Howard DGA-5

a *"**D**amned **G**ood **A**irplane"*

User Guide

Figure 1: 3D printed Howard DGA-5

Scale:	1 : 6.1
Length:	850 mm
Wingspan:	1000 mm
Wing airfoil:	NACA0012 -> NACA0009
Tail airfoil:	NACA0003
Empty weight:	600 g
Takeoff weight:	950 g
Wing area:	16 dm^2
Wing load:	59 g/dm^2

Content:

The original

The Howard DGA-5 *"IKE"* evolved from one of two almost identical prize-winning racers *"MIKE"* and *"IKE"* developed by Benny Howard in 1932 [1]. From 1932 to 1936 both planes won plenty of racing prices culminating in 1935 when Howard aircraft won the Bendix, Thomson, and Greve Throphy – a season of racing events that became unofficially known as *"Benny Howard National Air Races"* [2].

Figure 2: Harold Neumann with Miss Chevrolet in Miami, Florida. "Ike" (NR56Y) was sponsored by the Chevrolet Division of General Motors and was therefore also known as "Miss Chevrolet" [3].

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What you need

3D printer specification

All STL files have been successfully tested with my Prusa i3 MK3S.

3D print volume	Minimum requirement for single STL file (ensures printability of all plane parts): X=190mm; Y=180mm; Z=171mm Optional files (STL, project, gcode) are provided to print the most inner wing parts with such small printer bed sizes (see optional print parts below). Minimum requirement for other gcode: X≧240mm; Y≧200mm; Z=171mm
Nozzle diameter	0.4mm
Filament support	PLA, TPU, (PETG)

Required materials

All basic plane parts are printable except for a few components such as steel wires or nylon screws.

Filament	White **PLA** for majority of print parts: ~625g (e.g., FormFutura Premium PLA Frosty White) Black **PLA** for exhaust pipes: ~2g (or paint a white PLA print with black color) Transparent **PETG or PLA** for the wind shield: ~2g (e.g., FormFutura Hdglass Clear) Black **TPU** for tires: ~15g, (e.g., 3D WarHorse TPU Black)
Spring steel wires	Ø 2.0mm, 1pc of length ~930mm (main landing gear) Ø 1.5mm, 1pc of length ~70mm (tail landing gear) Ø 1.0mm, 2pcs of length ~800mm (pushrods)
Linkage stopper	2pcs for pushrods e.g., Hobbyking Brass Linkage Stopper For 1mm Pushrods
Screw-in nuts	2pcs M4x10 (outer Ø ≤8.0mm, also used for furniture)
Self-tapping screws	8pcs M2.3x6 for wing servo cover 8pcs M2.3x6 for servo holder (optional)
Nylon screws	2pcs M4x20mm
CA hinge sheet	1pc e.g., Hobbyking CA Hinge Sheet 180mmx140mmx0.3mm
Elastic cord	Ø 1.0mm – 1.5mm, grey or white (“flying wires”, I am using 1.0mm grey)
CA glue	Medium viscosity e.g., Hobbyking Super Glue CA (50g / 1.7oz) Medium
CA accelerator	Optional but recommended e.g., Hobbyking Insta-Set CA Accelerator 2. Oz
Double-sided tape	Strong sticky tape to fix the receiver and optionally the servos to the plane e.g., Hobbyking Double Sided Tape (Clear) 25mm x 1m
Decal sheet	2pcs A4 or letter format (e.g., inkjet waterslide decal paper)
Clear spray coating	~200ml, for decal sheets (e.g., acrylic clear finish)

Radio control components

There is a huge variety of products available on the market that fulfills the requirements to provide enough power and precise control for the Howard DGA-5. The following set is what I have used and can recommend.

Motor	Hobbyking Turnigy Aerodrive SK3 – 2836-1500 (max. Ø 32mm)
ESC	Hobbyking Turnigy Plush-32 30A (2~4S) Brushless Speed Controller W/BEC
Battery	Hacker TopFuel LiPo 25C ECO-X 1800mAh 3S MTAG
Propeller	Hobbyking Meister Airscrew Propeller 9x6inch
Servos (4pc)	Hobbyking Corona DS-843MG
RC control	5 channel TX/RX

What you get

3D print files

In addition to the complete set of STL files, the package includes a set of Ultimaker Cura project files and the hereof generated gcode. Cura is a powerful open-source software that can be downloaded for free. The project files (and the gcode) were created with version 4.9.1. They also contain all detailed information needed to print each plane part on its own.

