

RECONSTRUCTION OF SAF PILATUS ACCIDENT WITH PARTIAL WING LOSS

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ABOUT THIS PROJECT

- proposed by the Republic of Slovenia MOD Accident Investigation Board (Col. M. Klavžar, head)
- carried out as applied science project MOD AIB / J. Stefan Institute

ABOUT THE AUTHOR

- Theoretical physics
 - **Three-body problem in quantum mechanics**
 - **Quasilinearization method for differential equations**
 - *NRC/Karlsruhe; NRL/Washington; HU/Jerusalem; U/Pittsburgh*
- High-performance computing in physics

NEW EXPERTIZE GENERATED

- real-time simulation (simulator-grade speeds); 3D graphics
- associate membership of military and civilian Investigation Boards



MAP



(image: AIB)



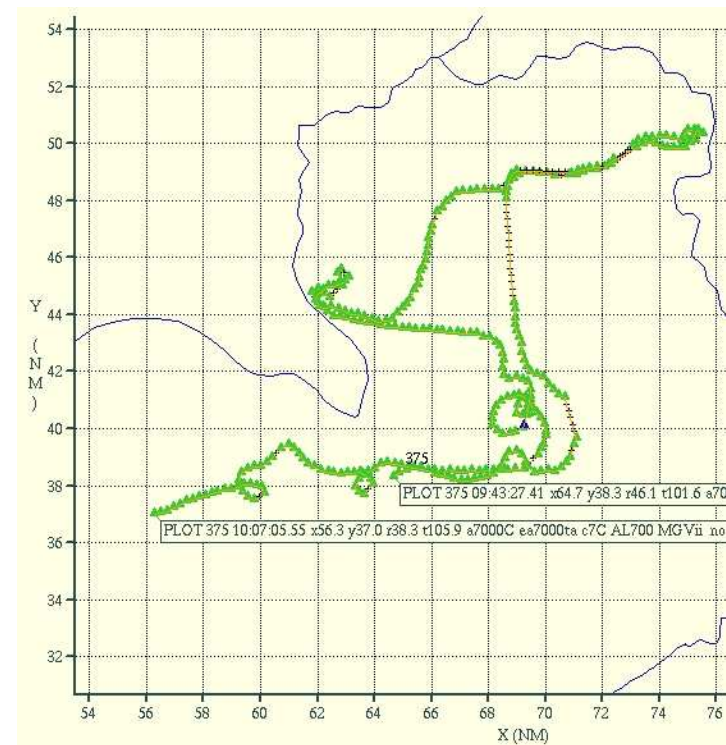
MISSION DATA

- type: low-altitude training
- aircraft: Pilatus PC-9
- engine: Pratt&Whitney PT6A-62
- 3287 flight hours

