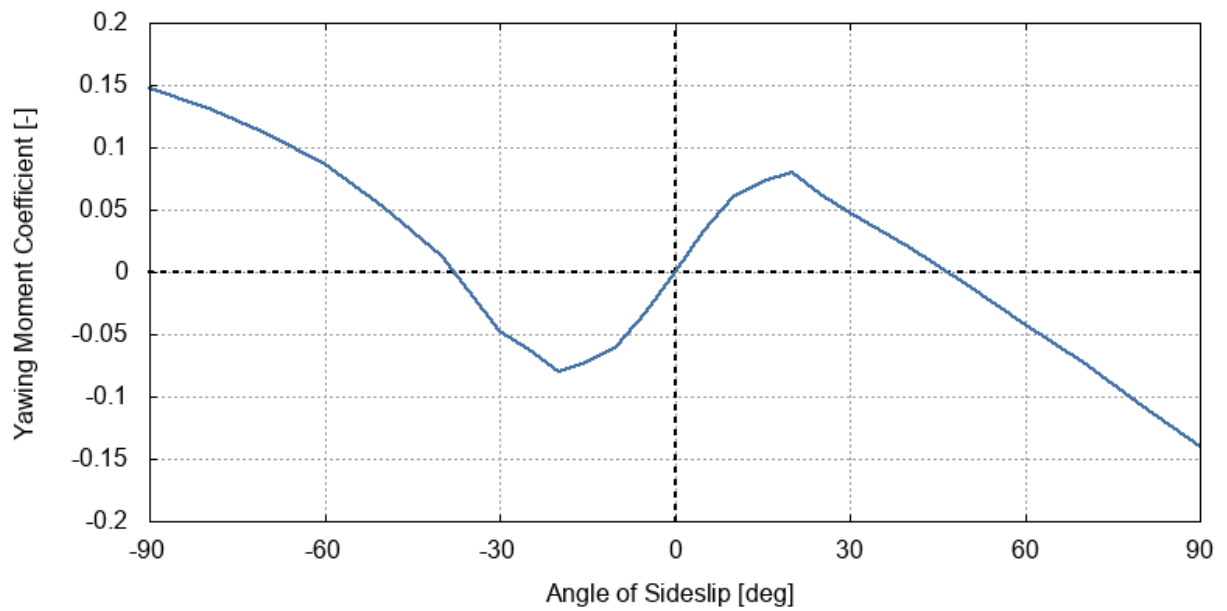
Fuselage rolling moment coefficient due to angle of sideslip [3]



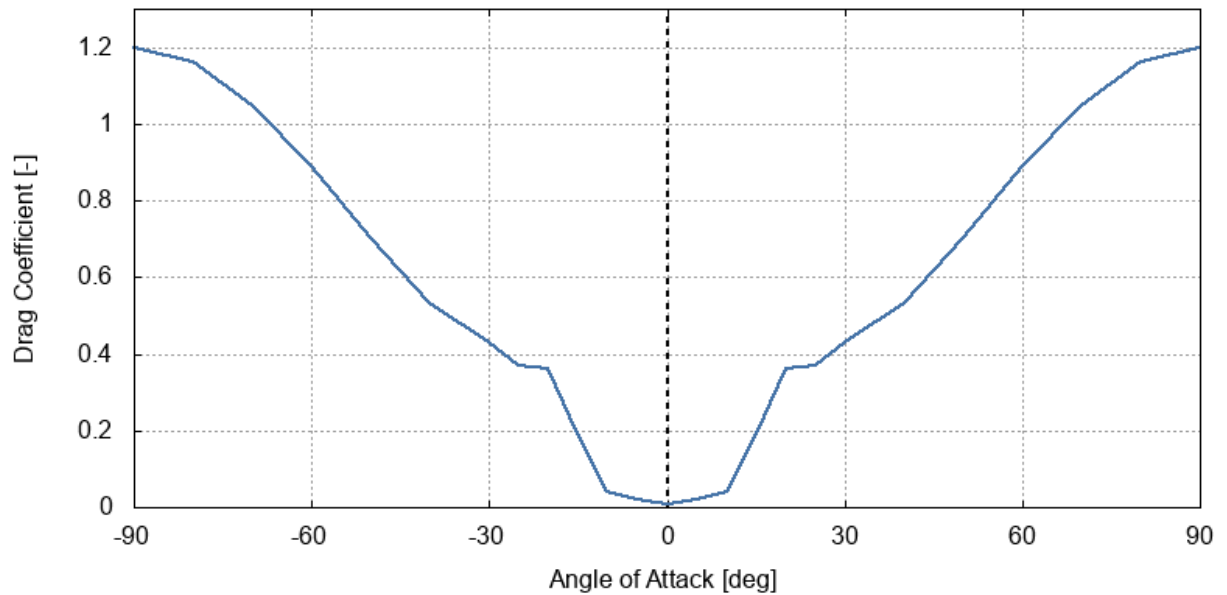
Fuselage pitching moment coefficient due to angle of attack [3]