STL	STL stands for Standard Tessellation Language, a file format that describes the surface geometry of a three-dimensional object. The package includes STL files for all printable parts of the plane including a bending template to form the spring steel wires of the landing gear.
Project files	Multiple STL files can be combined into a single project file (.3mf) and “print job” (.gcode). Even more important, specific slicer settings can be applied to each part e.g., to increase stability of a certain part area or consider support for part areas with large overhang angle. The package includes 14 project files (4 are optional) which offer full access to all specific slicer settings used for each plane part. All project files can be easily modified with the graphical user interface of Cura to comply with the print volume and other unique parameters of your 3D printer.
Gcode	For each project file a corresponding gcode file is provided to minimize your preparation time. Please note that these gcode files are optimized for the Prusa i3 MK3S. For many 3D printers and filaments, the gcode should work out of the box. If you experience issues with the print quality, I recommend having a closer look at the slicer parameters listed below to optimize the gcode for your printer.

Figure 3 depicts an exploded view of the Howard DGA-5. Together with the following part list it provides an overview of all 3D printable Howard DGA-5 parts. The color code of the index numbers visualizes to which project file and gcode the part belongs.

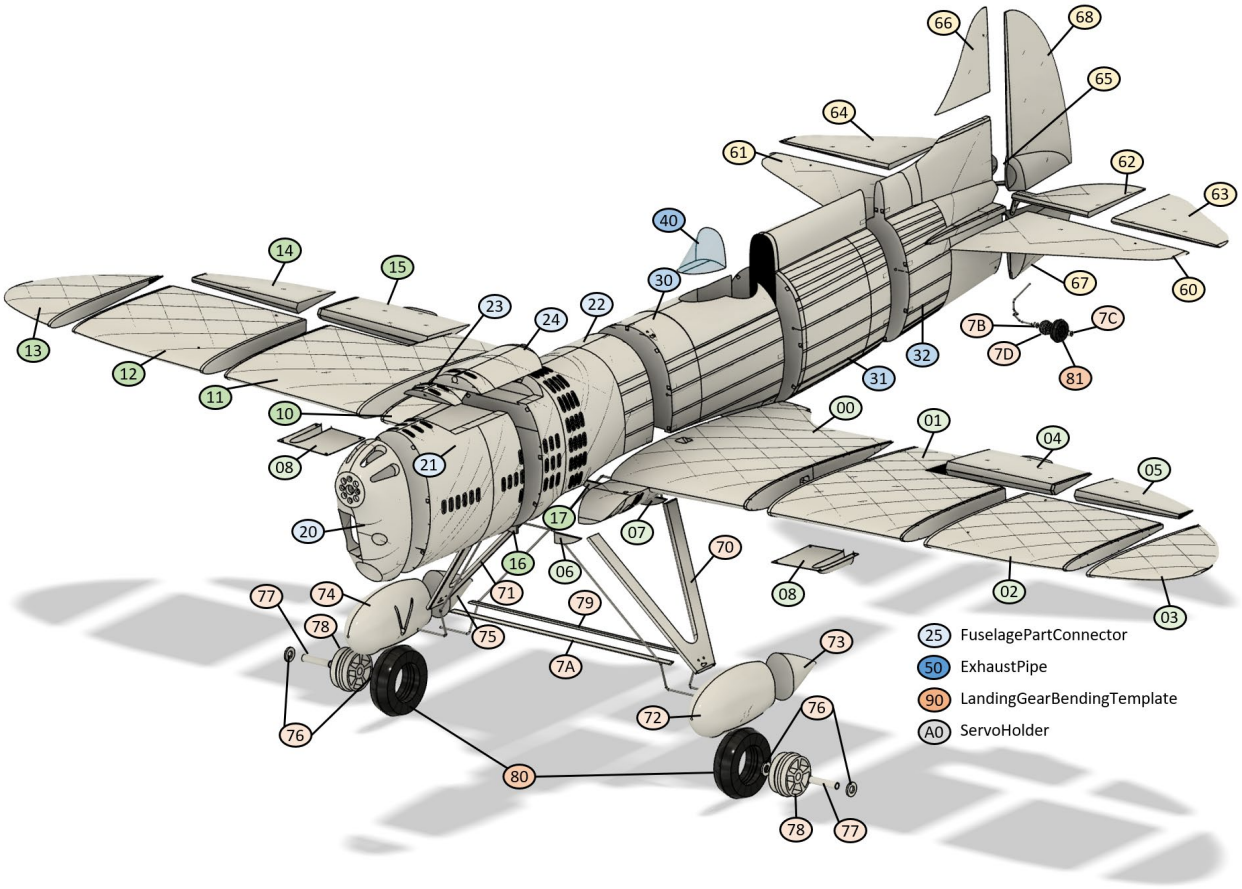
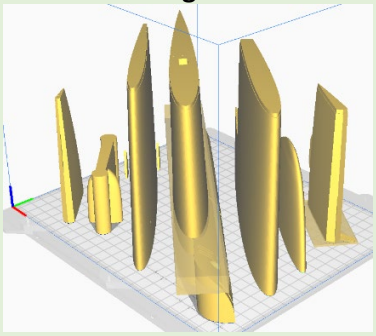


