Lecture 8

VJ 101
and
VAK 191B

VTOL Aircraft

Find attached the throttle quadrant. DHC-7 is Transport Category (Part 25?)

Note, standardized layout, left to right

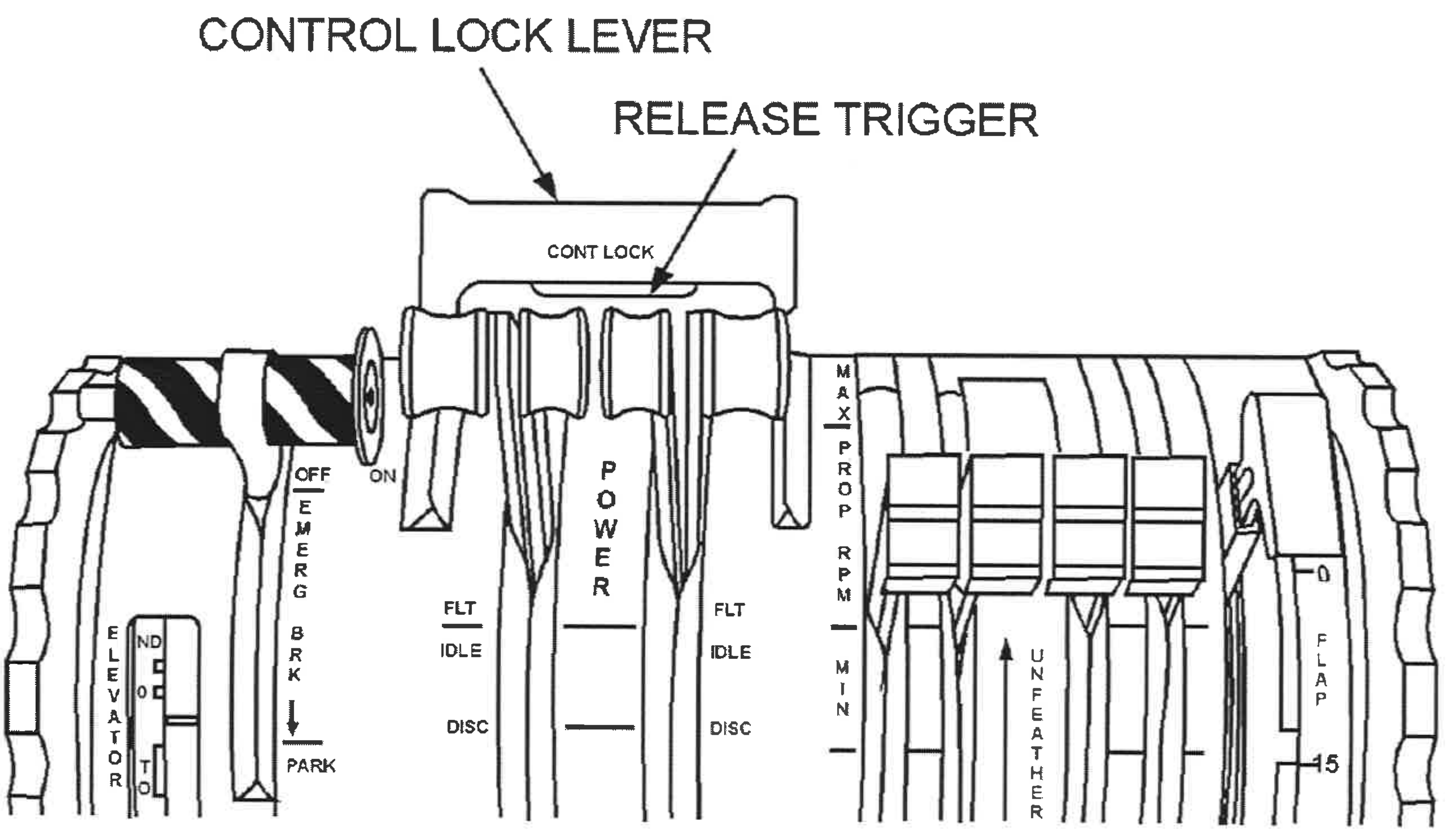
(1) Trim Wheel and indicator
(2) Parking Brake
(3) Power quadrant and Control Locks
(4) Propeller RPM levers (combined with fuel cutoff) which mimic illustration in CFR
(5) Flap Selector
(6) 1st Officer's Trim Wheel

All controls labeled per CFR, Landing Gear handle (not shown) is on panel to the upper right of quadrant (certified as a 2x pilot aircraft)

Speaking of controls locks and "warning if engaged" (28:44 in Lecture 009)

The first turbine modified DeHavilland DHC-4 crashed specifically due to the pilots' failure to disengage the control locks. https://www.youtube.com/watch?v=Jpq09_ak_ZM

However, the DHC-7 control locks are actuated by a metal "bar" across the power quadrant which prohibits the pilot from setting takeoff power without disengaging the control locks.


CONTROL LOCK LEVER
RELEASE TRIGGER
CONT LOCK
OFF
ON
EMERG
BRK
PARK
ELEVATOR
ND
0
TO
FLT
IDLE
DISC
POWER
FLT
IDLE
DISC
MAX
PROP
RPM
MIN
UNFEATHER
FLAP
0
15
GPD0344

In the 1960s, the German Airforce had a problem. The front line fighters required dedicated airfields with long runways. (Ex. F104 liftoff at ≈190^{kts})

Just a few nuclear blasts could knock out their entire airforce. Even a few carefully placed conventional bombs could prevent T/O. (See: Img 91).

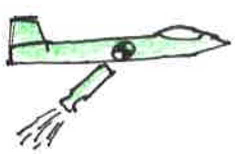
Solutions:

- Disperse and Decentralize
- ↓
- VTOL

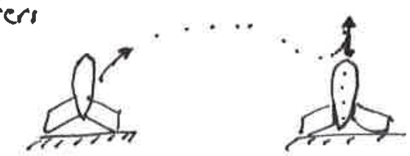
Q: How do you design a front line air superiority fighter with F104 performance in a VTOL configuration?

A: F-35 is still having deployment issues using modern materials. (present day)

A: F104 "Zell" ZLL (zero length launch) .... Landing?



