Guide 1: FlightStream and pyfts, an overview

What the solver does, how a simulation is built, and where each guide takes over

Written for pyflightstream 0.58.2.

Sources: the FlightStream user manual, the panel-method literature, and the package pages "The workspace and the workflow" and "Storage and sync" [1, 2, 6, 7, 8, 10].

pyflightstream is the work of Geovana Neves: https://github.com/nevesgeovana/pyflightstream, concept DOI 10.5281/zenodo.21482924.
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Who reads what

You are new to FlightStream

- Part 1: what the tool is, and what it will not do.
- Part 2: how a surface vorticity panel solver works, steady, unsteady and rotating.
- Part 3: the simulation workflow, stage by stage.

You know FlightStream, and meet pyfs

- Part 4: how pyflightstream carries each stage: the matrix, the references, the setups, the pproc, run and post, the four workflows, storage and sync.
- Part 5: the other eight guides, and when to read each.

Takeaway *This deck orients; it defines nothing. Every key, command and refusal it names is defined in the guide it points to.*

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FlightStream

How a panel solver works

The simulation workflow

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The guides

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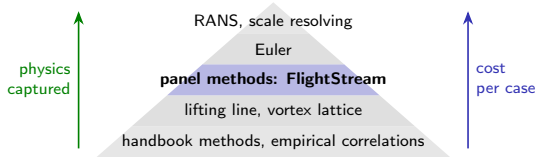
Part 1

FlightStream

Where a panel method sits

- Aerodynamic tools form a **fidelity ladder**: each level resolves more physics and costs more per case.
- A panel method sits in the middle: the **whole configuration** in three dimensions, in seconds to minutes per point on a workstation.
- That is the regime of **interference and installation**: where a propeller sits, what a fuselage does to a wing, a pitching moment slope.



Takeaway *A panel method buys full-configuration aerodynamics at a cost that still allows design iteration.*

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What FlightStream is

- A **surface vorticity** panel solver: the potential-flow problem, with vorticity carried on the surface mesh [7, 8]. It tolerates [REF-21], [REF-27] unstructured, engineering-quality meshes and reads the common exchange formats [6, pp. 72-75].
- The core is **inviscid**. The rest is correction models on top of it: a boundary layer, with optional viscous coupling, for friction drag and decambering [6, pp. 204-211]; subsonic compressibility, chosen at initialisation [6, pp. 218-221], [12]. [REF-31]
- Steady, unsteady and rotating solutions, driven from a graphical interface or from a **script** of commands.

Check the validity envelope

- Deep stall and buffet need separate validation.
- Transonic options need build-specific validation.
- Acoustics needs the separate toolbox and acoustic exports.

And it does not warn you

A case that leaves the validity envelope still converges and still prints coefficients.

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The build number is part of the answer

- FlightStream is released as **builds**; this series names build 26.123 in its examples. The scripting language changes between builds of one version: a command that runs on one build may be absent, renamed or spelled differently on another.
- The manual ships inside each build, and **editions are not page aligned**. A page number is quoted with its edition, or not at all.
- A coefficient without the build that produced it is **not reproducible**. Record the build next to every result.

How pyflightstream holds this

Every command it writes comes from a **command database per build**, and every row of a study names its build in the column `FS_BUILD`. `plan` checks the whole study against that build's database before any seat is spent (Part 4, Guide 2).

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The tool's own view of the workflow

- The manual closes with three checklists: the **general** workflow [6, p. 411], the workflow from **CAD cross sections** (CCS) [6, p. 412], and the **rotor and turbine** workflow [6, p. 413].
- The general one has five steps: geometry preparation, half-model setup, surface detection, boundary conditions, simulation setup.
- Boundary conditions come **before** anything a user would call setup. Part 3 explains why: initialisation locks them.

A half model is expected

The manual recommends the half model under a mirror plane, and free edges along that plane are **expected**, not a defect [6, p. 411].

A reference case ships with it

A rotor in hover and cruise [6, p. 401]: the fastest check that an installation behaves.