ACCIDENT DATA

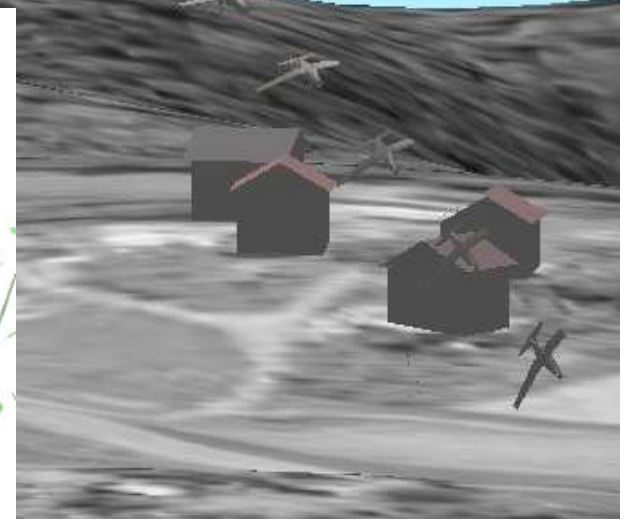
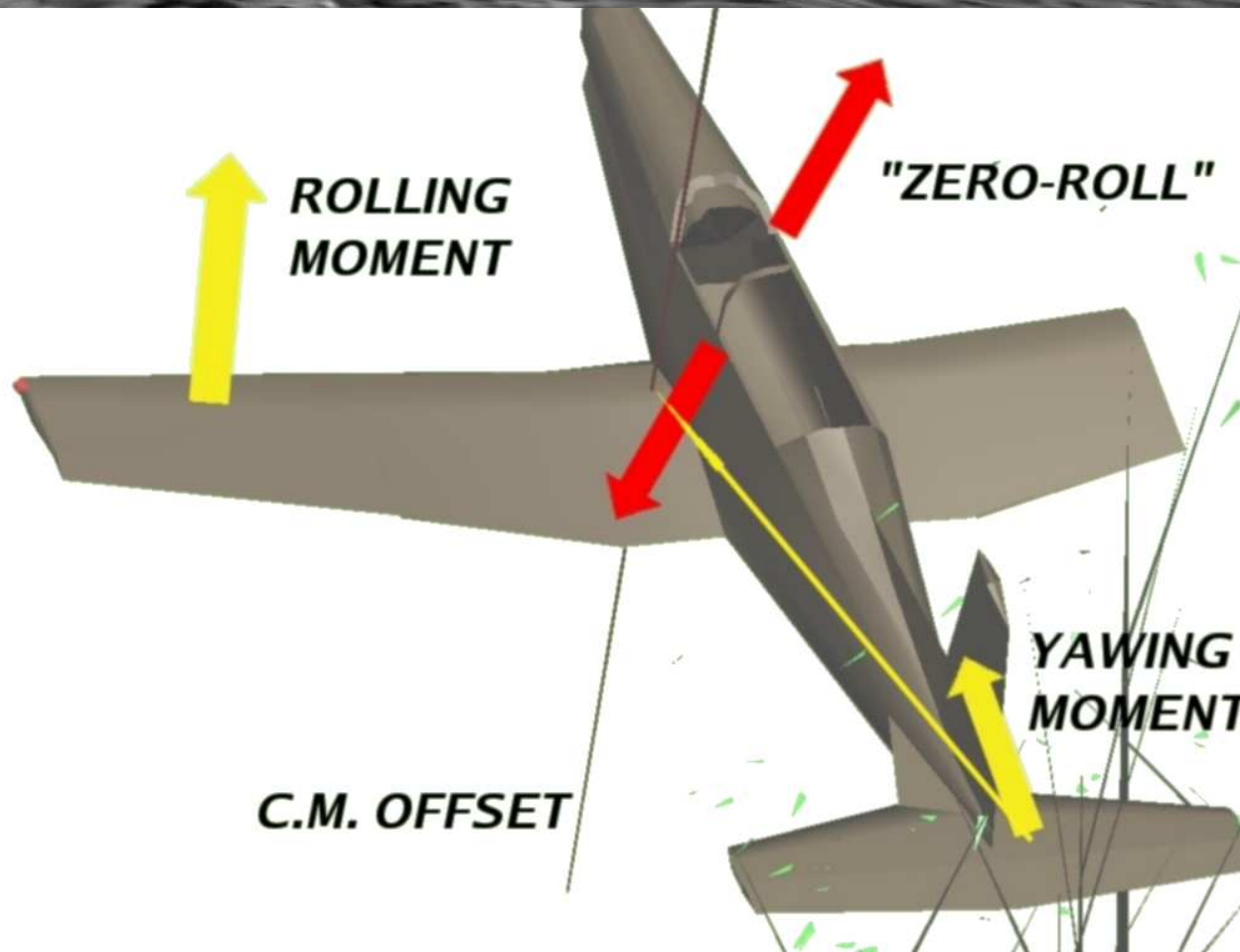
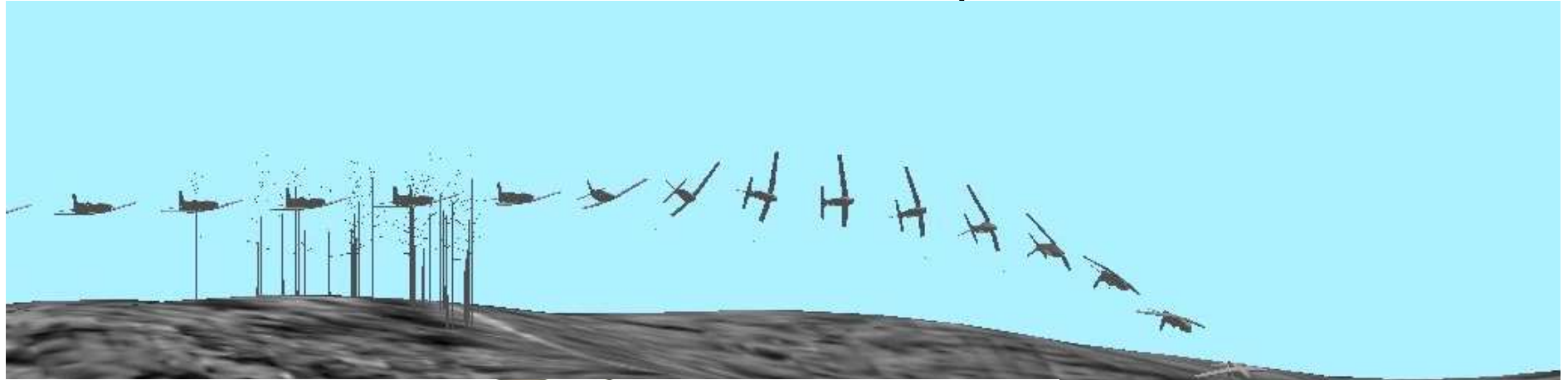
(image: AIB)

- time: 2004/03/03 10:07 (radar track end time)
- radar: departures from flight plan, high-G maneuvers
- witness: **nose-forward** flight after tree collision
- touchdown on left wing - minimum **270° roll**
- left aileron **not blocked**
- all systems OK





ACCIDENT: 5-IN. TREE TRUNK - 2/5 RIGHT WING LOSS



controls change

[Movie: MoD]



