Test any published attitude control law on your bus.

Without reimplementing it.

Generalized Attitude Control for Small Spacecraft

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Full paper

1 The porting problem

Published controllers are derived for one actuator set, pointing goal, orbit, and disturbance model. Porting one means reproducing the paper, validating the implementation, then changing hardware and mission assumptions together.

weeks, per law

OLD PORT	GENERALIZED
reimplement the law	⟶ **write it once**
rebuild *their* setup	⟶ **validate in isolation**
mutate it for your bus	⟶ **configure adapter stages**

The law stays fixed. Everything else becomes configuration.

Steps 2 and 3 are where the weeks go. In both you change implementation and setup together, so a divergence could be a bug or a real result — nothing tells you which.

```
class MyLaw(ControlLaw):
    interface = LawInterface()   # full attitude + rate
    kp, kd = 2e-5, 2e-2

    def compute(self, q_err, w_err=None, **kw):
        return -(self.kp * q_err + self.kd * w_err)
ctrl = PipelineController(sat, MyLaw(),      # steps 2-3
    alloc_config=AllocationConfig(method='lp'))
```

That is the whole port.

2 The adapter: four transformations around your law

3 Actuator Selection

Screen hardware before simulation: rank tests whether the goal is controllable; torque geometry shows why.

	frozen	orbit	frozen	orbit
	Full attitude		**Vector pointing**	
1 MTQ	✗ 2/6	✗ 4/6	✗ 2/4	✗ 2/4
2 MTQ	✗ 4/6	✓ 6/6	✓ 4/4	✓ 4/4
3 MTQ	✗ 4/6	✓ 6/6	✓ 4/4	✓ 4/4
3 MTQ + 1 RW	✓ 6/6	✓ 6/6	✓ 4/4	✓ 4/4
3 MTQ + 2 RW	✓ 6/6	✓ 6/6	✓ 4/4	✓ 4/4
3 MTQ + 3 RW	✓ 6/6	✓ 6/6	✓ 4/4	✓ 4/4

boxed: the lightest bus controllable everywhere

Controllability $\operatorname{rank}\mathcal{C} = n$ ⟷ **Torque geometry** $\mathcal{T}(t) = B_\tau(t)\,\mathcal{U}$

4 Torque Compensation

Add the feedforward the law omits; disable any term it already handles internally, so nothing is double-counted.

Nominal τ_{ref} ⟷ **Compensated** $\tau_{\text{ref}} + \tau_{\text{gyro}} + \tau_{\text{frame}} + \tau_{\text{dist}} + \tau_{\text{damp}}$

YOUR CONTROL LAW HERE

5 Control Law Transformation

Map native actuator commands back to the torque they represent, then re-allocate that torque to the installed hardware.

Actuator law $\mathbf{u}_{\text{law}} = f(x)$ ⟷ **Torque law** $\tau_{\text{ref}} = A_{\text{law}}\mathbf{u}_{\text{law}}$

6 Goal Selection

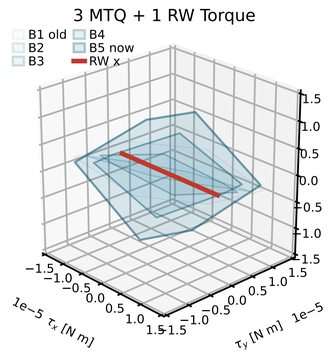
Translate goals outside the controller, so the law always receives its native error representation.

Quaternion goal $\bar{q}_e = \bar{q}_g \otimes \bar{q}^{-1}$ ⟷ **Vector goal** $A(q)\hat{b} = \hat{u}$

Every arrow runs **both** ways; numbers match the case studies below.

3 Choose the minimal bus

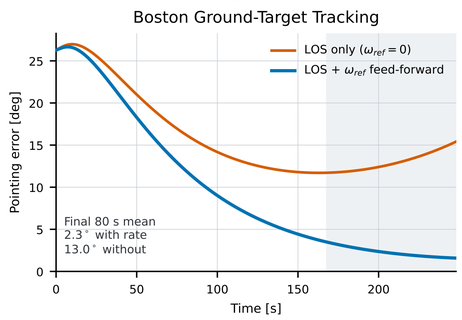
Find the smallest actuator set for a CubeSat-class mission: a 3MTQ+1RW torque volume spans 3D over the orbit, satisfying the full LTV rank condition before any simulation.



$\dim J_\tau \mathcal{T}(t) = 3 \iff \operatorname{rank} W_c = 6$: the swept magnetorquer planes plus one wheel axis fill torque space.

4 Track a moving target

A static-attitude pointing law follows a ground station: the adapter supplies the target-rate feedforward — the rotating-goal term τ_{frame} from (4) — that the original law did not include. The law still sees an ordinary pointing error.