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The method, and where it has been measured

What it solves

- The integrated-circulation formulation, in full [7]. [REF-27]
- The surface vorticity panel method in the archival literature: the reference to cite when someone asks what FlightStream solves [8]. [REF-21]
- The classical panel-method background: [9, 10]. [REF-28], [REF-29]

Where it has been compared with experiment

- Stability and control of a vehicle against wind-tunnel data: derivatives agree acceptably, control effectiveness is overpredicted, propellers off [13]. [REF-32]
- A high-lift wing with distributed propulsion, against experiment: the closest published case to a powered airframe [14]. [REF-33]

Takeaway *Convergence against a theoretical anchor is verification; agreement with measured data is validation. Say which one a result shows.*

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Part 2

How a panel solver works

Potential flow and its boundary conditions

- Assumptions: **incompressible, irrotational, inviscid**. The velocity derives from a potential, $V = \nabla\phi$, and mass conservation becomes the Laplace equation, $\nabla^2\phi = 0$ [9, 10]. [REF-28], [REF-29]
- The equation is **linear**: elementary solutions superpose, and the flow about a body is assembled from them.
- Two conditions close it: **flow tangency** on the surface, and **decay** of the disturbance far away.

What is absent

No volume grid, so **no farfield to size** and no blockage to correct: the disturbance decays because the elementary solutions decay [6, p. 164].

What it can predict

Pressure effects: lift, induced drag, moments, interference. Friction drag does not come from the potential-flow solution; it comes from the optional boundary-layer correction.

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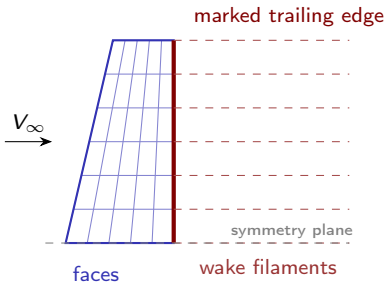
From source and doublet panels to surface vorticity

- A classic panel method gives each surface panel a source or doublet strength, enforces tangency at one point per panel, and solves a dense linear system [9, 10]. [REF-28], [REF-29]
- FlightStream carries **vorticity** on the surface mesh instead [7, 8]. Degenerate faces are removed in preprocessing, and [REF-21], [REF-27] flow-aligned quadrilaterals are preferred on lifting surfaces [6, pp. 75, 156].
- Whatever the singularity: **surface resolution drives the induced velocities**, and cost grows steeply with the panel count.



Takeaway *Different singularity, same physics: enforce tangency, resolve the circulation, integrate the pressures.*

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The Kutta condition and the wake

- Potential flow alone **does not fix lift**: any circulation satisfies the equations. The physical statement that selects the real solution is smooth flow leaving a sharp trailing edge [10, 11]. [REF-29], [REF-30]
- In the solver, **marking a trailing edge** is that statement: wake filaments are shed from marked edges, and an unmarked edge sheds nothing at all [6, p. 165].
- The wake carries the trailed vorticity downstream. Its strength mirrors the spanwise load gradient, and **induced drag** is the price of that vorticity.

The most critical input

An unmarked trailing edge raises no error. It returns a converged solution with the wrong lift; the manual calls the trailing edges by far the most critical input [6, p. 164].

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How much circulation is shed: the factor K

- The strength of the wake filament leaving a marked edge is

$$\Gamma_{s_t} = \frac{K}{2}\left(q_u^2 - q_l^2\right)\Delta t,$$

  with q_u and q_l the velocities above and below the filament [6, p. 165].
- **Standard Kutta**, $K = 1$: the full net circulation is shed. The default, and the right choice at any real lifting trailing edge.
- **Relaxed Kutta**, $K = 0.5$: half is shed. For an edge that is not sharp, typically the aft end of a rounded fuselage, so that the body carries an equivalent lifting load rather than none.
- Two more types exist: exhaust outflow, and vortex shedding, which has no vortex-bursting model and is not recommended beyond 25 to 30 degrees of incidence [6, p. 165].