A: Tailsitters

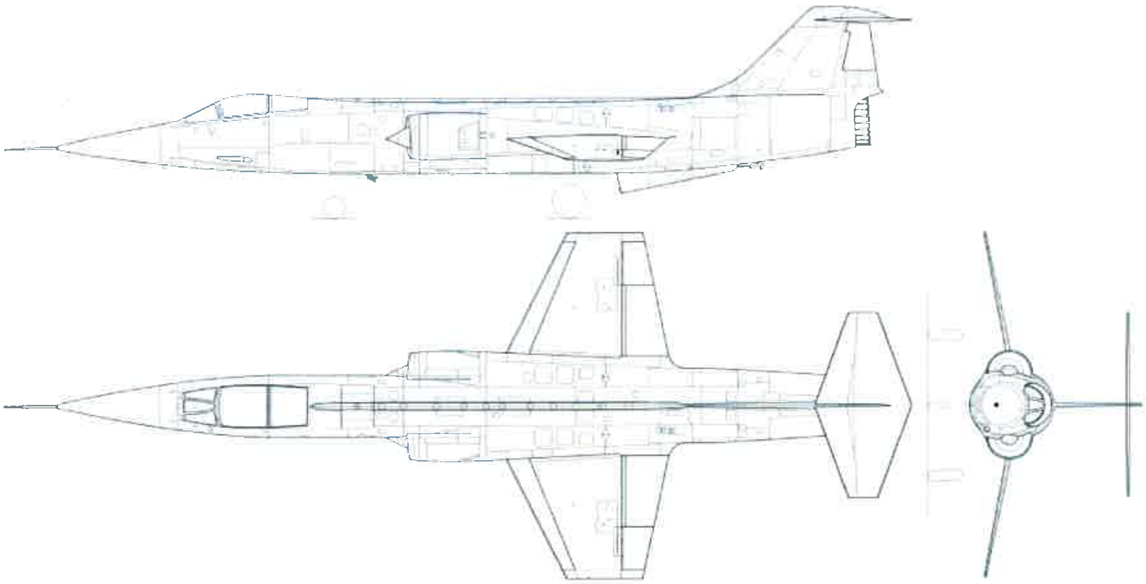


problem:
- Sears-Haack says "long and slender" for high Mach aircraft.
- Landing stability of tailsitters says "wide and short".

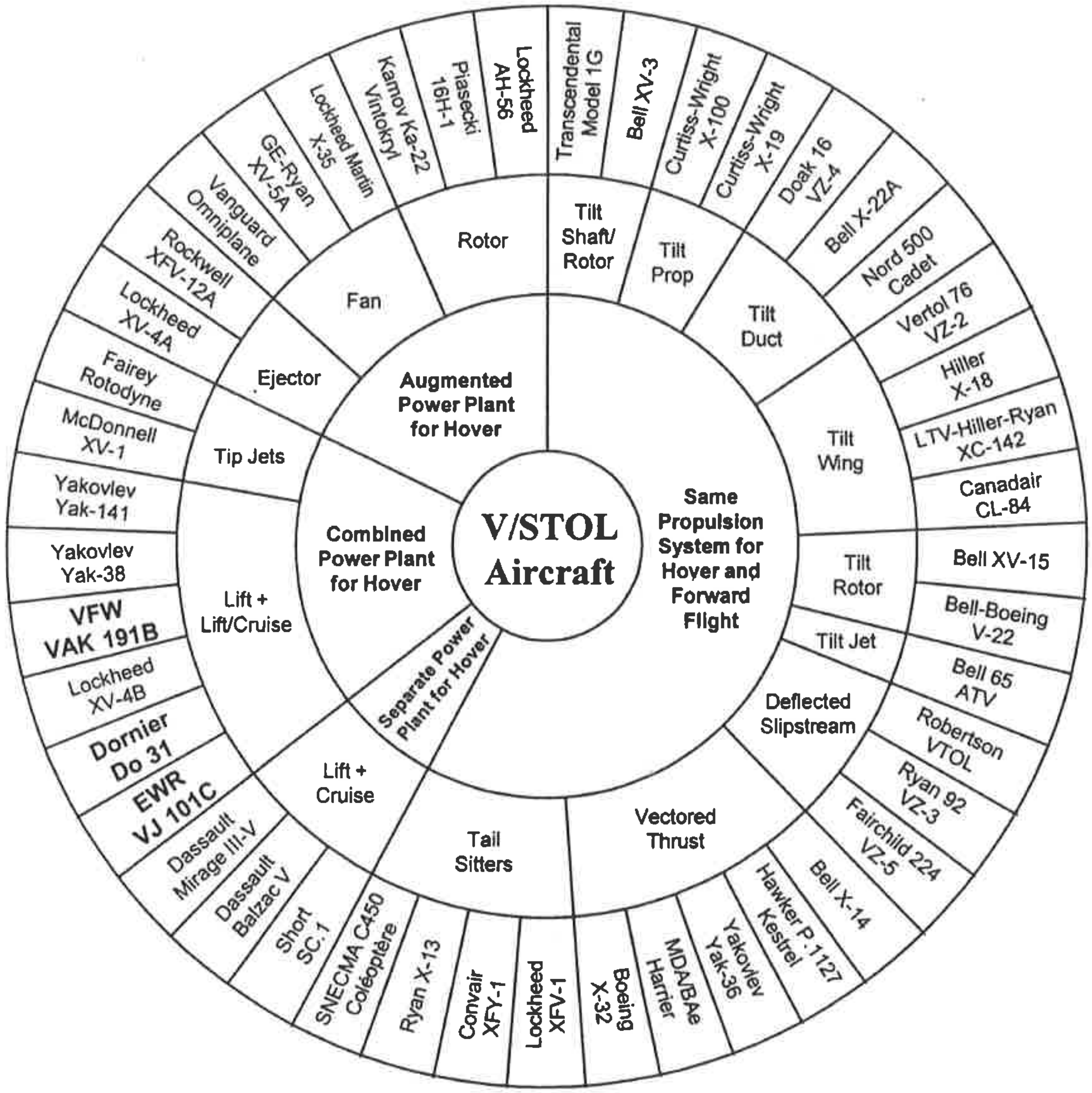
A: Vectored Thrust

VJ 101: tilt the cruise engines

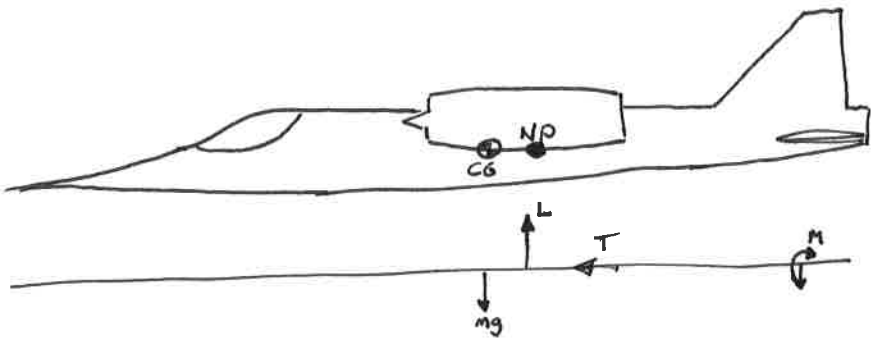
VAK 191B: Nozzle vectored thrust (eg. Harrier)