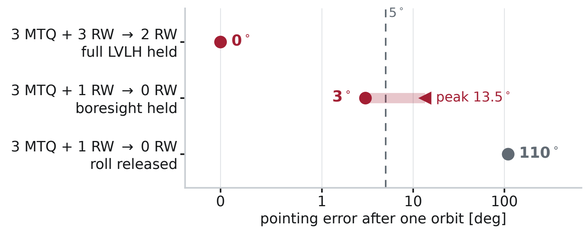


Final-80 s mean: 2.3° with rate feedforward, 13.0° without.

3U CubeSat (BeaverCube-2 derived), 4 kg; 663×693 km, 45°; 3×ISIS MTQ 0.2 A m²; 3×CubeWheel Small+ (2.3 mN m, 3.6 mN m s).

5 Survive a wheel failure

The wheel on a 3MTQ+1RW bus fails mid-orbit. The control law commands the same torque; allocation re-solves over the smaller polytope and redistributes to the survivors.

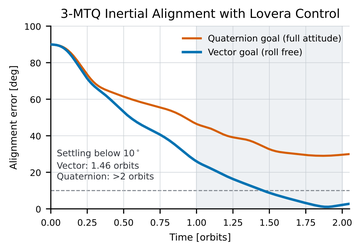


Three wheels degrade to two with no transient. One degrades to magnetorquers only — relaxing to a boresight goal keeps the pointing, with no tumbling:

Goal	Alloc.	Boresight	Rate
Full LVLH	LP	71.3°	1.01°/s
Full LVLH	QP	0.25°	0.06°/s
Reduced	LP	13.5°	0.07°/s
Reduced	QP	1.66°	0.04°/s

6 Relax the goal, keep the law

A 3MTQ-only satellite adapts a quaternion-pointing law to vector alignment: keep the payload direction, free the roll, and give the magnetic controller more authority.



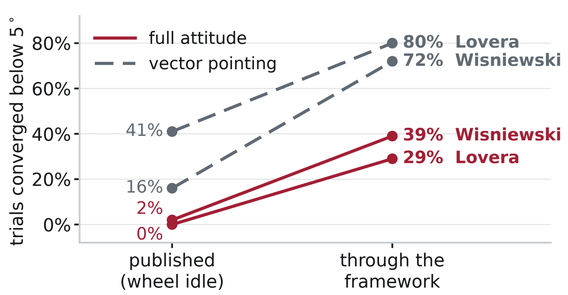
The vector goal settles below 10° in 1.46 orbits; the full-attitude goal does not settle within two. Same law, same bus — only the goal changed.

4 kg Lovera test satellite; 622×2602 km, 45°; 3×ideal MTQ 1.0 A m²; no reaction wheels.

	Full law	Reduced law
Full goal	direct	alternating sub-goals
Reduced goal	quaternion-set selection	direct
No goal	identity error	aligned vectors

7 Case study: two published laws, one pipeline

Lovera · Wisniewski (published MTQ laws, unchanged) **+** wheel **(3)** **+** compensation **(4)** **+** torque mapping **(5)** **+** vector goal **(6)** **+** LP ⟶ **results:**




```
law = Lovera_Law(J=sat.J_0, kp=2e-5, kd=2e-2)  # unmodified
mtq_only = PipelineController(sat, law)        # published
with_wheel = PipelineController(sat, law,      # + the wheel
    alloc_config=AllocationConfig(method='lp'))
```

```
class Lovera(ControlLaw):
    # law does its own w x (Jw + h), so
    # Stage 4 must not add it again:
    interface = LawInterface(includes_gyroscopic=True)
```

A law declares the compensation it performs internally; the adapter adds every term except those.

One law, four things changed (100 paired trials): actuator set 1% → 80% → 100%; goal type 49% → 83% at fixed hardware; inertia scale 100% across a 20× range; wheel failure absorbed by reallocation.

8 Try it

Runs in your browser

We help you port your law

```
pip install generalized-adcs
```

Open source, MIT licensed.
github.com/nscheuer/Generalized_ADCS

Ships the laws above, LP/QP/clipping allocators, MTQ and RW models, UKF-family estimators, IGRF-13. Bring a law, or bring a bus — we will help you port one.

References. [1] Wie, *Space Vehicle Dynamics and Control*, AIAA, 2008. [2] Lovera & Astolfi, *JGCD* 28(5), 2005. [3] Wisniewski, *IFAC* 31(22), 1998. [4] Pong & Miller, *JGCD* 38(6), 2015. [5] Hogan & Schaub, *JGCD* 38(10), 2015. [6] McKeen & Cahoy, *JGCD* 45(8), 2022. [7] McKeen, MIT PhD thesis, 2024. Simulation setup: paper §IV-A and the landing page.