Takeaway *Standard against relaxed is not a numerical knob: it states whether an edge is a real trailing edge.*

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When a trailing edge is not a Kutta edge

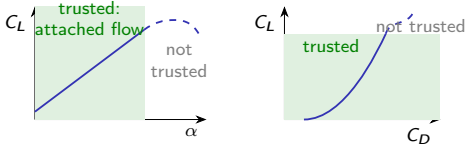
- A **blunt** trailing edge is a separated base: the solver applies a constant pressure over a **base region** [6, p. 164].
- Rule of thumb: thicker than **2 percent of the chord**, keep it blunt with a base region, and mark the base perimeter as trailing edges [6, pp. 164, 167]. Thinner, collapse it to a sharp edge: no loss of accuracy, faster and cleaner convergence.
- A body protruding through a wing trailing edge by a length L, on a chord c: the carry-over decision turns on $L > c/2$ [6, p. 166].

Taken in CAD

Collapsed or blunt is decided **before the mesh is made**, and it governs every stage after it. Part 3 places it in the geometry stage.

What the method captures, and what it does not

- **Inviscid core**: lift slope, induced drag, spanwise loading, thickness effects, interference between components.
- **Correction models**: friction drag by the boundary layer, decoupled by default, coupled through transpiration for nonlinear decambering [6, pp. 204-211]; subcritical Mach effects by Prandtl-Glauert [6, pp. 218-221], [12]. [REF-31]
- **Not captured** under any setting: deep stall, buffet, shock stall.



Takeaway *A polar is trustworthy where the flow is attached, and nothing in the output says where that ends.*

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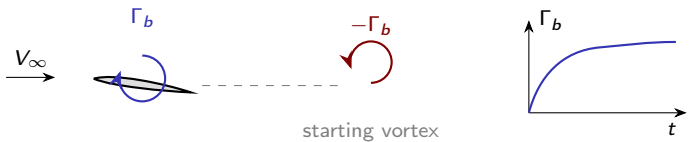
Unsteady: the wake remembers

- **Kelvin**: in inviscid flow the circulation of a material contour is conserved. When the bound circulation changes, an equal and opposite vortex is shed into the wake [10]. [REF-29]
- The **starting vortex** is the canonical picture: a wing set impulsively in motion leaves behind a vortex that mirrors the circulation it gains.
- The wake stops being a fixed sheet and becomes part of the solution: it carries the history of every change of lift, and induces velocity back on the wing.



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The time step is a mesh dimension

- The solver marches in **physical time**: each step runs a block of iterations under the steady settings, and the wake grows one shed segment per step [6, pp. 212-213].
- The streamwise length of a shed segment is the convection velocity times the step: **the step sets the wake resolution** as the panel size sets the surface resolution. Choose it from a physical time the geometry has, for example the chord's convective time $t_c = c/V$.
- The judge is the **reduced frequency** [15, 10]: [REF-29], [REF-34]

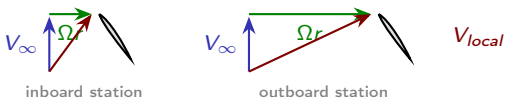
$$k = \frac{\omega c}{2V_\infty}.$$

  At low k the flow adjusts quasi-statically; as k grows, wake memory and phase lag become the answer.

Takeaway *Run unsteady only when the question demands it: gusts, oscillation, dynamic derivatives, rotors. A slow angle sweep is a sequence of steady points.*

Rotation added to the unsteady problem

- Each blade section sees the sum of Ωr and the free stream; the inflow angle $\varphi = \arctan\left(V_\infty/(\Omega r)\right)$ varies along the radius, which is why blades are twisted [16, 17]. [REF-35], [REF-36]
- Blade geometry and section loads live in the **rotating** frame; the wake, the airframe and the performance numbers in the **inertial** one. Name the frame when you report a number.
- Everything unsteady still holds. Rotation adds geometry to the wake, not new principles.