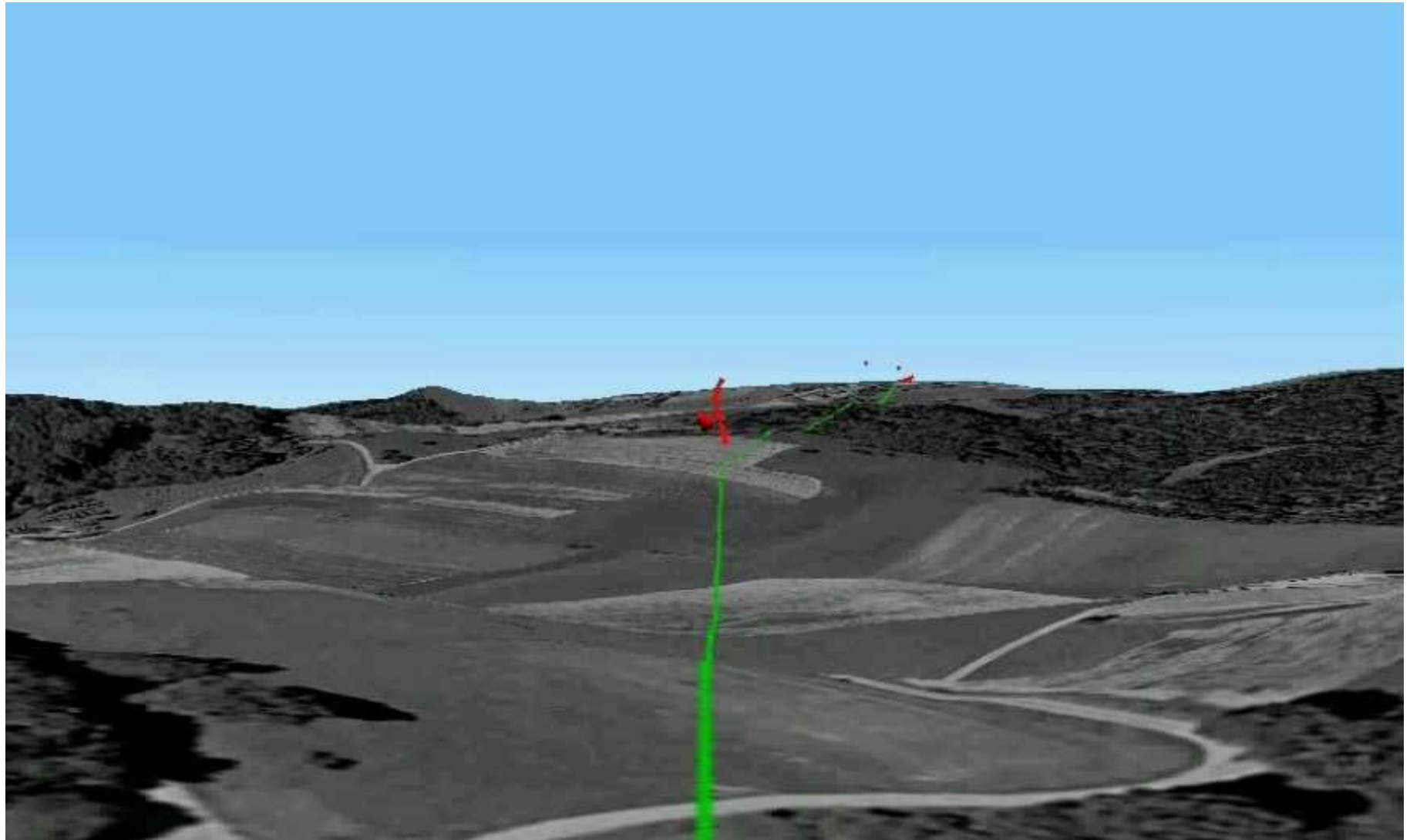
CRASH SITE



(image: AIB)



MoD: PRE-MISHAP FLIGHT (PART)



(movie: AIB)

AIB: INDEPENDENT DUAL-TRACK INVESTIGATION

- standard (STANAG / ICAO), including MEDICAL
- external, AERODYNAMICAL
 - to determine the role of human factors:

* **Q1:** did pilot **USE CONTROLS** after collision?

* **Q2:** was aircraft with 2/5 wing loss **CONTROLLABLE?**



PROJECT CHALLENGES

- need simulation code for **damaged/asymmetric aircraft**
- only \approx 6 months time
- incomplete aerodynamic data, none for **asymmetric a/c**
- **critical issue:**
 - project fails if trajectories depend strongly on the **hard-to-estimate tree collision FORCE**

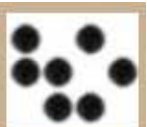
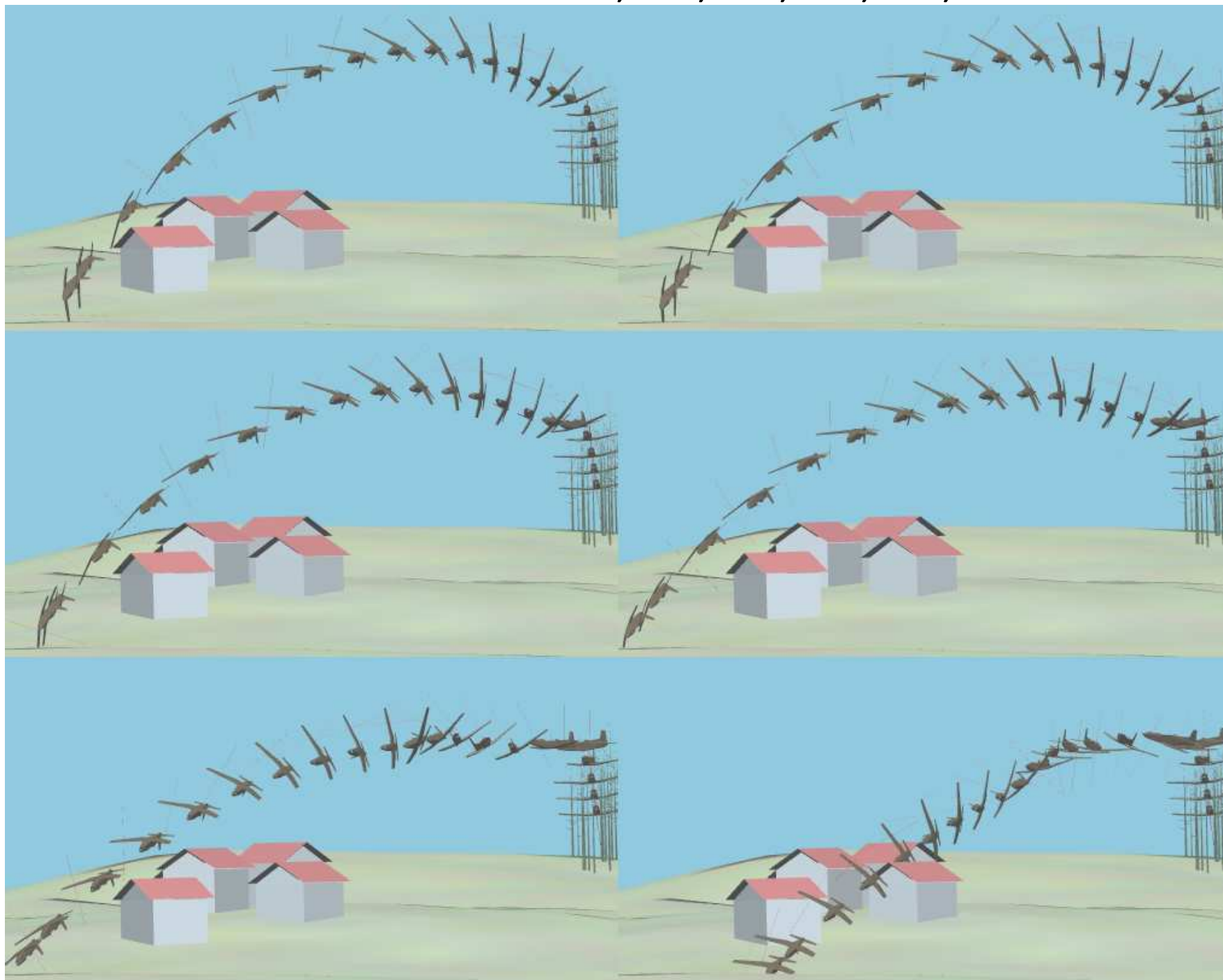