Figure 3: Exploded view with labeled plane parts

Project (.3mf/.gcode)	Part name (.stl)	Idx	Print weight	Setting
WingLeft  time: 25h 58m, weight: 140g	Wing1L	00	52 g	Modified
	Wing2L	01	31 g	Default
	Wing3L	02	25 g	Default
	Wing4L	03	12 g	Default
	Aileron1L	04	10 g	Modified
	Aileron2L	05	5 g	Default
	LandingGearShimFrontL	06	< 1 g	Default
	LandingGearShimBackL	07	< 1 g	Default
	ServoCover (left+right)	08	5 g	Default

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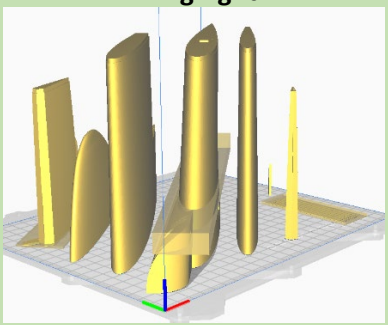
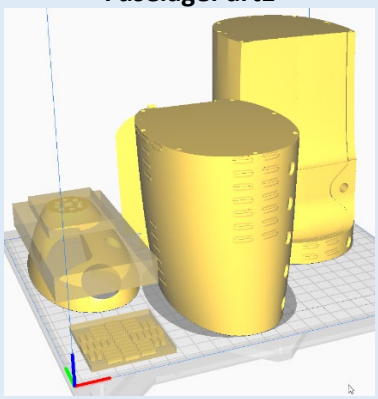
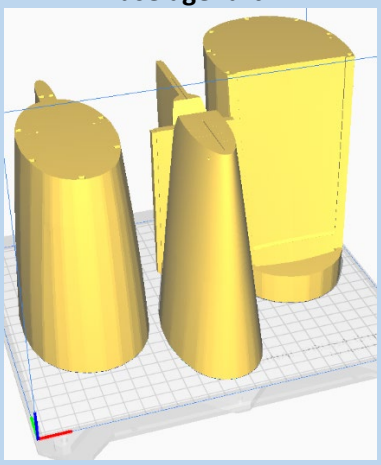
WingRight  time: 25h 8min, weight: 136g	Wing1R Wing2R Wing3R Wing4R Aileron1R Aileron2R LandingGearShimFrintR LandingGearShimBackR SpacerFlyingWires	10 11 12 13 14 15 16 17 18	52 g 31 g 25 g 12 g 10 g 5 g < 1 g < 1 g 1 g	Modified Default Default Default Modified Default Default Default Modified
FuselagePart1  time: 19h 23m, weight: 108g	Fuselage1 Fuselage2 Fuselage3 CanopyFront CanopyBack FuselagePartConnector (45pcs)	20 21 22 23 24 25	24 g 37 g 39 g 6 g 1 g 1 g	Modified Default Default Default Default Modified
FuselagePart2  time: 15h 56m, weight: 93g	Fuselage4 Fuselage5 Fuselage6	30 31 32	34 g 28 g 31 g	Default Default Default