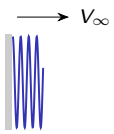
Propeller performance, and the helical wake

$$J = \frac{V_\infty}{nD}, \qquad C_T = \frac{T}{\rho n^2 D^4},$$
$$C_P = \frac{P}{\rho n^3 D^5}, \qquad \eta = \frac{J C_T}{C_P}$$

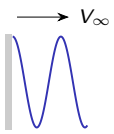
n in revolutions per second, D the diameter [16, 17] [REF-35], [REF-36]. At fixed J the non-dimensional picture is fixed; the rotation rate alone only rescales the Reynolds and tip Mach numbers.

The solver reports forces

It reports forces and moments normalised on the reference values you set; J, C_T, C_P and η are built by you, or by the post-processing (Guide 7).



low J: tight helix



high J: open helix

- The wake is a **helix** whose pitch is set by J: a low J packs the turns behind the disc, and each blade meets the wake of the others.
- The clock is the shaft: resolution in degrees per step, about 10 to 12 degrees, run length in revolutions, reference velocity the tip speed [6, p. 413].

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Part 3

The simulation workflow

Ten stages, in the order decisions constrain each other

#	Stage	The decision it owns
1	Case study and scope	what question the case answers, and what it does not
2	Matrix definition	which points are run, and why those
3	Water-tight geometry	blunt or sharp trailing edge, and where the components split
4	Surface mesh	where resolution is spent
5	Boundary conditions	which edges shed vorticity, and how much
6	Solver setup	what the solver is allowed to assume
7	Execution and monitoring	whether the answer has converged
8	Output definition and export	what evidence the run leaves behind
9	Verification and validation	whether the answer is right
10	Engineering analyses	what the answer means for the design

Takeaway *The stages are not a checklist to tick: a decision taken out of order has to be taken again.*

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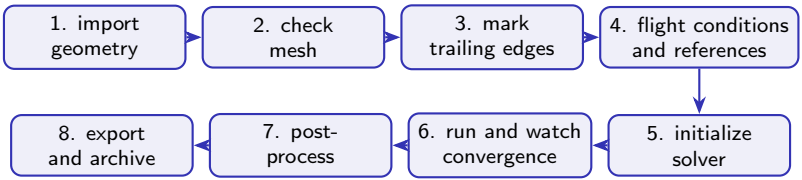
One session in the interface, and the lock in it



- **Initialisation is a lock.** It freezes the solver against the mesh and the boundary conditions as they stand, and fixes the solver mode and the symmetry claim [6, pp. 218-221].
- A runtime setting (angle, velocity, iterations) can change after it. A mesh or boundary change needs the initialisation removed and taken again. That is why boundary conditions precede setup [6, p. 411].

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Stages 3 and 4: geometry and surface mesh

Geometry

- **Water-tight** means the body closes, not the domain.
- Collapsed or blunt trailing edge: decided in CAD (Part 2).
- Components are split by the **boundary condition they will receive**, and by the loads you will want per component, never by CAD convenience.

Surface mesh

- Four sources: the tool's cross-section meshers, transfinite interpolation, the wrapper, or an imported mesh [6, pp. 72-75]. Only the first two regenerate in seconds.
- Faces go where the gradients are: leading edge, tip, junction, the row the wake leaves from [6, p. 62].
- A mesh convergence study is an obligation, and it is affordable.

Takeaway *The mesh carries the boundary conditions. A boundary is a decision about what you will be able to ask for later.*

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Stage 5: boundary conditions are marking

- **Farfield**: there is none to set. **Walls**: every face is a slip wall once meshed, switched to no slip by the solver when the boundary layer is active [6, p. 164].
- What remains is **marking** where that default is wrong: trailing edges, with their type (Part 2); base regions; wake termination nodes; and, when the case needs them, actuator discs, inlets and outlets, custom free-stream fields [6, pp. 164-197].

Auto-detection is a proposal

The solver can detect trailing edges; it proposes, you decide. Inspect every marked edge before initialisation: a split trailing edge is two edges, and a missing one is silent.