PROJECT APPROACH

- **to control physics**
 - write simulation code from scratch
- **compute** aerodynamic properties from more basic data
 - NACA airfoil database
 - **forces by segment**, vorticity, etc.
- **add physics by importance** until results stable
 - from “ballistics” ...
 - ... to prop moments, wing downwash



FORCE-INDEPENDENT: 10, 20, 30, 40, 60, 70 TONS



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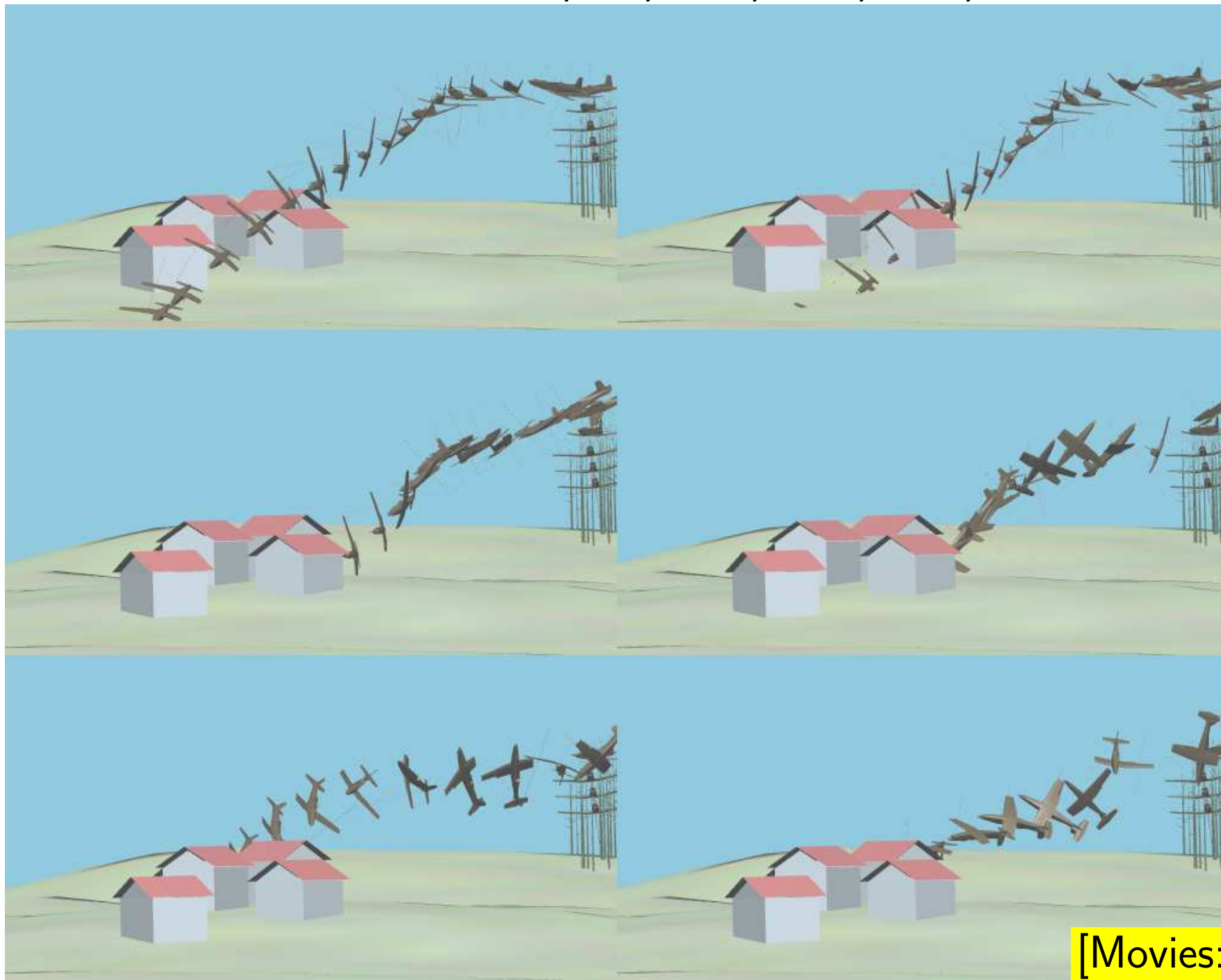