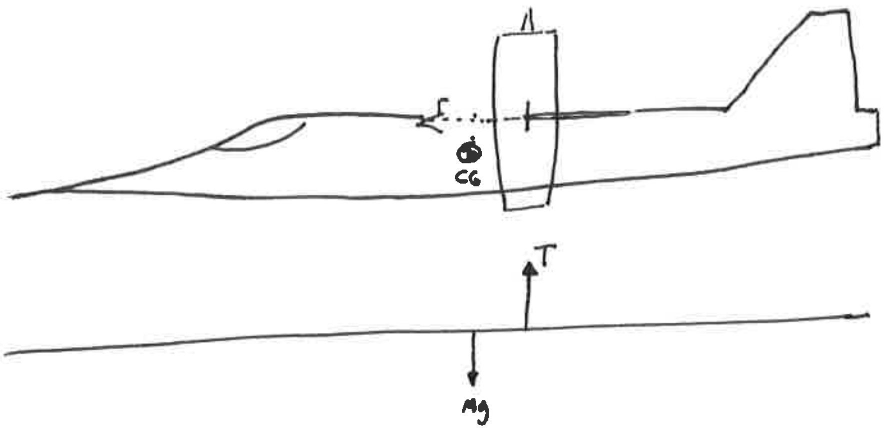
Figures from: German V/STOL Fighter Program
by Albert C. Piccirillo. AIAA, 1997



Forces and Moments (Conceptual VTOL system)

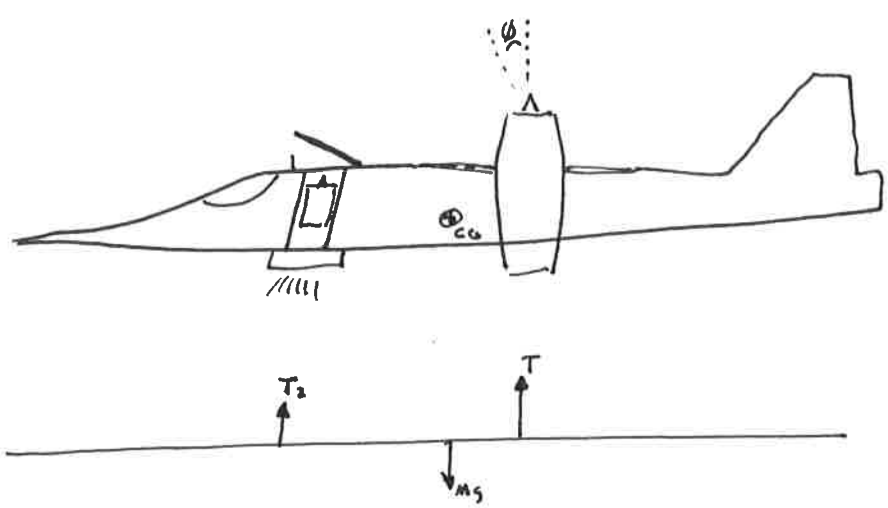


✓ Stable



✗ not balanced

- We clearly need an additional moment (Nose Up). Ahead of the CG would be most efficient. Add lift engines ahead of CG.



✓

- pitch control with lift engines
- roll control with wingtip (cruise) engines
- yaw control with differential tilt angle of wingtip cruise engines

Engine Systems

Thrust:

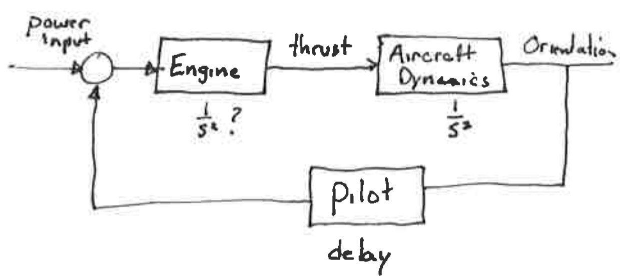
RB 145 axial flow turbojet   2750 lb dry   3650 lb Afterburner

The VJ 101 used thrust modulation for pitch and roll control (and yaw). Turbojet engines have a rotating core, which gives a spool up time of seconds.

Modern civilian engines are required under 14 CFR 33.73 ("engines") to provide 95% takeoff power within 5 seconds from idle.

Early jets were <u>not</u> known for fast power response.

How to design a control system?



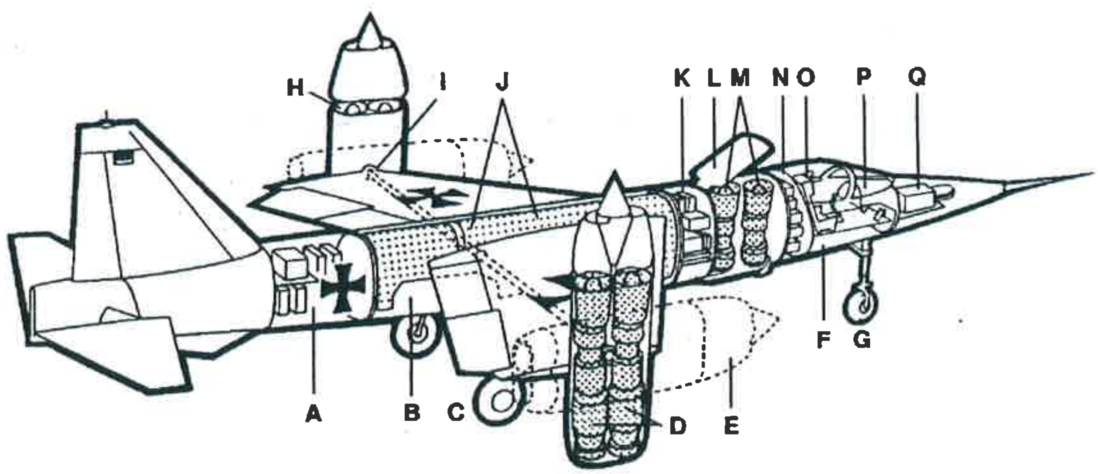
$$I\ddot{\theta} = M$$

$$H(s) = \frac{A(s)\,E(s)}{1 + P(s)\,A(s)\,E(s)}$$

Succesfull operation in VTOL mode requires slow steady maneuvers.

In practice, transition took 90 seconds from/to VTOL.

By Ralf Manteufel - http://www.airliners.net/photo/Dornier-VJ-101-X1/1230006/L/, GFDL 1.2, https://commons.wikimedia.org/w/index.php?curid=16659073



A. Equipment bay
B. Main landing gear bay
C. Rearward retracting main wheels
D. Afterburning RB.145 turbojets in swivelling nacelles
E. Nacelle in forward position
F. Nosewheel bay
G. Rearward retracting nosewheel
H. Nose section of nacelle raised for V/STOL flight
I. Hollow shaft on which nacelles swivel
J. Two-cell fuselage tank
K. Avionics bay
L. Retractable air intake door for lift engines
M. RB.145 lift engines
N. Avionics bay
O. Pilot ejection seat
P. Instrument panel
Q. Nose radar installation (planned)

Fig. 10 Cutaway drawing of the afterburner-equipped VJ 101 X2.