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Stage 6: what the solver may assume

Symmetry	What it asserts
None	nothing: the mesh in front of the solver is the whole problem
Mirror	a symmetry plane in the flow, not only in the geometry; false as soon as the sideslip is not zero
Periodic	an onset flow the same at every azimuth, plus a copy count; false as soon as the angle of attack is not zero

- **Coordinate systems first**: loads are reported in one, and a moment without its frame and point is not a number.
- **Reference velocity, area and length** normalise every coefficient. Set them; never inherit them.
- **Convergence is three controls**: an iteration cap, a residual threshold, and how long the residual must stay below it [6, pp. 202-203]. Viscous settings change the answer; leaving them off is a decision too.

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Stages 7 and 8: run, watch, and declare the outputs

Execution and monitoring

- **Converged is a state that was held**, not a number that was touched. A run stopped at its cap ran out of iterations.
- Unsteady asks twice: the residual inside each step, and the history of the quantity you want. They are independent.
- Periodic: judge the **per-revolution** statistic, not the sample.

Output definition and export

- **An output not declared was not computed**: sections, probes and plots are set before the run.
- Symmetry-load doubling changes what the solver computes. Two runs set differently are not the same quantity.
- Every coefficient carries a normalisation: record it with the number.

Takeaway *Recovering a variable that was never declared means running the case again, which for a rotor is the most expensive mistake available.*

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Stages 9 and 10: is it right, and what does it mean

- **Verification**: the solution against a theoretical anchor and against itself. A finite-wing lift slope, a span efficiency, a mesh and a time-step study, a sector against the full wheel.
- **Validation**: the solution against measured data, inside the envelope where the method has been compared with experiment [13, 14]. [REF-32], [REF-33]
- An error that scales the whole solution divides out of a ratio. An efficiency can agree while thrust and torque are both off: check the forces, not only their ratio.
- **Engineering analyses** use the answer: derivatives, trim, installation deltas, component breakdowns. They inherit every assumption of stages 3 to 8.

Takeaway *A mid-fidelity number is defensible when its build, its settings, its convergence and its verification travel with it.*

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Part 4

pyflightstream on the workflow

What pyflightstream is

- A Python driver for FlightStream, MIT licensed, installed from PyPI (`pip install pyflightstream`). FlightStream itself, and its licence, are separate.
- It **writes** the solver script from a command database per build, **runs** it, **reads** what the solver exported, and **post-processes** it into tables with their provenance.
- A study is a **workspace**: a folder with a run matrix and the input files the matrix cites. No Python is written to run it.



Takeaway *A row names things, and the package makes the link: a row never carries a path.*

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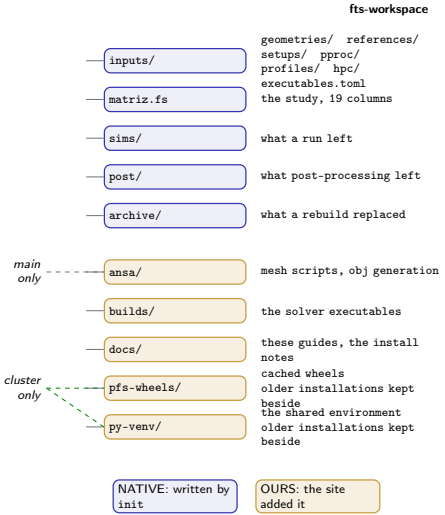
The workspace



The ten stages, and where each one lives

Stage	In the workspace	Guide
1, 2 Scope and matrix	one row of `matriz.fs` per study point or sweep: `DESCRIPTION`, `FLIGHT_CONDITION`, `SWEEP_VALUES`, `RUN`	2
3, 4 Geometry and mesh	made outside the package; the file sits in `inputs/geometries/`, the row names it in `GEOMETRY`; `pyfs-mesh inventory` reads its boundaries	2, 3
5 Boundary conditions	the trailing edge by file or by detection, base regions and wake nodes as keys; rotors and actuator discs in the reference file	3, 5
6 Solver setup	`inputs/setups/s<id>.toml` (column `SET`); lengths, moment point and frames in `inputs/references/r<id>.toml` (`REF`); `SYMMETRY` and `WORKFLOW` on the row	5, 6
7 Execution	`plan`, `run`, `collect`; `FS_BUILD`, `NCPUS`, `WALLTIME` on the row	2, 4
8 Output definition	`inputs/pproc/p<id>.toml` (`PPROC`): what the run exports, declared before it runs	6, 7
9, 10 Verification and analyses	`post` writes `post/`: polars, series, sections, probes, provenance; FSI couples a structure	7, 8