FORCE-DEPENDENT: 70, 80, 120, 150, 200, 300 TONS



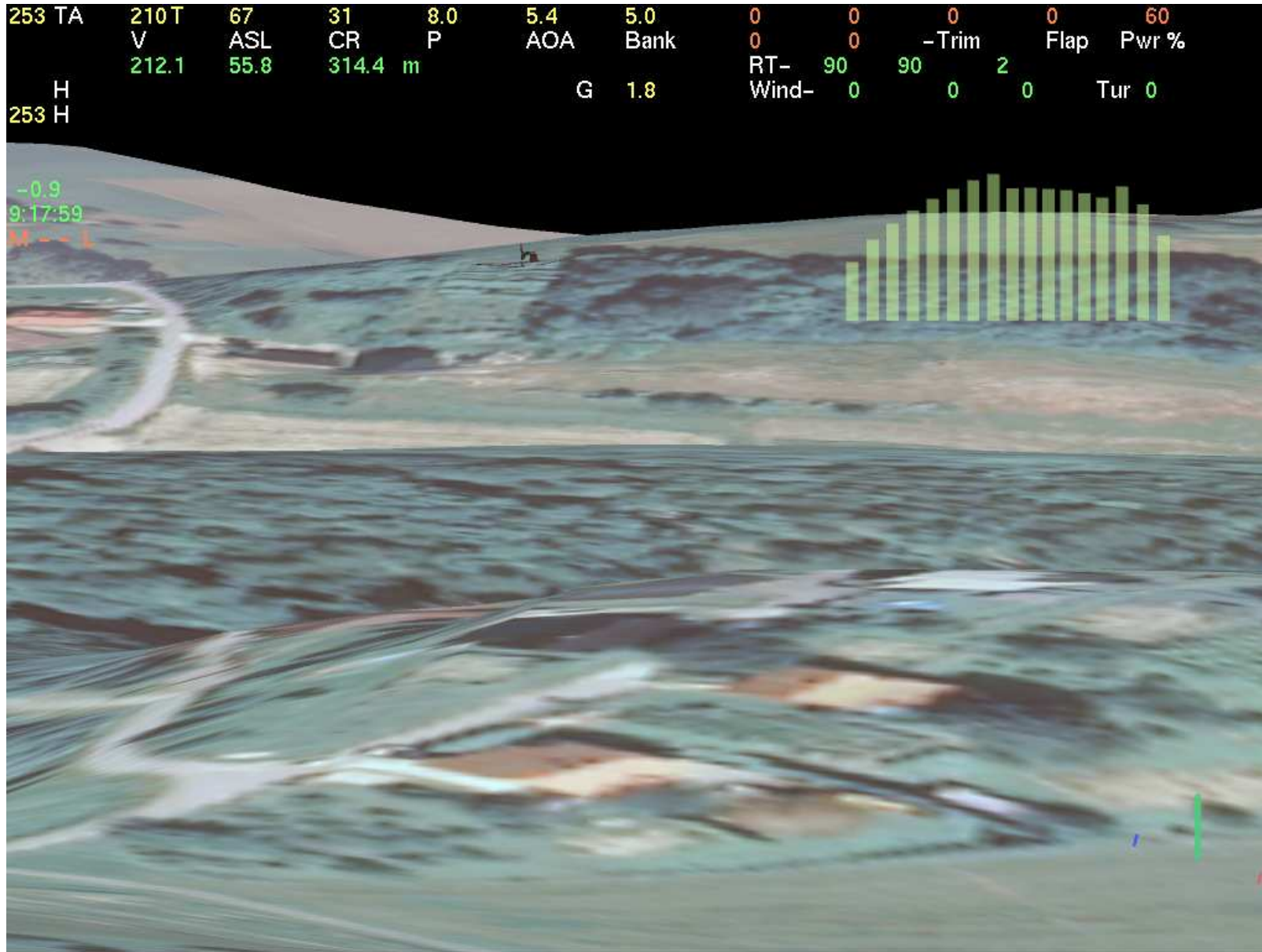
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[Movies: force]