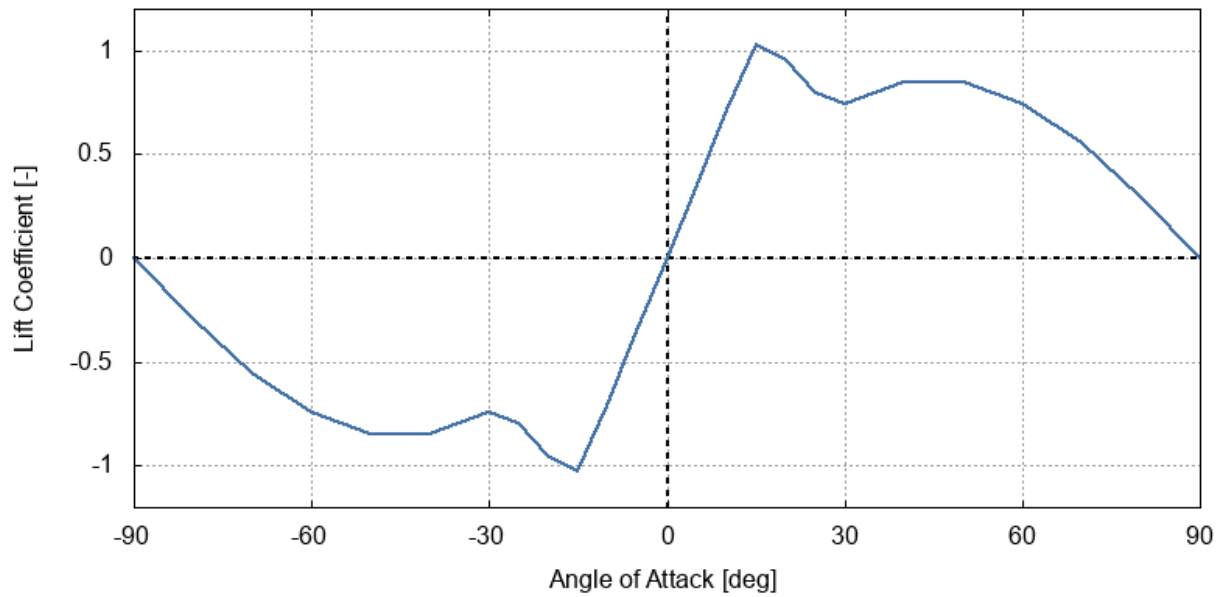
Incremental fuselage pitching moment coefficient due to angle of sideslip [3]