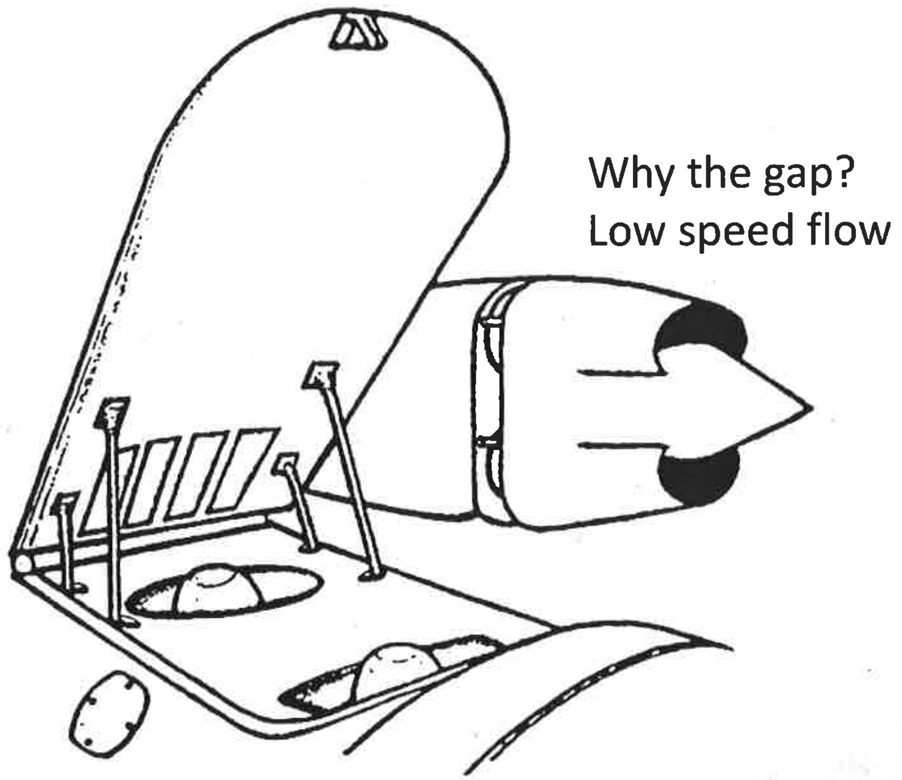


Fig. 12 VJ 101C fuselage and nacelle inlets in extended (low-speed) positions.

How do you evaluate and design the FCS?

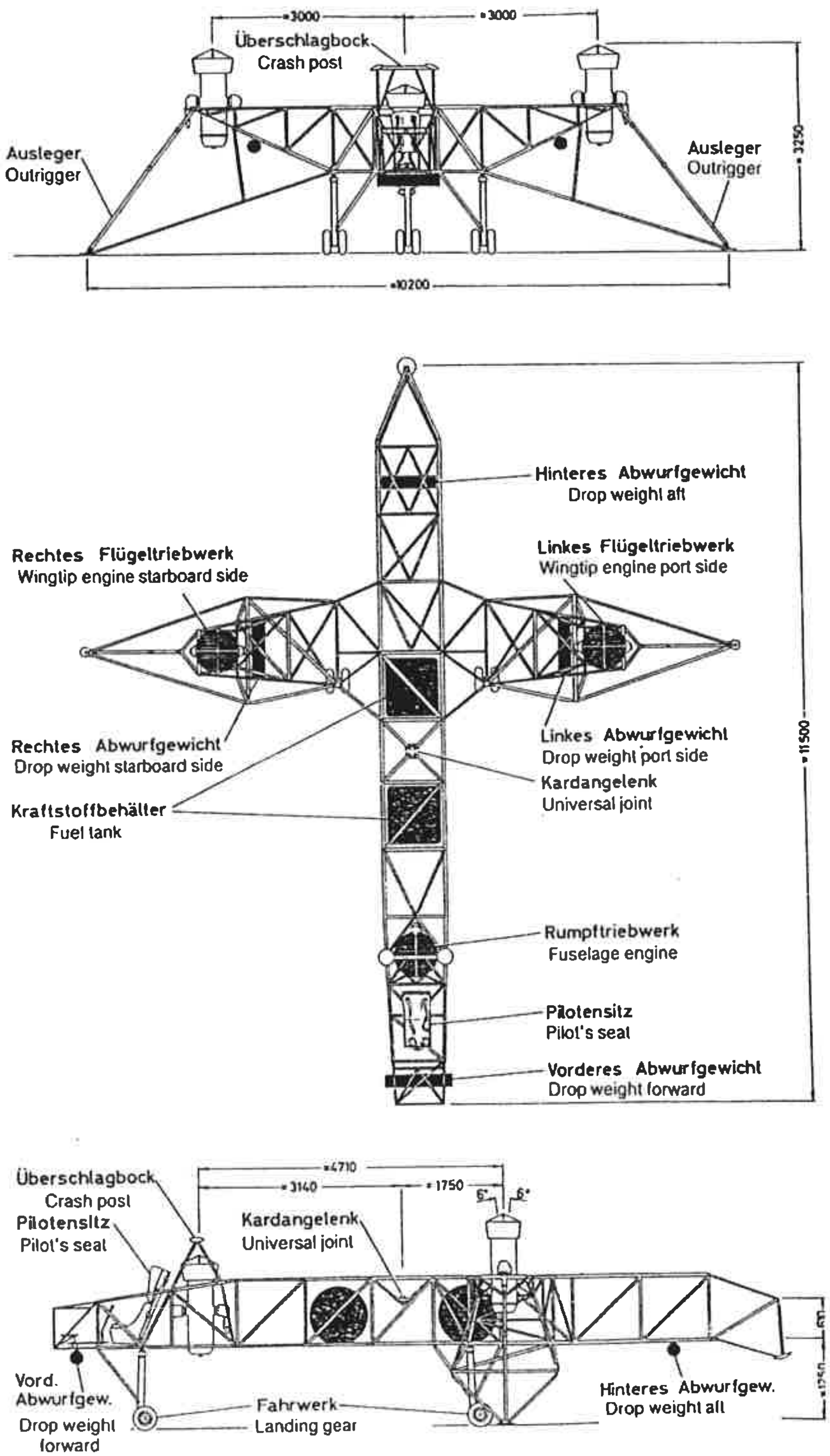
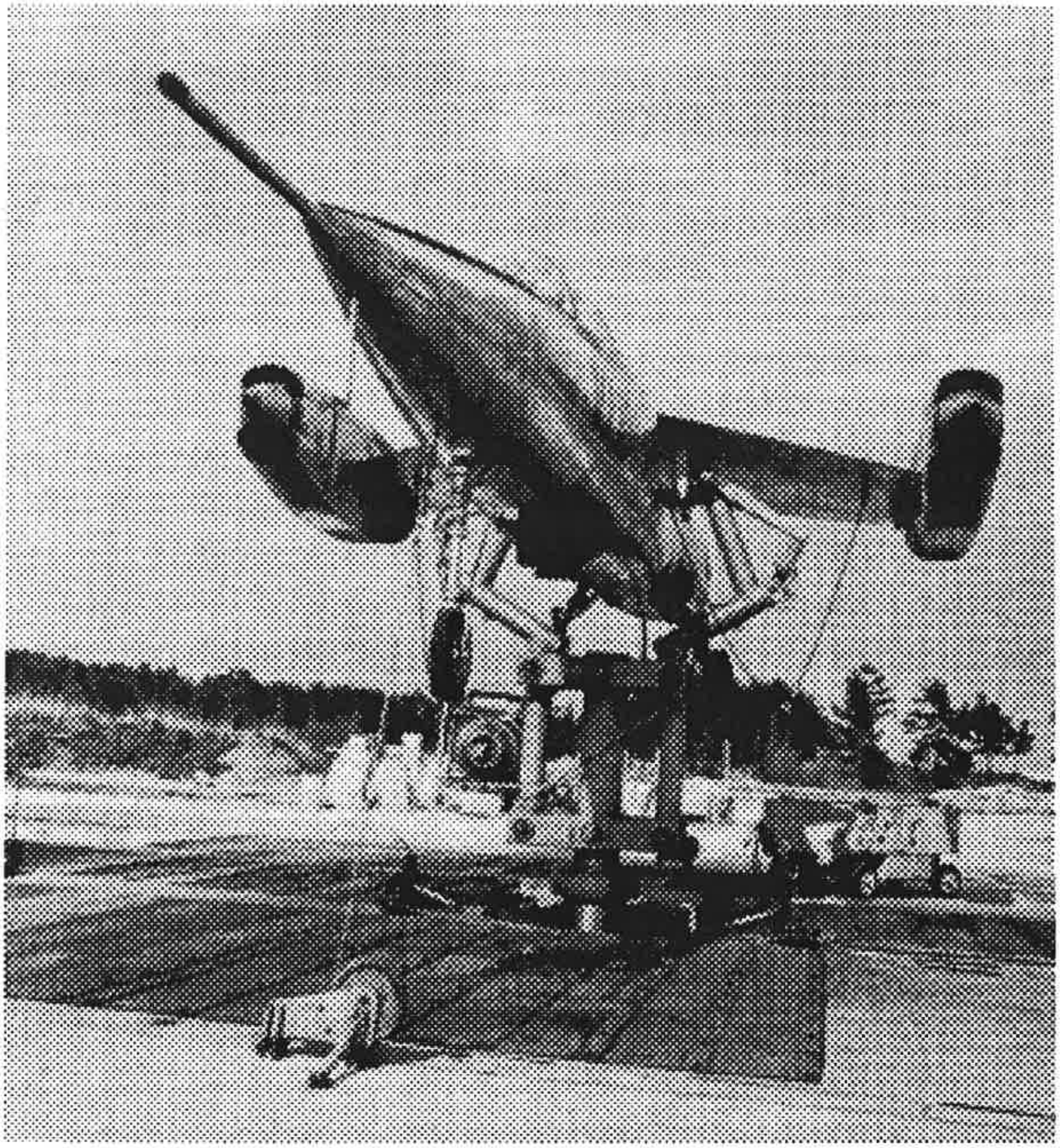


