Aircraft

Landing Gear

The Evolution of a System

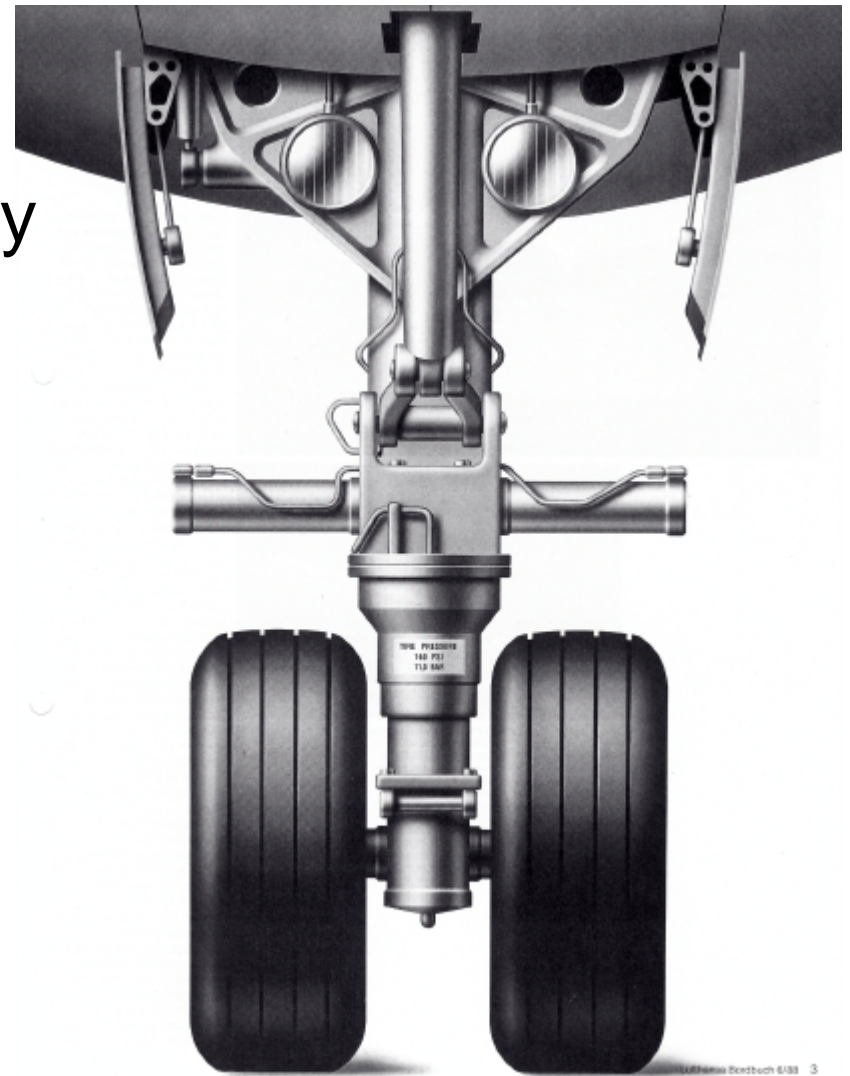**Gerd Roloff**
Systems General

Airbus-Deutschland GmbH

AIRBUS