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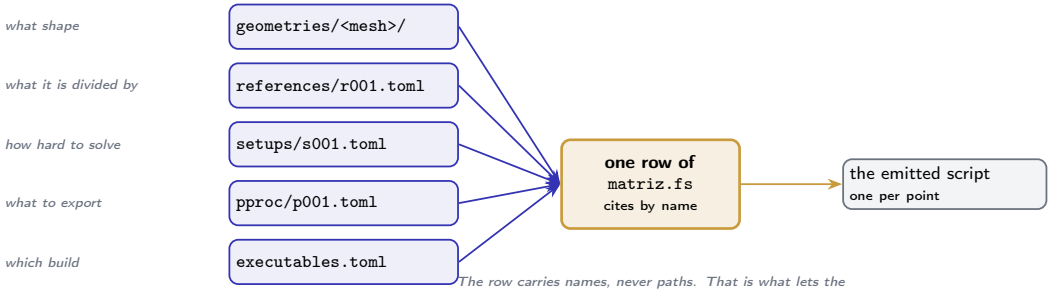
The row names things, the files define them



Takeaway *`REF`, `SET` and `PPROC` carry a file stem and `GEOMETRY` names the mesh: stated once, in one file, and every row citing it demonstrably used it.*

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Reference, setup, pproc: three files a row cites

`r<id>.toml`

What the coefficients divide by, and about which point: reference area and lengths, the moment point, aliases for groups of surfaces, custom frames, and one block per rotor or actuator disc (Guide 5).

`s<id>.toml`

How hard to solve and when to stop: iterations and convergence, the boundary layer and its coupling, the model and its initialisation, wake settings, and a raw table for any command without a key (Guide 6).

`p<id>.toml`

What the run exports, and how post reads it: loads, sections, probes, plots, the log last; the groups and derived columns post reduces with. The averaging window belongs to the row (Guides 6, 7).

- The flight condition is a cell of the row, not a file: Mach, speed, Reynolds number, altitude, a temperature offset, each a constraint on one flow state [1].
- Any key only some rows need goes in the row's free cell, `VAR_NAMES_VALUES`.

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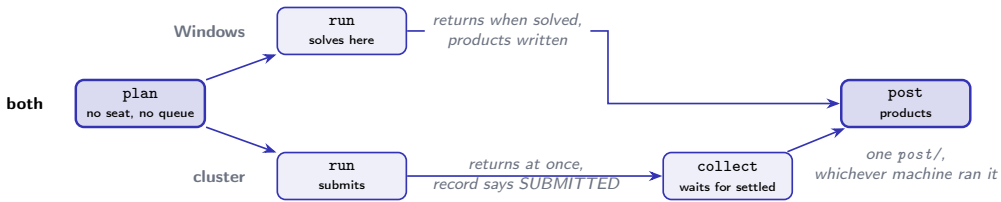
Four stages of a run




```
pyfs-matrix plan    matriz.fs --workspace . --fs-version 26.123   # no seat, no queue
pyfs-matrix run     matriz.fs --workspace . --fs-version 26.123   # solves, or submits
pyfs-matrix collect --workspace .                                 # cluster: settled outputs
pyfs-matrix post    matriz.fs --workspace .                       # rebuilds the products
```

`plan` validates every row against the build's command database and writes the receipt `run` refuses to start without (Guide 2).