Fig. 7 The hover test rig used to evaluate VJ 101C flight control system options.



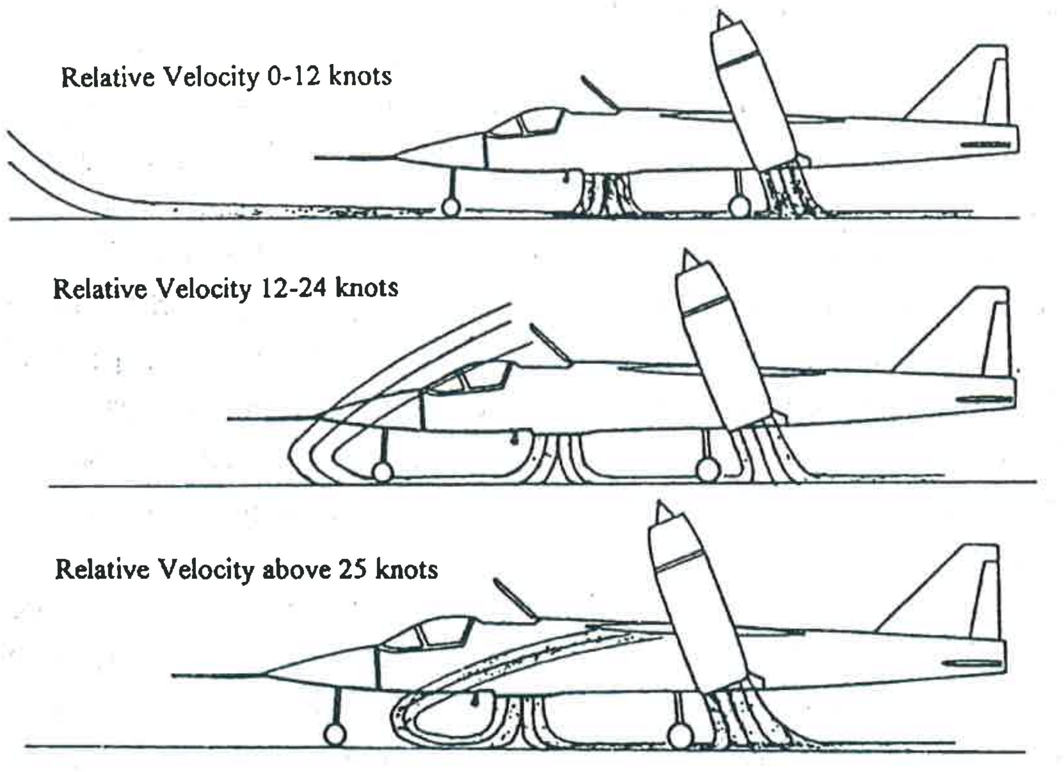
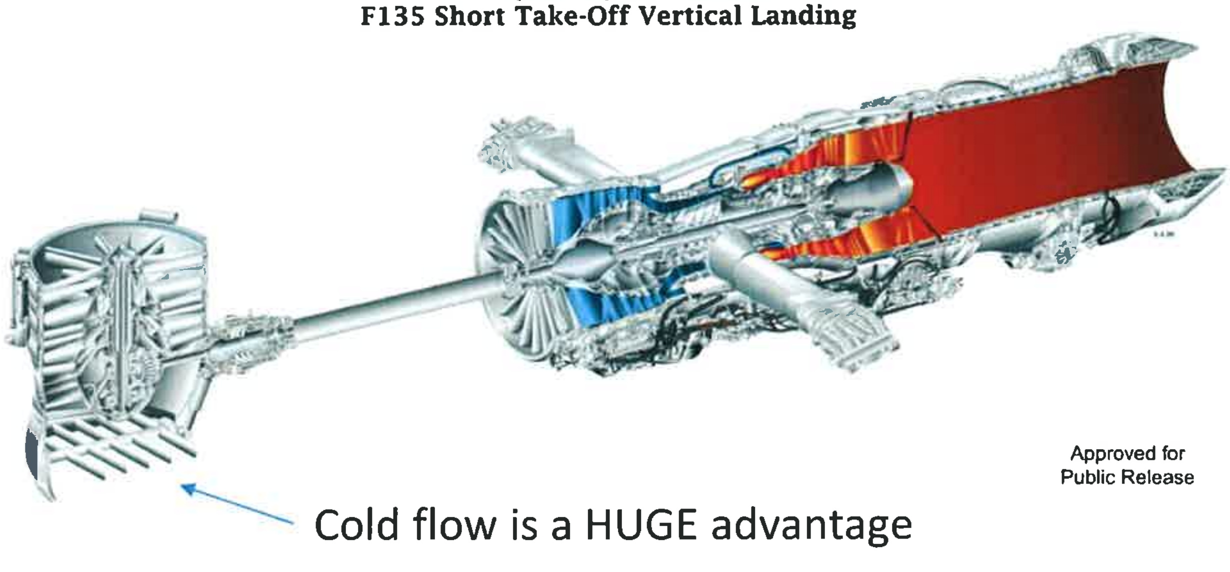


Fig. 26 VJ 101 critical forward velocity (center) for hot gas ingestion during RVTOs.