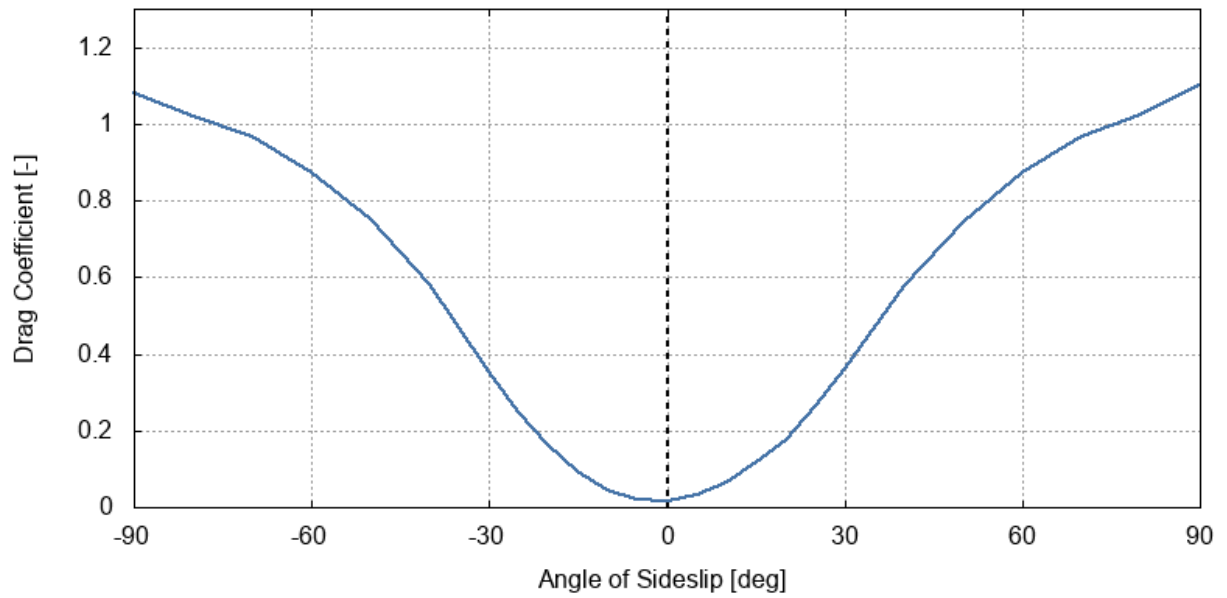
Fuselage yawing moment coefficient due to angle of sideslip [3]



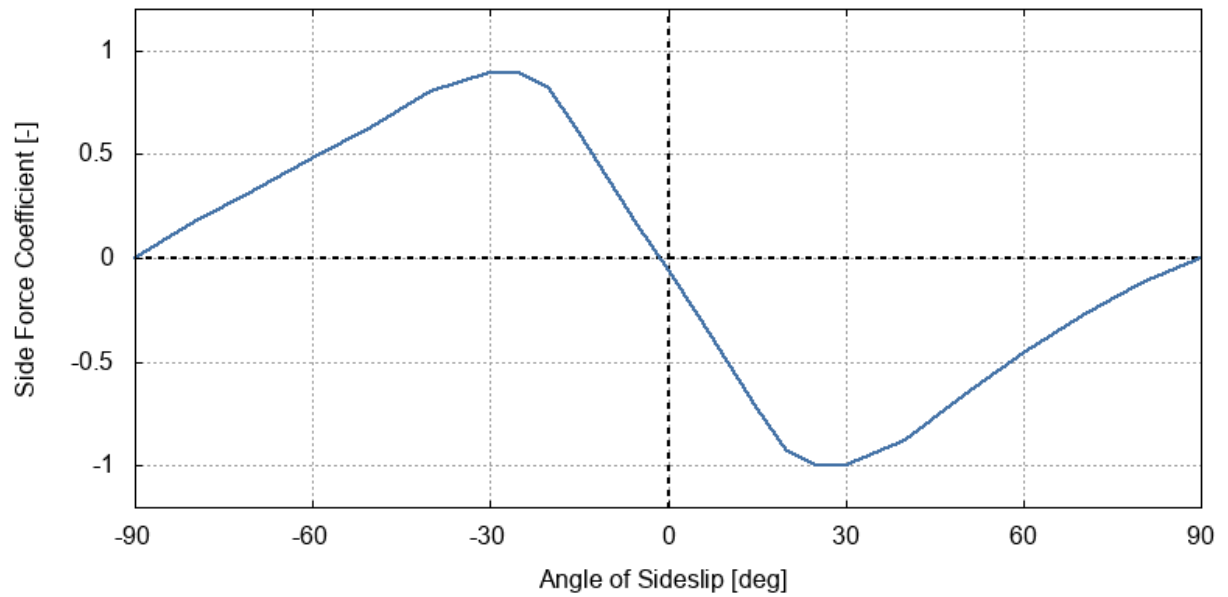
Horizontal tail drag coefficient due to angle of attack [3]