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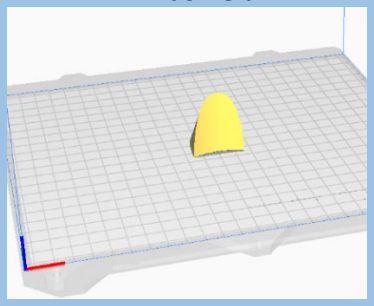
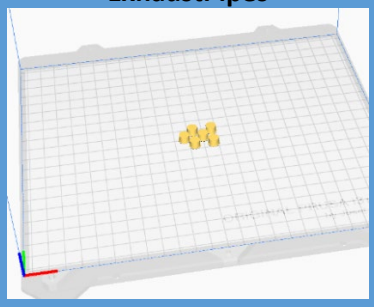
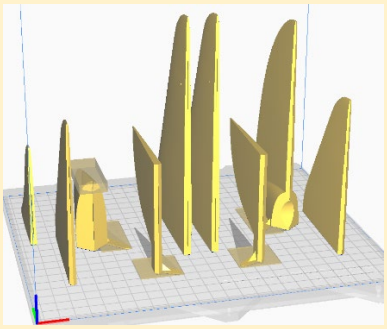
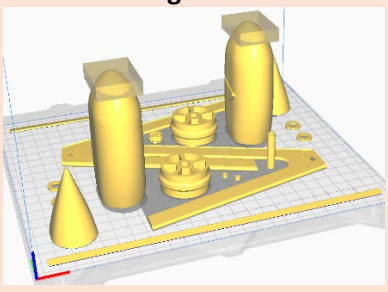
WindShield  time: 0h 18m, weight: 1g	WindShield	40	1 g	Modified
ExhaustPipes  time: 0h 5m, weight: 0g	ExhaustPipe (6pcs)	50	< 1 g	Modified
Tail  time: 12h 0m, weight: 70g	HorizontalStabilizerL HorizontalStabilizerR ElevatorL1 ElevatorL2 ElevatorR1 ElevatorR2 VerticalStabilizer RudderBottom RudderTop	60 61 62 63 64 65 66 67 68	13 g 13 g 5 g 6 g 5 g 6 g 3 g 6 g 11 g	Default Default Modified Default Modified Default Default Modified Modified
LandingGearParts  time: 8h 5m, weight: 47g	LegL LegR WheelPantFrontL WheelPantBackL WheelPantFrontR WheelPantBackR WasherMainWheel (4pcs) AxleMainWheel (2pcs) RimMainWheel (2pcs) CrossbarTop CrossbarBottom WasherTailWheelL WasherTailWheelR RimTailWheel	70 71 72 73 74 75 76 77 78 79 7A 7B 7C 7D	8 g 8 g 7 g 2 g 7 g 2 g < 1 g < 1 g 8 g < 1 g < 1 g < 1 g < 1 g < 1 g	Modified Modified Modified Default Modified Default Modified Modified Modified Modified Modified Modified Modified Modified

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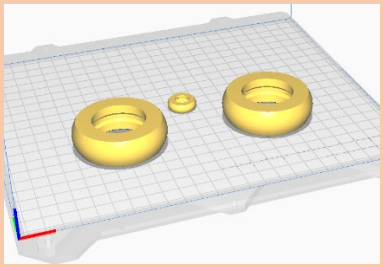
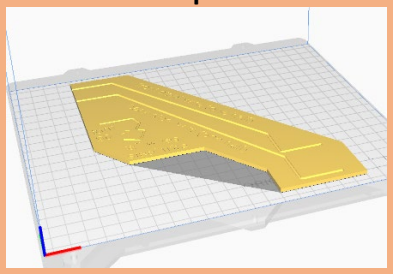
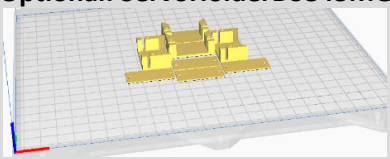
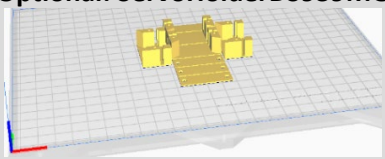
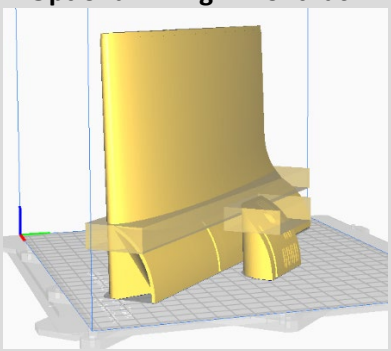
Tires  time: 2h 41m, weight: 13g	TireMainWheel (2pcs) TireTailWheel	80 81	12 g 1 g	Modified Modified
LandingGearBending Template  time: 3h 45m, weight: 20g	LandingGearBendingTemplate	90	20 g	Modified
Optional: ServoHolderDS843MG  time: 1h 53m, weight: 9g	ServoHolderDS843MG	A0	9 g	Modified
Optional: ServoHolderDS939MG  time: 1h 56m, weight: 9g	ServoHolderDS939MG	B0	9 g	Modified
Optional: WingL1FrontBack  time: 10h 1m, weight: 55g	WingL1FrontBack	01-	55 g	Modified