Contents

- Review of Landing Gear History

- Struts and Shock Absorbers
- Tyres, Wheels & Brakes
- Landing Gear Systems
- Test & Certification
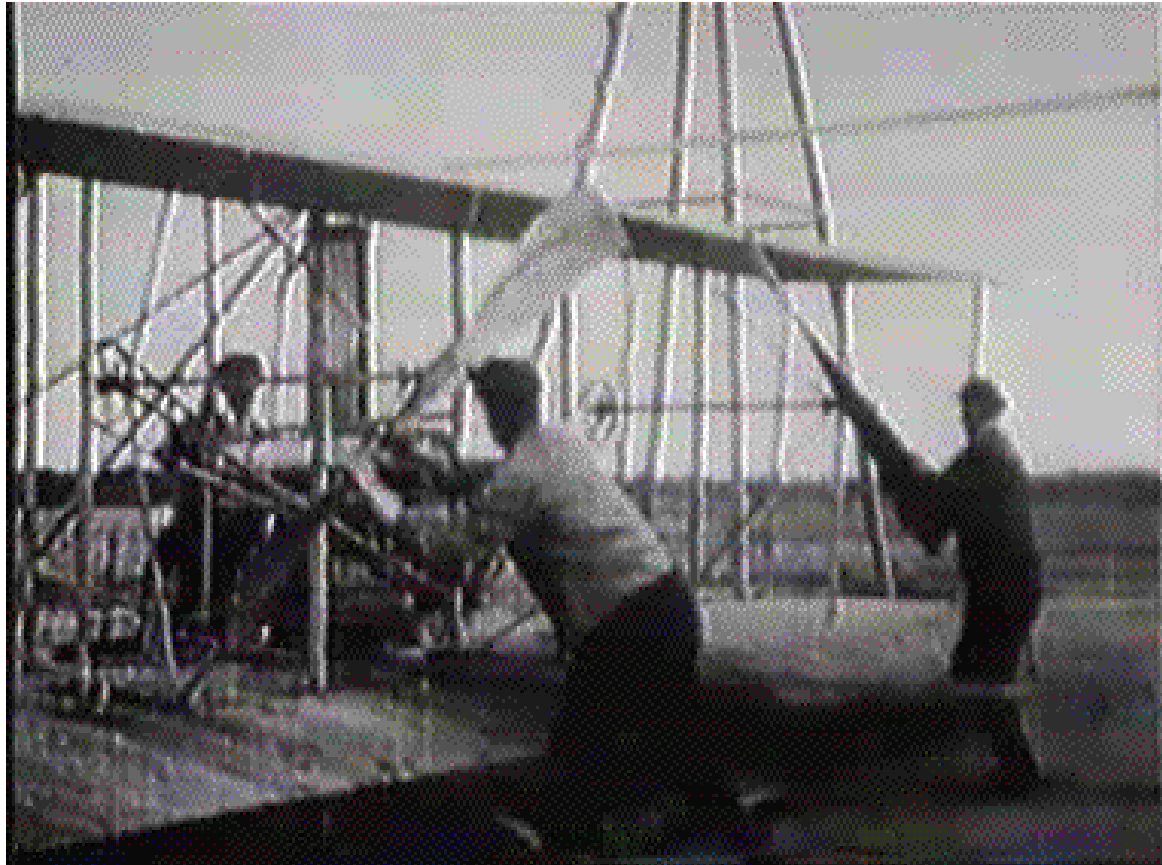
- Landing Gear Design
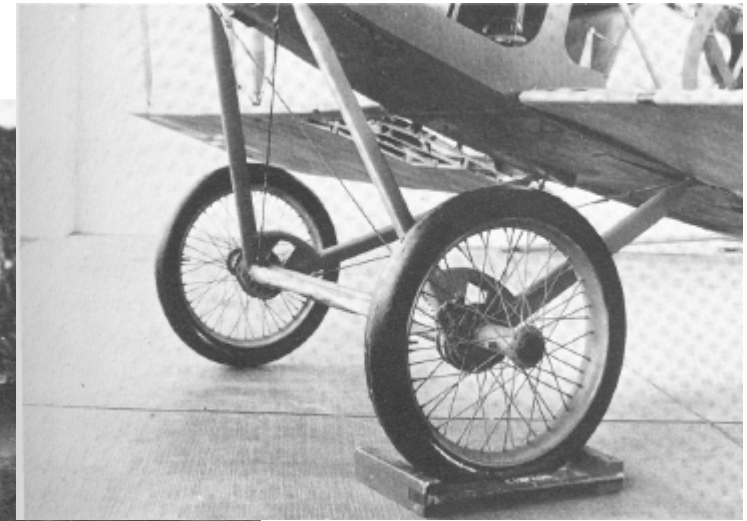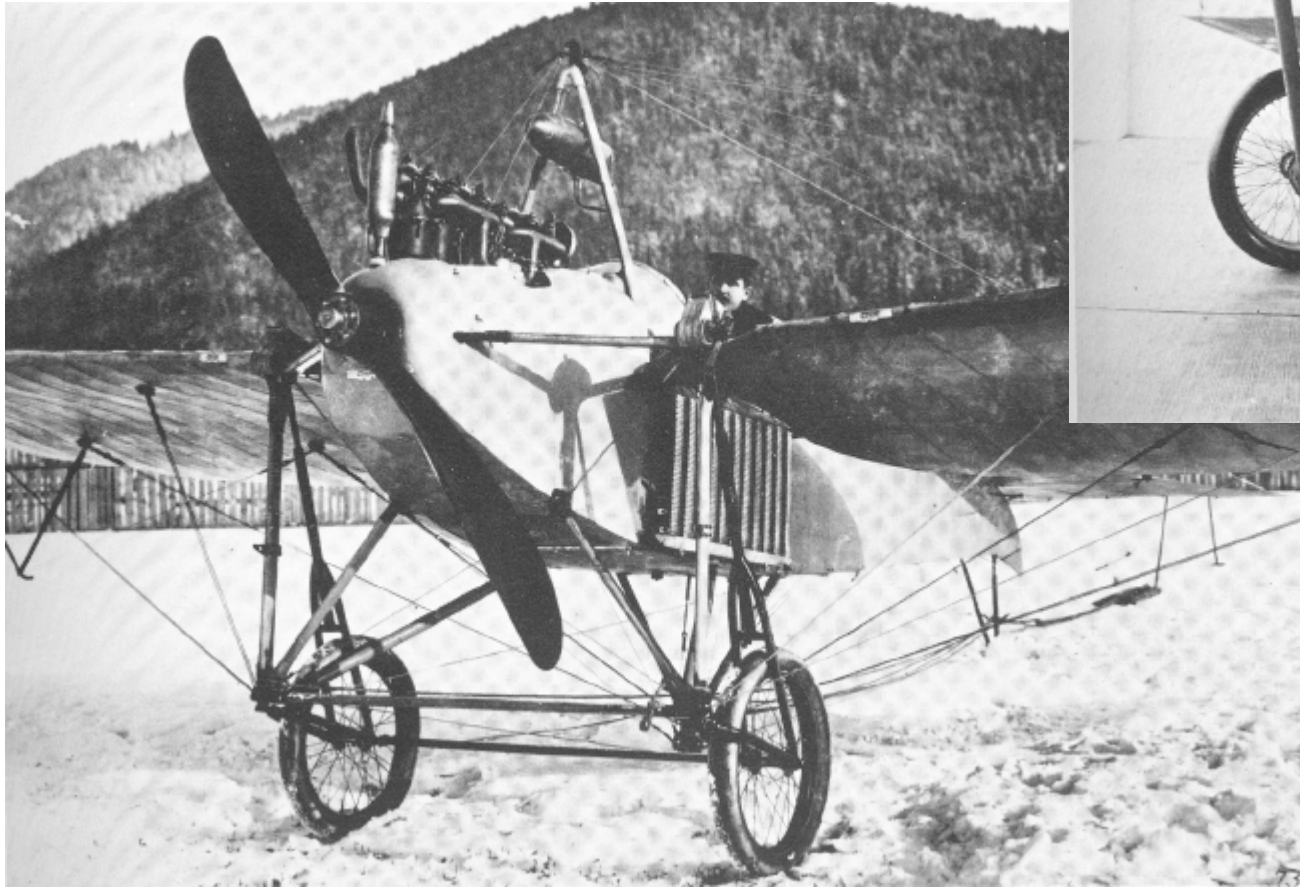- Special Purpose Undercarrige