F35 System

Joint Strike Fighter
F-35 Lightning II Propulsion
F135 Short Take-Off Vertical Landing



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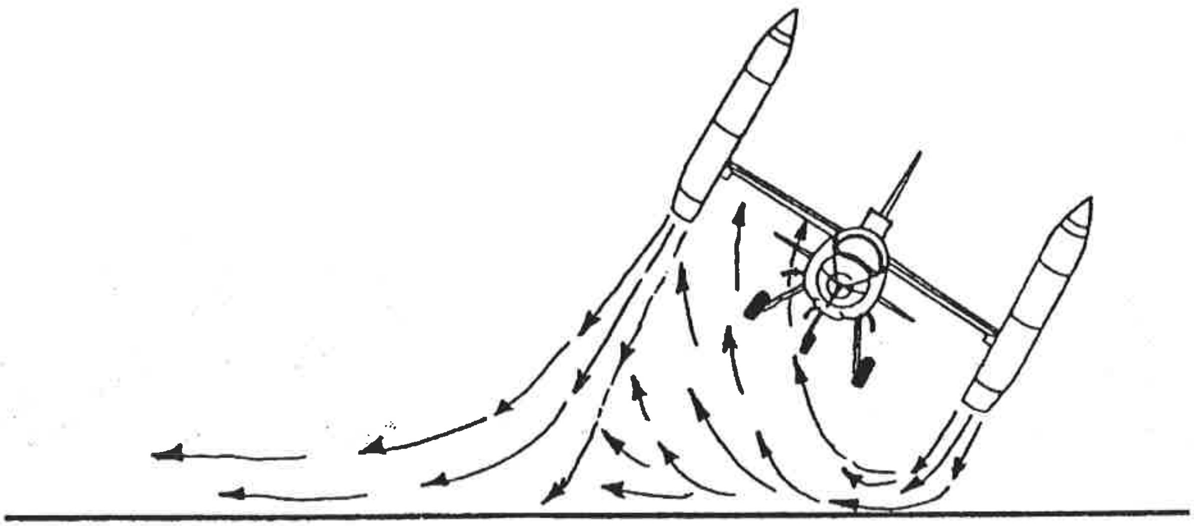
Cold flow is a HUGE advantage



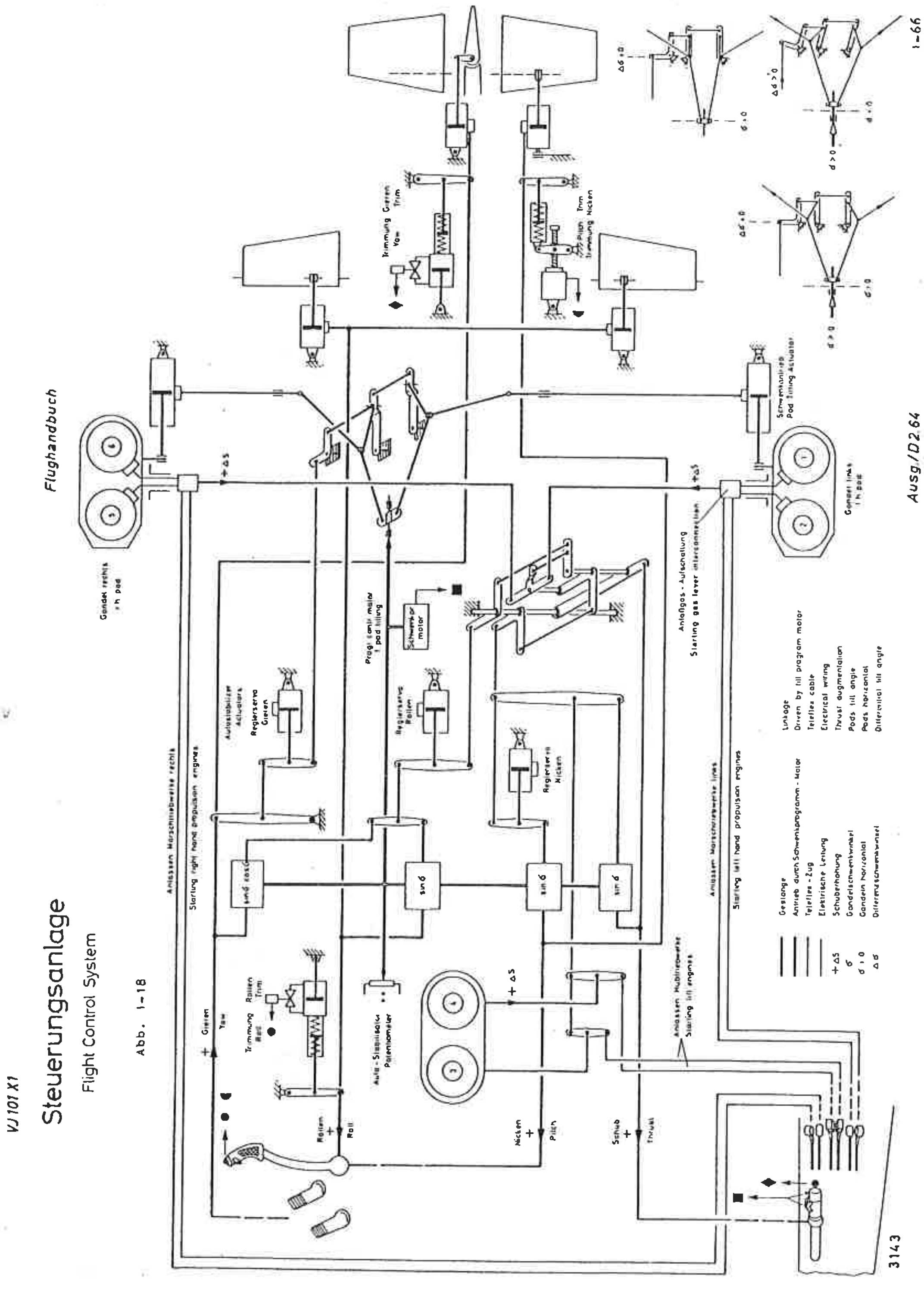


Fig. 17 VJ 101C flight control system.