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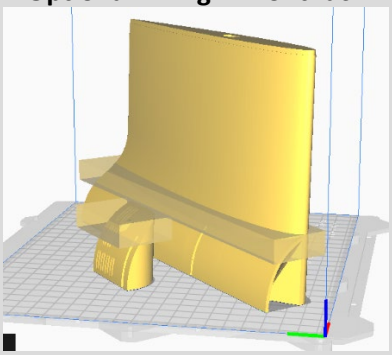
Optional: WingR1FrontBack  time: 10h 1m, weight: 55g	WingR1FrontBack	10-	55 g	Modified

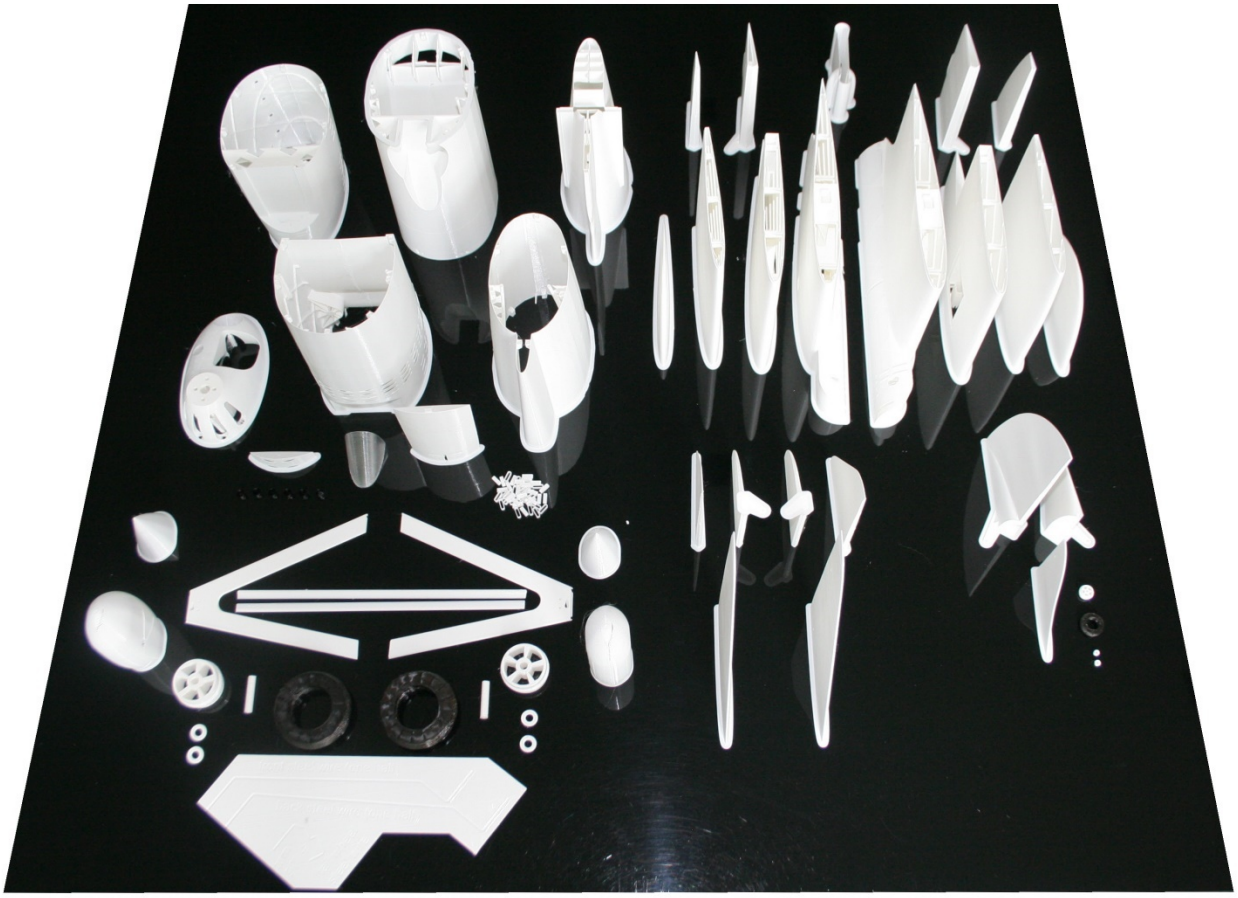


Figure 4: All printed parts at a glance

Ultimaker Cura slicer settings

A correct setting of the slicer parameters is essential to achieve excellent surface quality and layer adhesion. The following list shall help to get a better insight and to find the best Cura settings for your printer. Note that all modified settings used in the project files were derived from these default settings.

Cura slicer parameter		Default setting	Remarks
Quality	**Layer Height**	0.2mm	All parts can be printed with this default value. A smaller value (≥0.1mm) typically improves the surface quality and allows to print larger overhang angles without support. Print duration increases though.
	Initial Layer Height	0.2mm	Slightly increasing this value may improve first layer adhesion. If you experience first layer adhesion issues 1. Make sure that your printer is well calibrated. 2. Use 3DLac to avoid insufficient (PLA, ASA, etc.) or too strong (TPU) layer adhesion.
Walls	**Wall Thickness**	0.4mm	The plane is designed for 0.4mm wall thickness. Smaller values may lead to insufficient adhesion between the perimeter and inner structures. Larger values increase weight and are hence not recommended.
	Optimize Wall Printing Order	Off	Make sure to print the outer wall first to obtain a smooth surface. Without this setting, inner structures may appear as bumps on the outer surface.
	Outer Before Inner Walls	On	
	Compensate Outer/Inner Wall Overlaps	On	This setting also helps to avoid bumps.
	Filter Out Tiny Gaps	On	This function seems to have negligible impact on the print quality.
	Print Thin Walls	Off	I recommend turning off this setting to save print time and slightly reduce the weight of the printed part.