TRAJECTORIES WITH INCREASING FORCE



THE BEAUTY OF PHYSICS

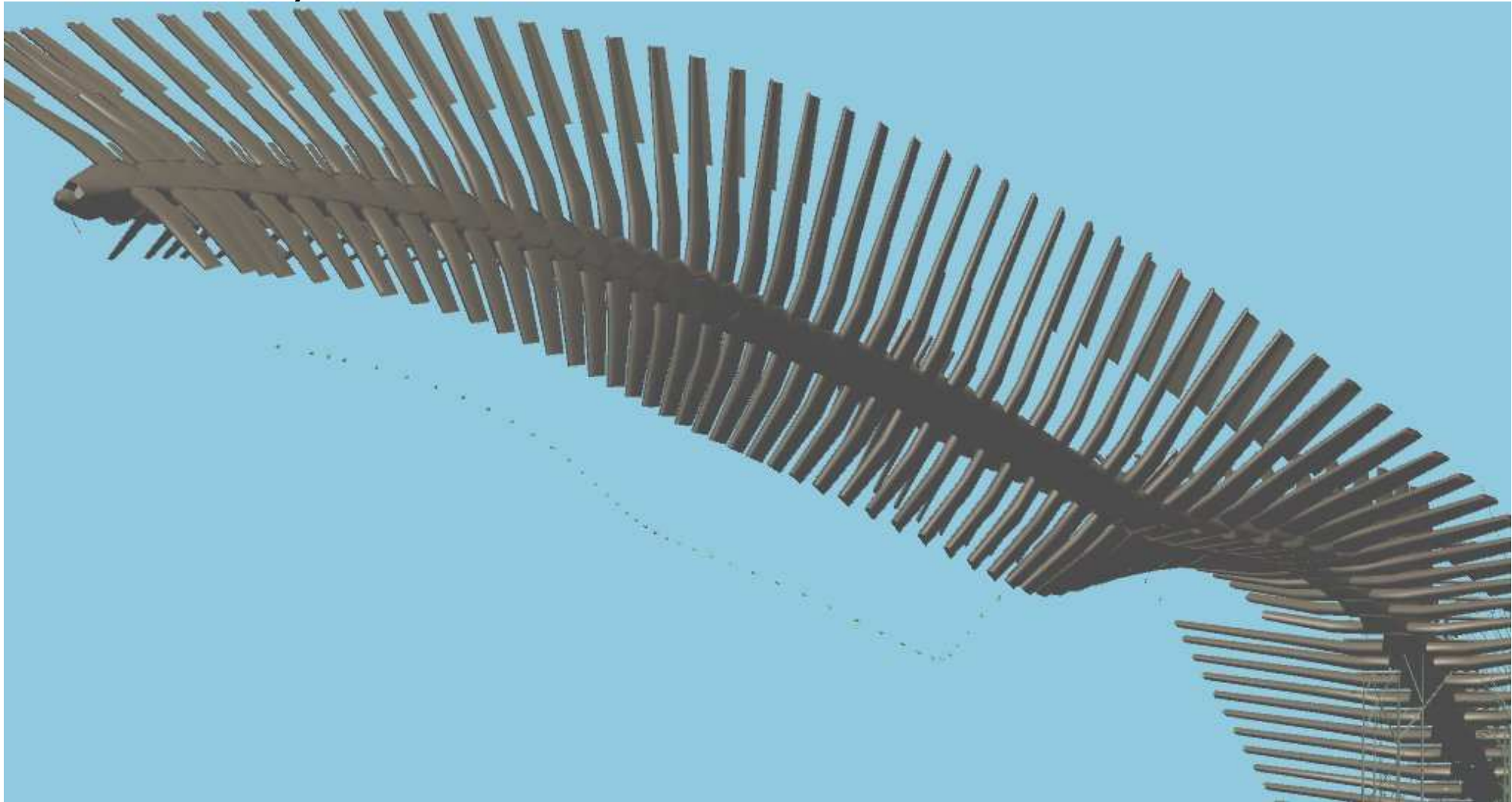
- **NO PILOT ACTION:**

- **force needs NOT be calculated**

- up to 30 tons: same final state
- above 50 tons: roll deviates
- above 70 tons: impact location deviates



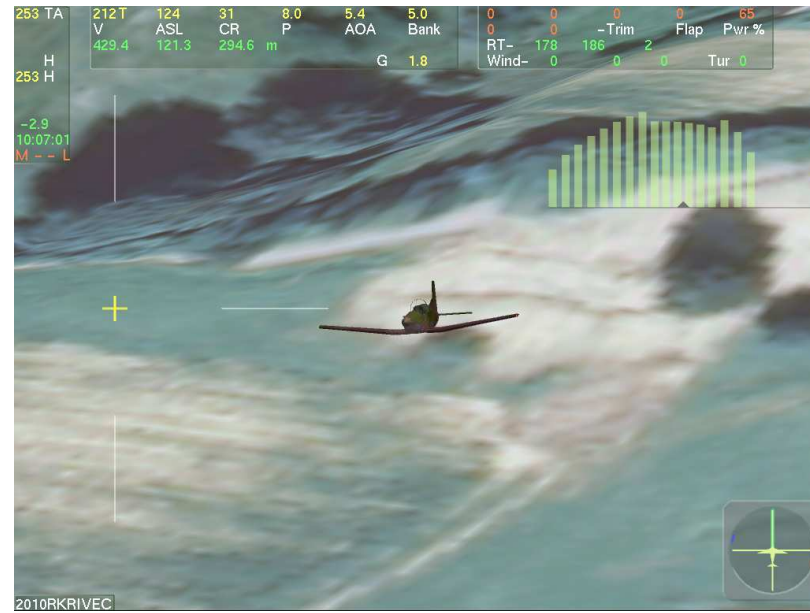
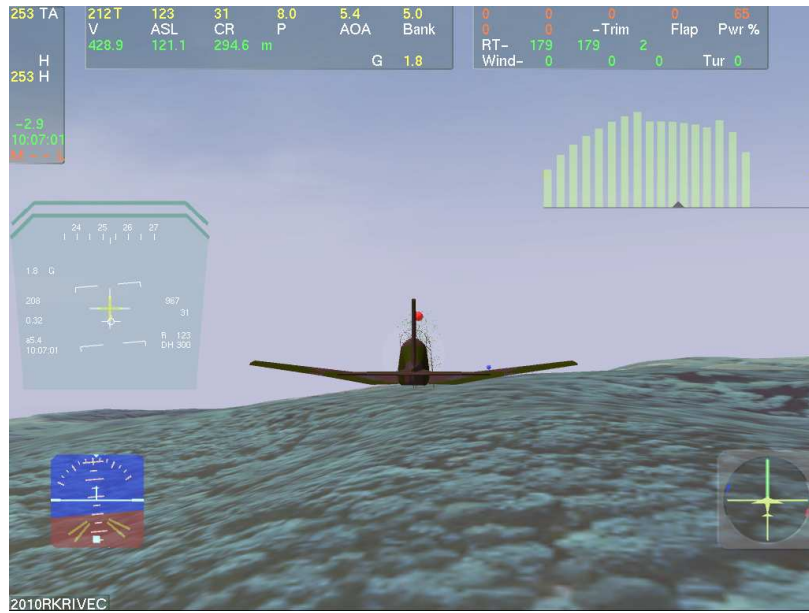
0–2 SEC. / 0.04 SEC. INTERVAL, FRONT VIEW