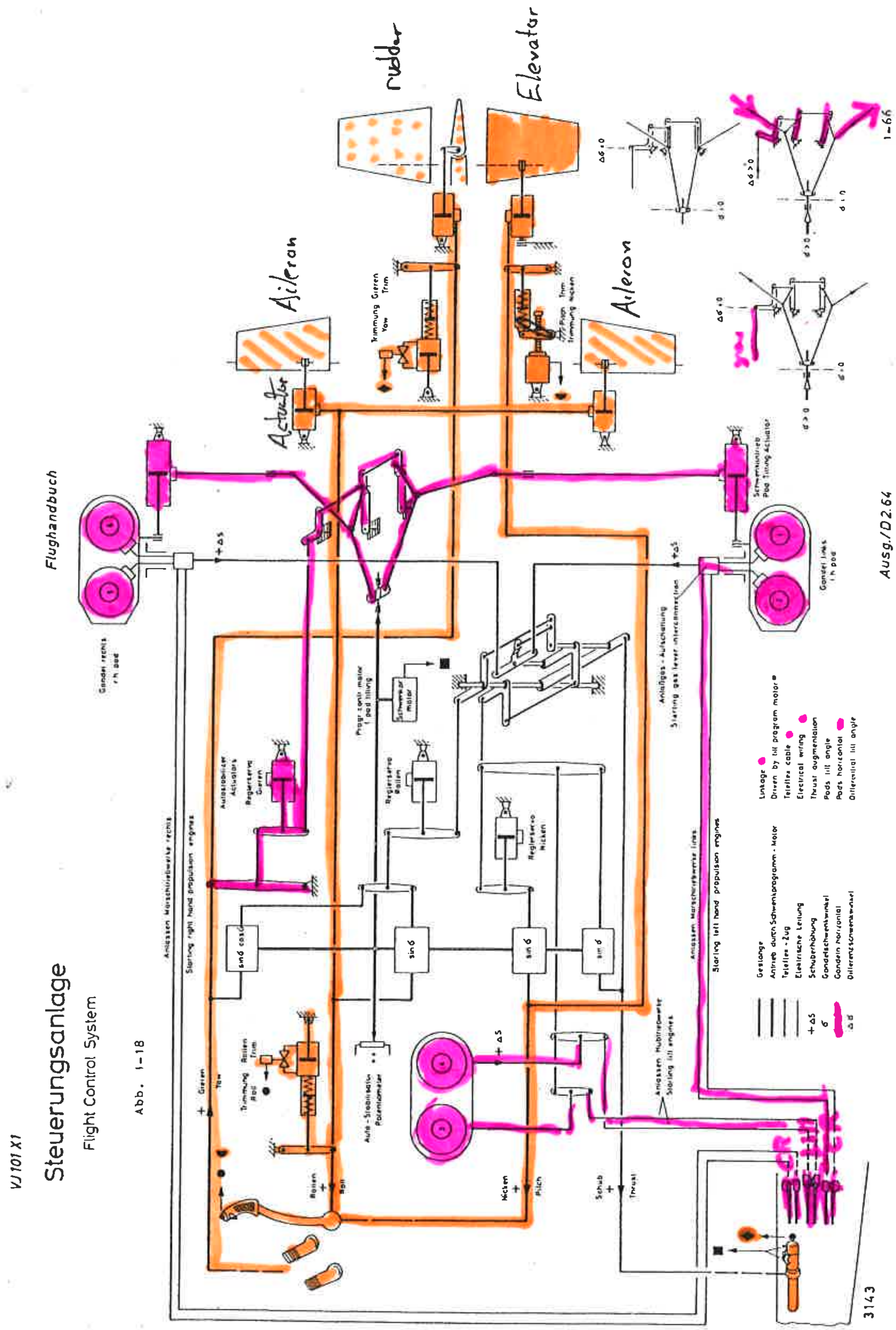


Fig. 17 VJ 101C flight control system.