	Z Seam Alignment	User Specified	Layer changes are always causing small blobs or gaps due to pressure fluctuations in the nozzle. I've tried to minimize its visibility for all prints by selecting suitable values for X and Y e.g., by selecting less visible areas or sharp corners.
	Z Seam X	Values are roughly optimized for each part (see project files).	
	Z Seam Y		

	Seam Corner Preference	Smart Hiding	This setting may help to minimize the visibility of layer changes.
Top/Bottom	**Top/Bottom Thickness**	0.0mm	Top/bottom layers are not needed for most plane parts.
Infill	**Infill density**	0%	Infill is not needed for most plane parts.
Material	**Printing Temperature**	220°C	This value is at the upper limit for PLA to maximize layer adhesion. Anyway, if you experience stringing issues, feel free to reduce this value by a few degrees. For PLA, I recommend using at least 210°C. TPU and PETG require higher temperatures of around 240-250°C.
	Build Plate Temperature	50°C	Do not go above 50°C for PLA. Otherwise, a deformation of the thin wall print may occur in the first ~30 layers. Use 0°C for TPU to avoid too strong first layer adhesion.
	Built Plate Temperature Initial Layer	60°C	If you experience first layer adhesion issues with PLA, please refer to my remarks on “Initial Layer Height” instead of increasing the build plate temperature above 60°C. Use 0°C for TPU to avoid too strong first layer adhesion.
	Flow	100%	This default value is typically fine. In rare cases, your printer might require a slightly different setting.
Speed	**Print Speed**	30mm/s	These settings are rather on the conservative side (slower typically results in better print quality) to ensure nice print and surface quality. Same setting can be used for PLA, PETG and TPU.
	Outer Wall Speed	20mm/s	
	Travel Speed	120mm/s	
	Initial Layer Speed	15mm/s	
Travel	**Enable Retraction**	On	Reduces stringing.
	Retract at Layer Change	On	Helps to mitigate blobs and gaps at layer change.