*Initially, lift drops – air “leaking” from under shorter wing
... roll accelerates, AOA increases (aileron moves freely).
... roll hesitates due to left wingtip negative lift, becomes steady.
Uneven fuselage trail: yaw stability.*



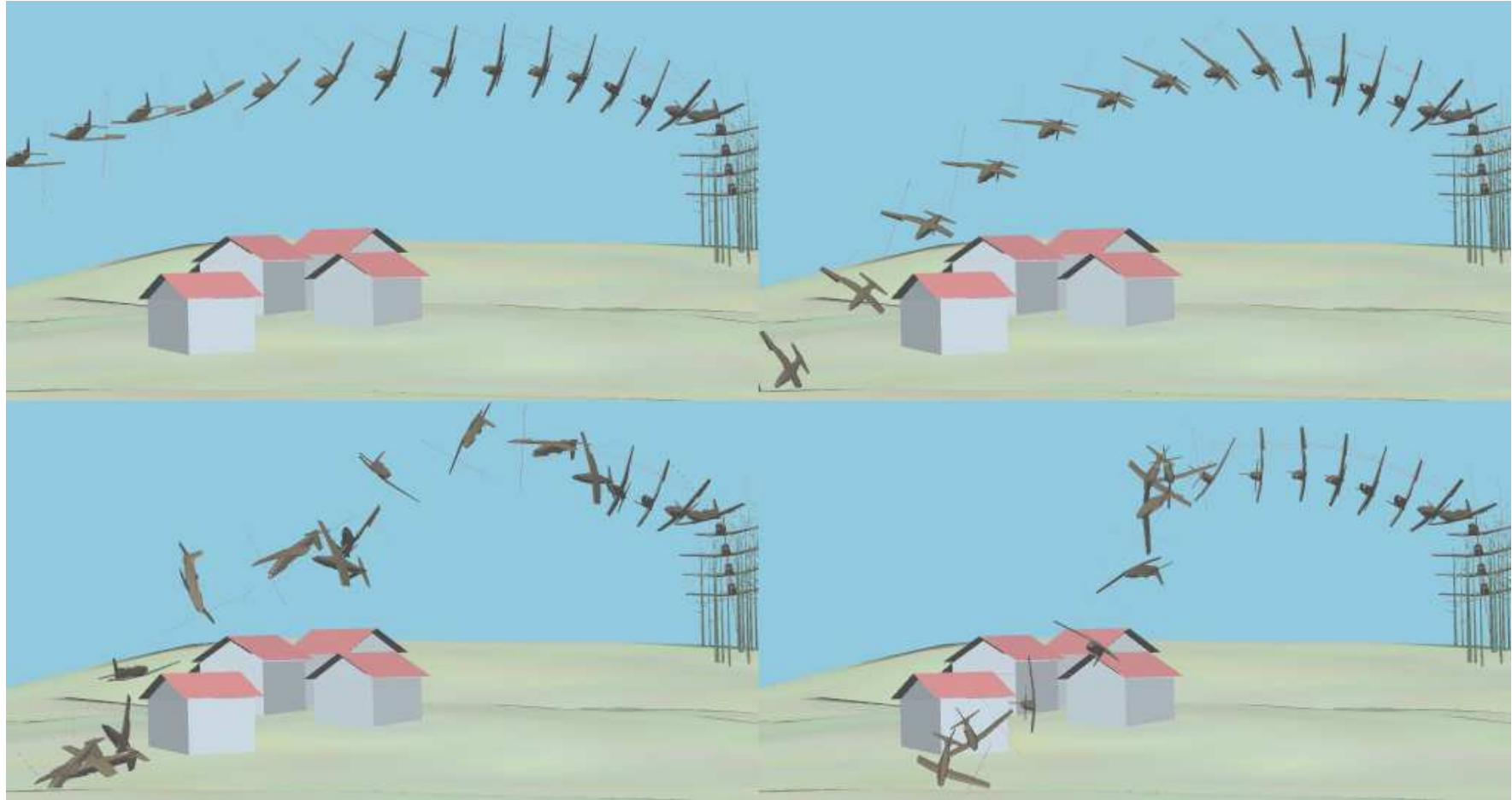
FINAL SIMULATION



PILOT ACTION AFTER COLLISION, FORCE 30 TONS

left stick quickly

left stick, late

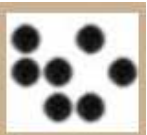


back stick

forward stick

SHORT-TIME RECOVERABLE!