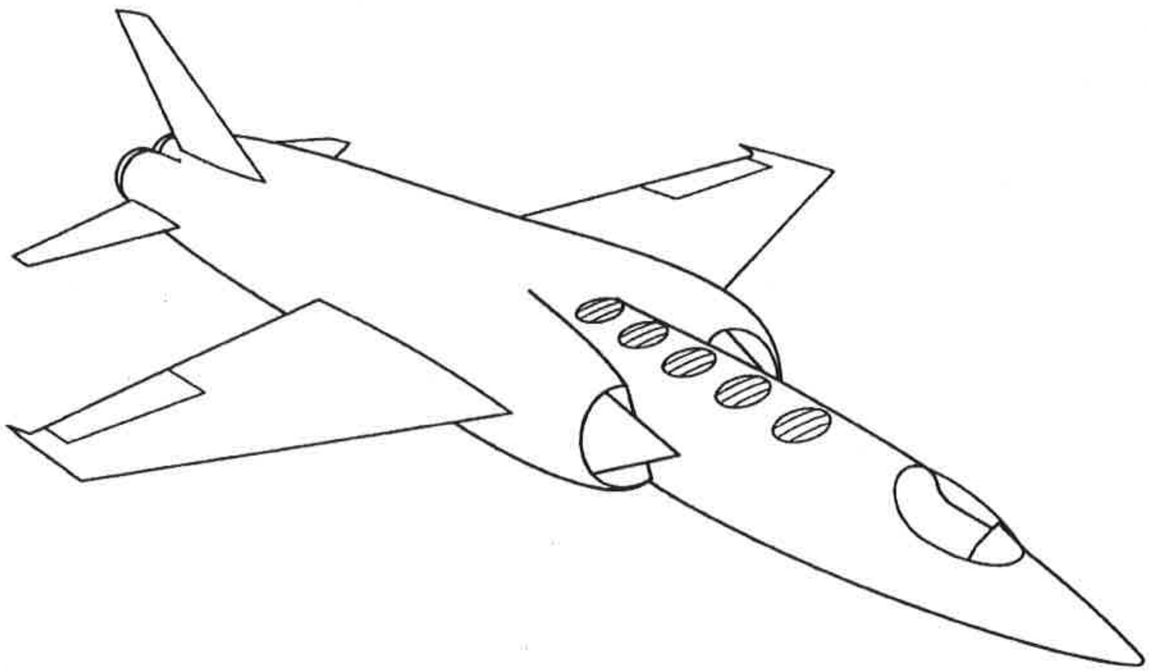
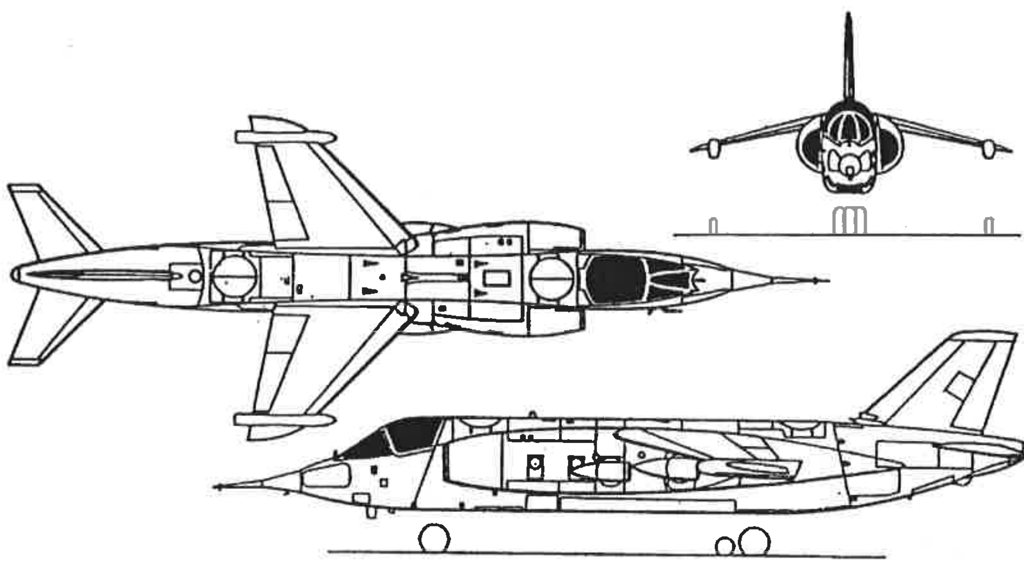
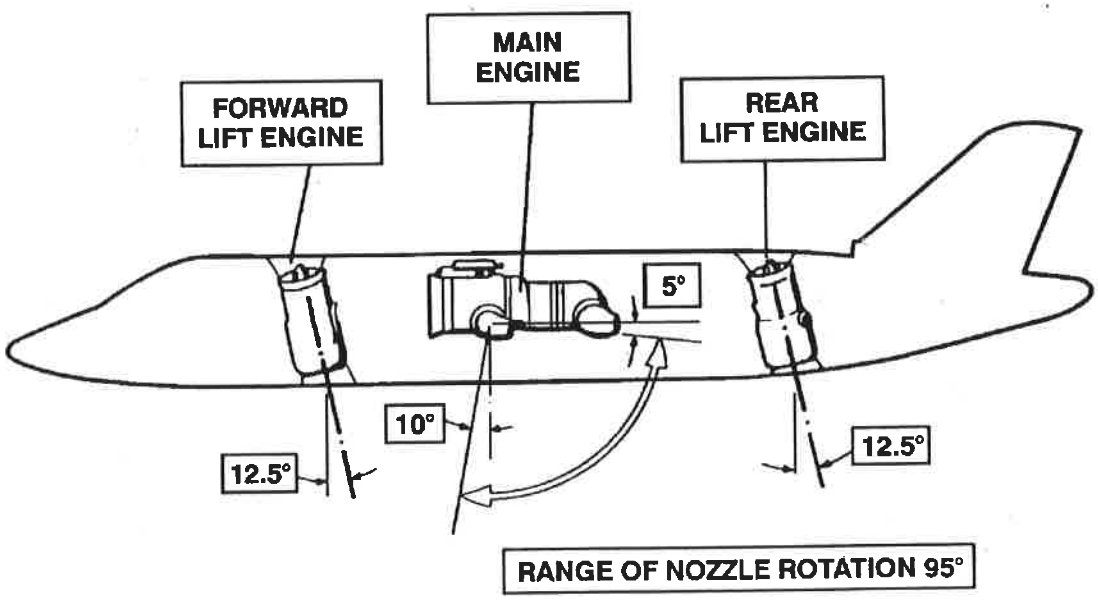


Fig. 34 The seven-engine VJ 101D supersonic V/STOL strike fighter.

VAK 191B




MAIN ENGINE
FORWARD LIFT ENGINE
REAR LIFT ENGINE
5°
10°
12.5°
12.5°
RANGE OF NOZZLE ROTATION 95°

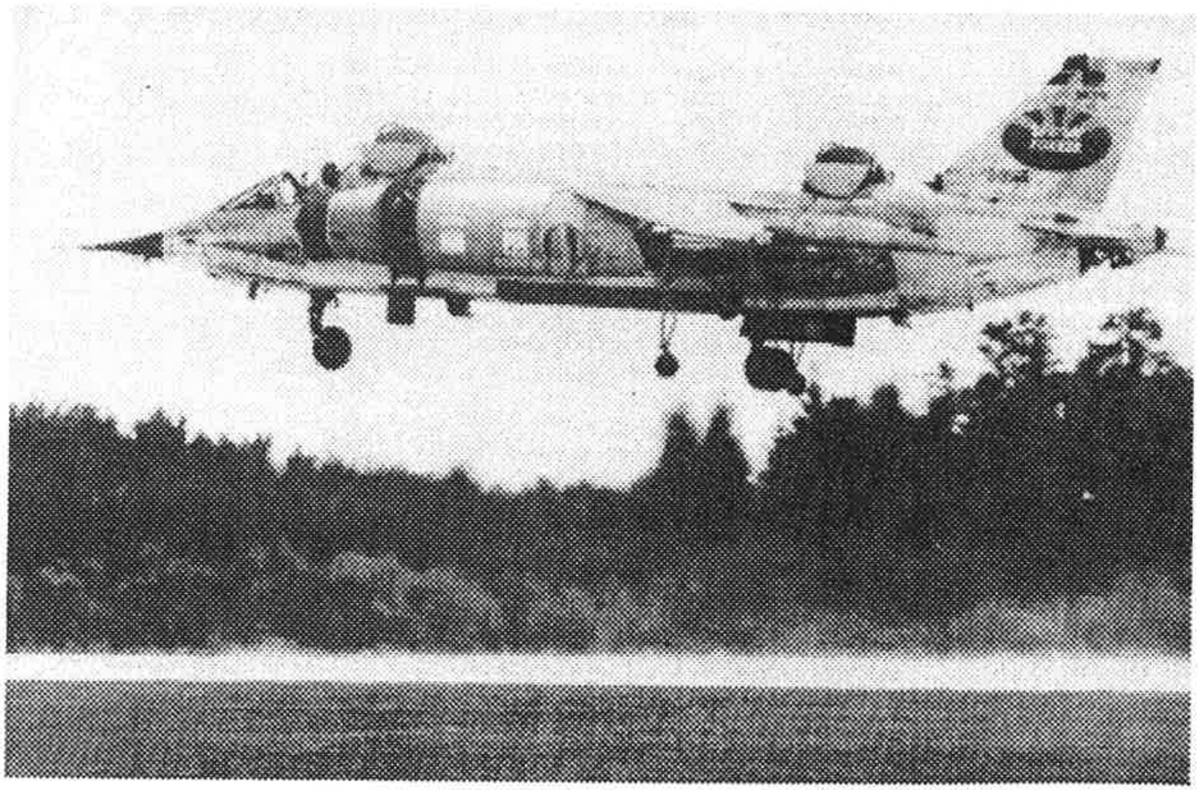


Fig. 58 The VAK 191B in hovering flight. Note the main engine inlet is in the forward (V/STOL) position. FOD-prevention devices are installed over all inlets.