	Retraction distance	0.8mm	This value strongly depends on the type of extruder used with the printer. The default value is suitable for direct extruders (e.g., Prusa i3 MK3S). Bowden extruders typically require larger values up to a few mm.
	Retraction Speed	35mm/s	This is the default Cura slicer value that works fine with my printer.
	Retraction Extra Prime Amount	0.02mm^3	During travel some material oozes out of the nozzle. This value allows to compensate for it. You may adjust it according to your printer and filament requirements.
	Retraction Minimum Travel	0.8mm	This value avoids too many retractions when printing very detailed areas.
	Combing Mode	Off	Very important setting to achieve good thin wall print quality. Please note that this setting is enabled by default in many Cura profiles.
	Z Hop When Retracted	On	Important setting to obtain nice print results. Without retract the nozzle may damage the printed part during travel moves.
	Z Hop Height	1.0mm	Typical and useful value.
Cooling	**Enable Print Cooling**	On	By default, these settings use 50% cooling. Only in case of single layer print duration below 20s 100% cooling is applied. These settings yield very good layer adhesion with my Prusa i3 MK3S. At the same time, insufficient cooling issues when printing e.g., only the wind shield are effectively avoided (HDglass, 250°C). Often, people recommend 0% cooling. You may give it a try if you experience insufficient layer adhesion.
	Fan Speed	50%	
	Maximum Fan Speed	100%	
	Regular/Maximum Fan Speed Thresh	20s	
Support	**Generate Support**	Off	Support is only needed for the part “Fuselage1”. Details can be found in the project file FuselagePart1.3mf.

Build Plate Adhesion	**Build Plate Adhesion Type**	Brim	A brim is used for most plane parts. Exception are parts that provide good bed adhesion without brim.
	Brim Width	3.0mm	This width value is typically sufficient to achieve reliable first layer adhesion to the printer bed.
Mesh Fixes	**Union Overlapping Volumes**	Off	Important: Enabling these values can lead to unsatisfactory print results. Please note that some of these settings are enabled by default in many Cura profiles.
	Remove All Holes	Off	
	Extensive Stitching	Off	
	Keep Disconnected Faces	Off	
	Merged Mashes Overlap	0.0mm	
	Remove Mesh Intersection	Off	
	Remove Empty First Layers	Off	
	Maximum Resolution	0.5mm	These are default Cura settings. They can be used to adjust the computational burden for the 3D printer. Older 3D printers may require larger values to achieve smooth print results.
	Maximum Travel Resolution	0.8mm	
	Maximum Deviation	0.025mm	
Experimental	**Slicing Tolerance**	Exclusive	Important setting to ensure proper slicing of the parts.

Decal sheets

The set includes PDF files (600dpi, letter and A4 format) to print decals for the Howard DGA-5. The original plane used black aircraft registration letters in the first years which were later partly replaced by golden letters. Unfortunately, gold is a special color that can only be approximated by the RGB or CMYK color space. With the provided decals, I have tried to approximate the golden color. Black registration letters are provided as an alternative.

Figure 5: Decal sheets with golden registration letters

Figure 6: Decal sheets with black registration letters

Assembly

Step by step video guide

[Howard DGA-5 – step by step video guide]

Chapters:

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Pre-flight setting & check

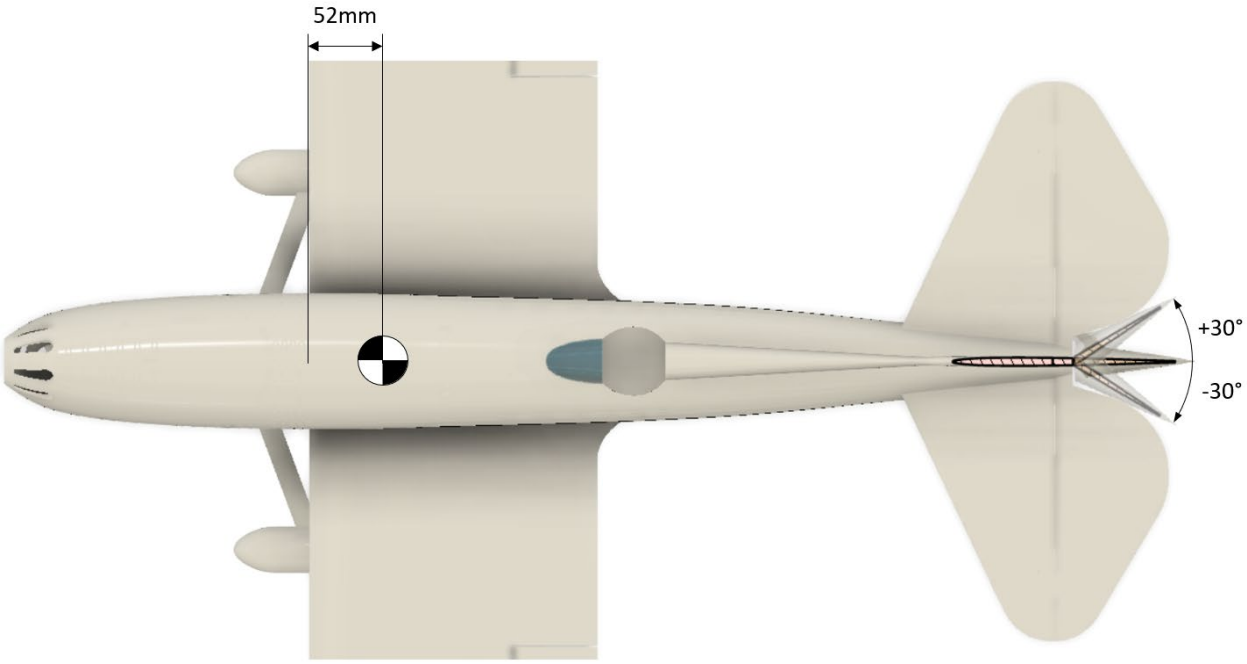

Figure 7: Center of gravity (CG) and rudder deflection angles

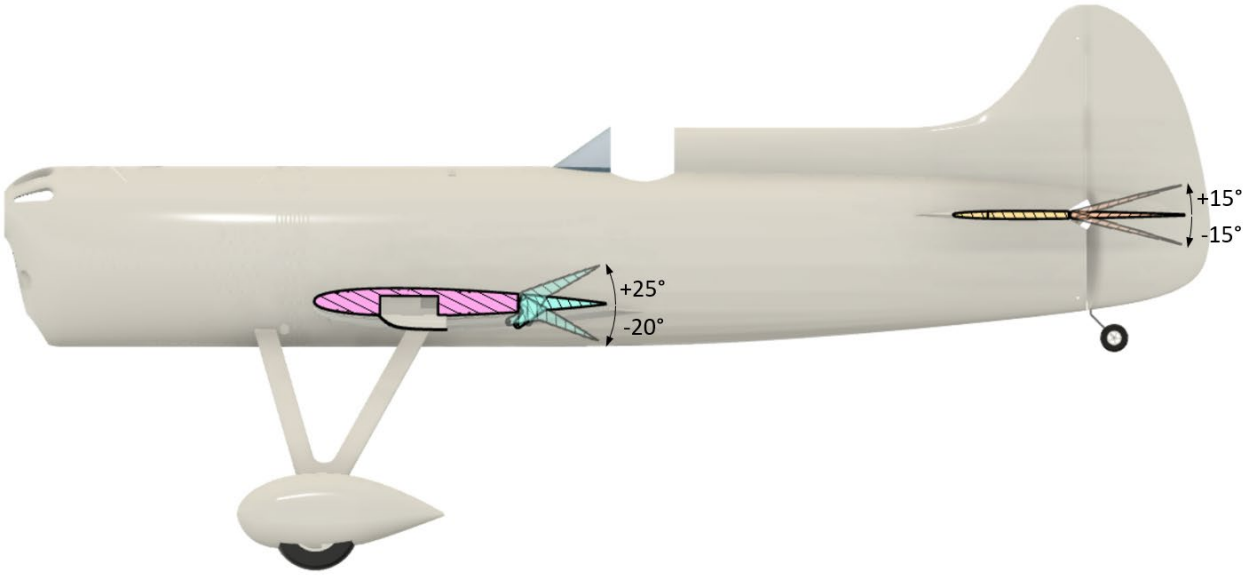

Figure 8: Aileron and elevator deflection angles