[Movies: manual]



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HYPOTHETIC RECOVERY (R. K., MANUAL)

253 TA	212 T	94	31	8.0	5.4	5.0	0.1	0	0	0	64	
	V	ASL	CR	P	AOA	Bank	RT-	176	184	2	Flap	Pwr %
	533.3	153.1	285.0 m				Wind-	0	0	0	Tur	0
				G	1.8							

253 H
-3.9
10:07:00

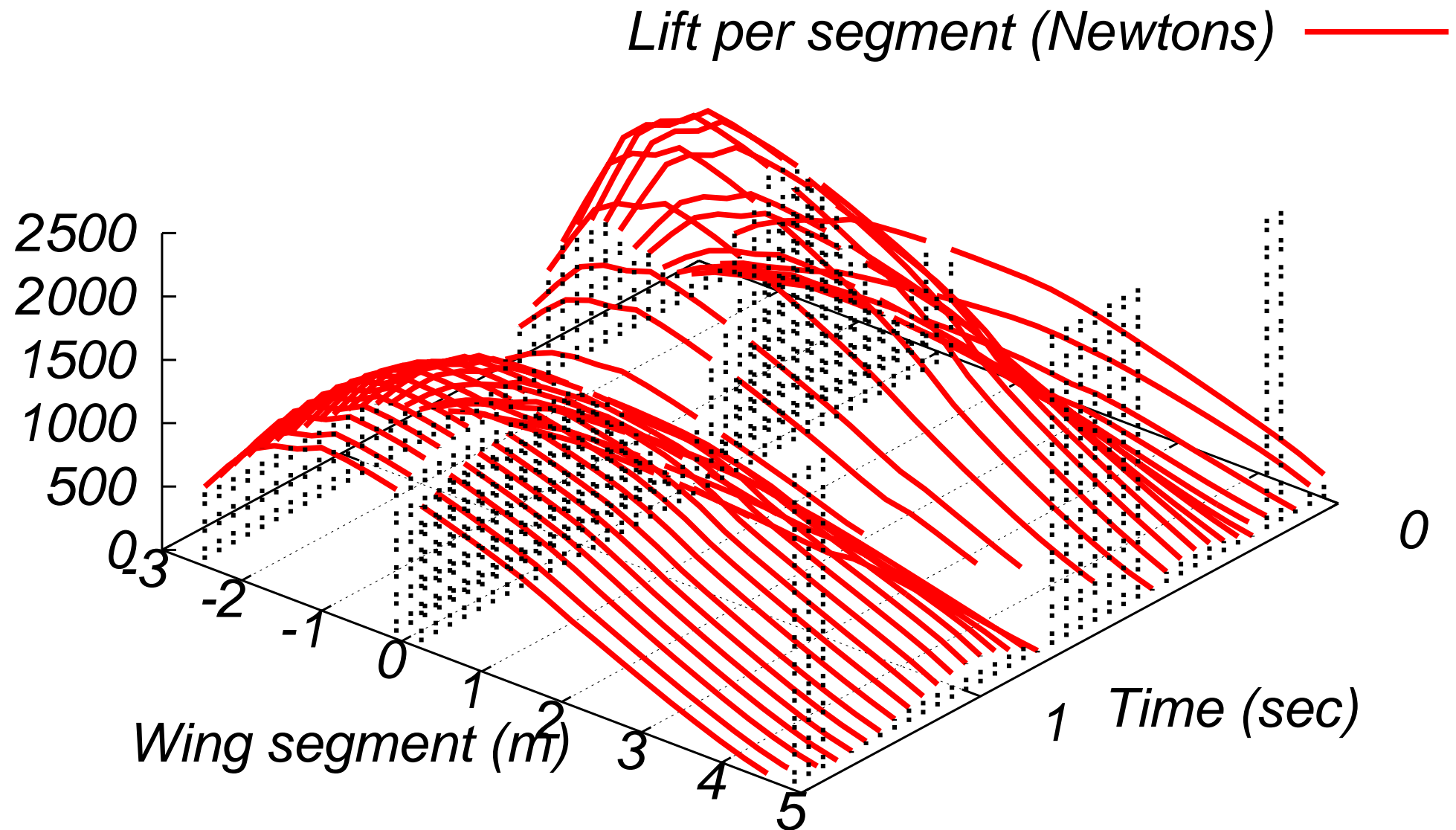
24 25 26 27

1.8 G
208
0.32
5.4
10:07:00

935
31
R 94
DH 300

2010RKRIVEC

WHY STILL CONTROLLABLE: SMALL OUTBOARD LIFT



0.5–0.8 sec: left wingtip lift negative, reduces fast initial roll.



SUMMARY - PHYSICS

- **A1:** pilot did not move commands
- **A2:** aircraft was controllable
 - a few seconds time
 - could level off, eject
- proper action on partial wing loss
 - back stick accelerates roll
 - to level off, use opposite and forward stick



SUMMARY - MEDICAL

- HISTOLOGICAL

- hypertrophic cardiomyopathy

- EXAMS

- JAA FCL-3 exam 2003, class 1 licence

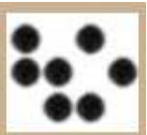
- last exercise ECG 1997



APPLICATIONS

- **Slovenian AF Pilatus PC-9 mishap, 2004** (1 fatality)
- **Slovenian AF PC-9 co-pilot ejection, 2008** (0 fatalities)
- **consulting work on 3D graphics, 2008/9** (Slo. power grid)
 - system already prevented one power grid outage
- **first Slo. flyer E. Rusjan 1911 crash reconstruction, 2008** (1 fatality)
- **civilian small-plane crash in central Slovenia, 2009** (in progress, 2 fatalities)





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DEMOS

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