Horizontal tail lift coefficient due to angle of attack [3]



Vertical tail drag coefficient due to angle of sideslip [3]



Vertical tail side force coefficient due to angle of sideslip [3]

3. Mass Data

Data given in [2], [3] and [5] were used to calculate empty aircraft inertia tensor and center of mass coordinates. Results are given in the following table.

Parameter	Value
Center of mass x-coordinate	-0.15 m
Center of mass y-coordinate	0.00 m
Center of mass z-coordinate	-0.25 m
Moment of inertia I_x	6 543.0 kg·m ²
Moment of inertia I_y	46 293.1 kg·m ²
Moment of inertia I_z	43 498.3 kg·m ²
Cross product of inertia I_{xy}	0.0 kg·m ²
Cross product of inertia I_{xz}	-3 753.0 kg·m ²
Cross product of inertia I_{yz}	0.0 kg·m ²

UH-60 empty aircraft inertia tensor and center of mass coordinates

Structure group	Weight [kg]	Coordinates [m]			First moment of mass [kg·m]			Moment of inertia (Body Axis System) [kg·m ²]					
		x	y	z	S_x	S_y	S_z	I_x	I_y	I_z	I_{xy}	I_{xz}	I_{yz}
Empty aircraft	5 118	-0.15	0.00	-0.25	-791.9	0.0	-1 274.0	6 543.0	46 293.1	43 498.3	0.0	-3 753.0	0.0
Pilot (left)	80	2.90	-0.70	0.40	232.0	-56.0	32.0	52.0	685.6	712.0	162.4	-92.8	22.4
Pilot (right)	80	-0.70	0.70	0.40	232.0	56.0	32.0	52.0	685.6	712.0	-162.4	92.8	-22.4
Fuel	1 100	-2.02	0.00	0.70	-2 222.0	0.0	770.0	539.0	5 027.4	4 488.4	0.0	1 555.4	0.0
Personnel (4 th row)	440	0.04	0.00	0.50	15.6	0.0	220.0	110.0	110.6	0.6	0.0	-7.8	0.0
Personnel (5 th row)	440	-1.17	0.00	0.50	-514.1	0.0	220.0	110.0	710.7	600.7	0.0	257.0	0.0
Gross weight	7 258	-0.42	0.00	0.00	-3 048.4	0.0	0.0	7 406.0	53 513.0	50 012.0	0.0	-2 134.0	0.0

UH-60 mass data intermediate results

Bibliography

- [1] Jackson P., et al.: Jane's All the World's Aircraft 2004-2005. Jane's Information Group, 2004
- [2] Operator's Manual for UH-60A, UH-60L and EH-60A Helicopters. Department of the Army, TM 1-1520-237-10, 1996
- [3] Howlett J.: UH-60A Black Hawk Engineering Simulation Program: Volume I - Mathematical Model. National Aeronautics and Space Administration, CR-166309, 1981
- [4] Hilbert K.: A Mathematical Model of the UH-60 Helicopter. National Aeronautics and Space Administration, TM-85890, 1984
- [5] Aviation Unit and Intermediate Maintenance for Army Models UH-60A, UH-60L, EH-60A, UH-60Q and HH-60L Helicopters. Chapter 1: General Information Equipment Description and Data Theory of Operation. Department of the Army, TM 1-1520-237-23-1, 2006
- [6] T700-401C/-701C turboshaft engines. [online]. 2014 [Accessed 2019-01-27]. Available from: <https://www.geaviation.com/sites/default/files/datasheet-T700-401C-701C.pdf>