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Four workflows, one per kind of physics

WORKFLOW	What is solved	The physics of Part 2	Cost
steady	one converged steady solve per point; a sweep is one job	the steady problem: tangency, Kutta, the fixed wake	seconds per point
unsteady	a march in physical time, nothing turning	Kelvin and the starting vortex; the step as a wake dimension; a window to average	minutes
unsteady_rotor	the blades turn, the wake is shed in time	the helical wake; degrees per step, revolutions, a per-revolution window; the reference for any rotor	minutes to hours
qsteady_rotor	blades held still, the free stream turning about the shaft; sector or wheel	an isolated, axisymmetric rotor where the reduced frequency is small	seconds

- The row names its workflow; a key another workflow owns is refused by name at `plan`. Costs are orders of magnitude on one workstation [20].
- Guide 2 carries the decision chart, the quasi-steady rotor in depth, and when its answer stands for the turning blade.

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Storage and sync

What a run leaves

- `sims/`: one folder per matrix row, `sim_<POL>`, with the scripts and one datapoint folder per point: the saved simulation and the solver's exports.
- `post/`: the products, rebuilt by `post` with no seat.
- `archive/`: whatever a rebuild replaced.
- `runs.json`: the record of every run, with its state.

Two workspaces, one main

- A workstation workspace for planning, one point, looking at results; a cluster workspace for long marches and many points.
- `pyfs-workspace sync`, run on the main, brings the cluster's runs home at a chosen level; it previews unless told `--apply`, and never copies a mesh [2].

Takeaway *You never edit anything under `sims/` or `post/`. If a number there is wrong, an input is wrong.*

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Part 5

The guides

Nine guides, and when to read each

	File `pyfts-guide-`	What it covers	Read it when
1	`01-fts-overview`	the solver, the workflow, the map	before anything else
2	`02-workspaces`	the tree, the inputs, choosing a workflow, running, two workspaces and sync	you set up or run a study
3	`03-gui-to-pyfs`	every step of a GUI session, and the key that takes it	you know the interface
4	`04-cheatsheet`	every command and option, then one page per stage	you need a command, not the explanation
5	`05-references`	lengths, the moment point, aliases, frames, rotors, actuator discs	you write a reference file
6	`06-solver-setup`	the setup file, its keys and the solver commands behind them	you tune how a point is solved
7	`07-pproc-definitions`	what every product, reduction and window means	you read or plot a result
8	`08-fsi`	the fluid-structure loop, the structural input, calibration, limits [22]	a structure deforms under load
9	`09-python-environment-offline`	Python, a virtual environment and the package with no internet	once per offline machine

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Four ways through them

A first study

1, then 2 (Parts 1 to 11), then 5 and 6 for the files you cite, then 7 before you plot, with 4 beside you. The package page "Getting started" is the shortest path to a first run [21].

From the interface to the workspace

1 (Parts 3 and 4), then 3 side by side with your own session, then 6.

A rotor

1 (Part 2, rotation), 5 (the rotor block), 2 (choosing a workflow and the quasi-steady rotor), 7 (per-blade, phase-locked and window products); 8 for a blade that deforms.

Installing and operating

9 on each machine without internet, then 2 (the cluster, two workspaces and sync, space on disk).

Takeaway *Each guide is written for one version of the package; its title page says which.*

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Where to practise, and how to cite

A public practice geometry

- **SMI**: an airframe geometry, wing and wing-body, published for practice [18].

Where to take a question

Solver behaviour to the vendor, with the build and the page. The driver to the repository, as an issue.

Citing the tool

Geovana Neves. *pyflightstream: version-aware, didactic Python driver for the FlightStream panel-method solver*, 2026. `https://github.com/nevesgeovana/pyflightstream`. Concept DOI: `10.5281/zenodo.21482924`.

The Python library

For scripts written in Python rather than a matrix: the library guide, `pyflightstream_user_guide.tex` in the repository's `guide/` folder.

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[21] Geovana Neves, *pyflightstream documentation*, page "Getting started".
`https://nevesgeovana.github.io/pyflightstream/latest/getting-started/`

[22] Geovana Neves, *pyflightstream documentation*, page "FSI in a workspace".
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