- Discussion

AIRBUS

Landing Gear Data

Weight:	**2,5 … 5 % of the MTOW**
Cost:	**1.5 to 1.75 % of the Aircraft**
Maintenance:	**20 % of the Airframe DMC**
Loads:	**up to 30,000 kg/wheel**
Speeds:	**over 300 km/h**
Rolling distance:	**up to 500.000 km**
Life time of:	**60.000 hours / 20 years**
In-Service cycle:	**20.000 hours (overhaul)**

AIRBUS

History

The Beginning - Wright Brothers , 1903

AIRBUS

History

Etrich , 1914 / Albatros , 1918

AIRBUS

Messerschmitt Me 20 , 1928

AIRBUS

History

Junkers Ju-52/3m , 1932
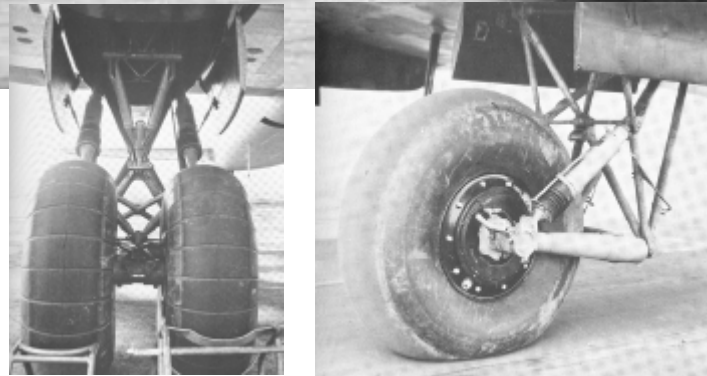
✈AIRBUS
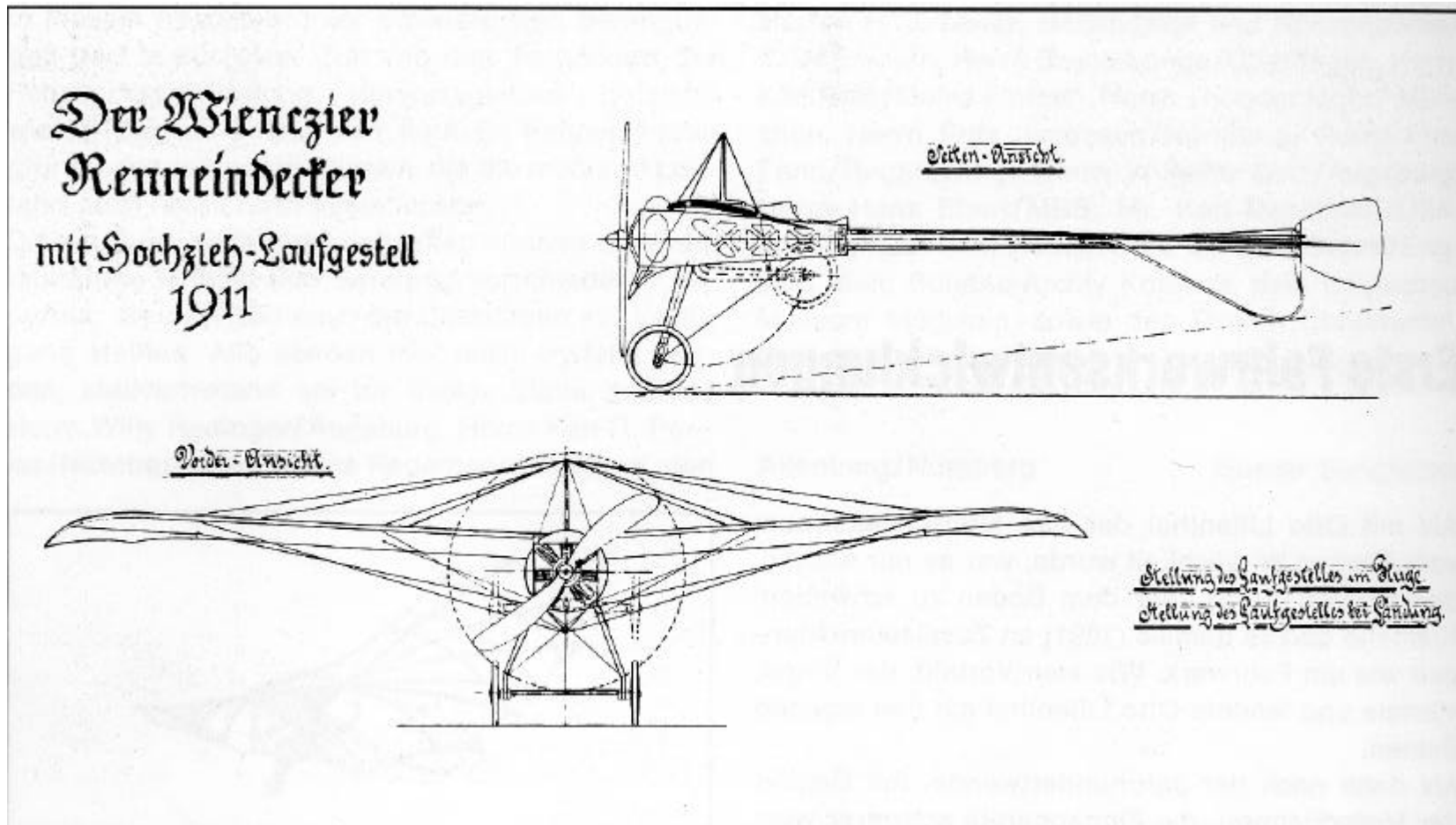
Retractable Landing Gear , 1911

History
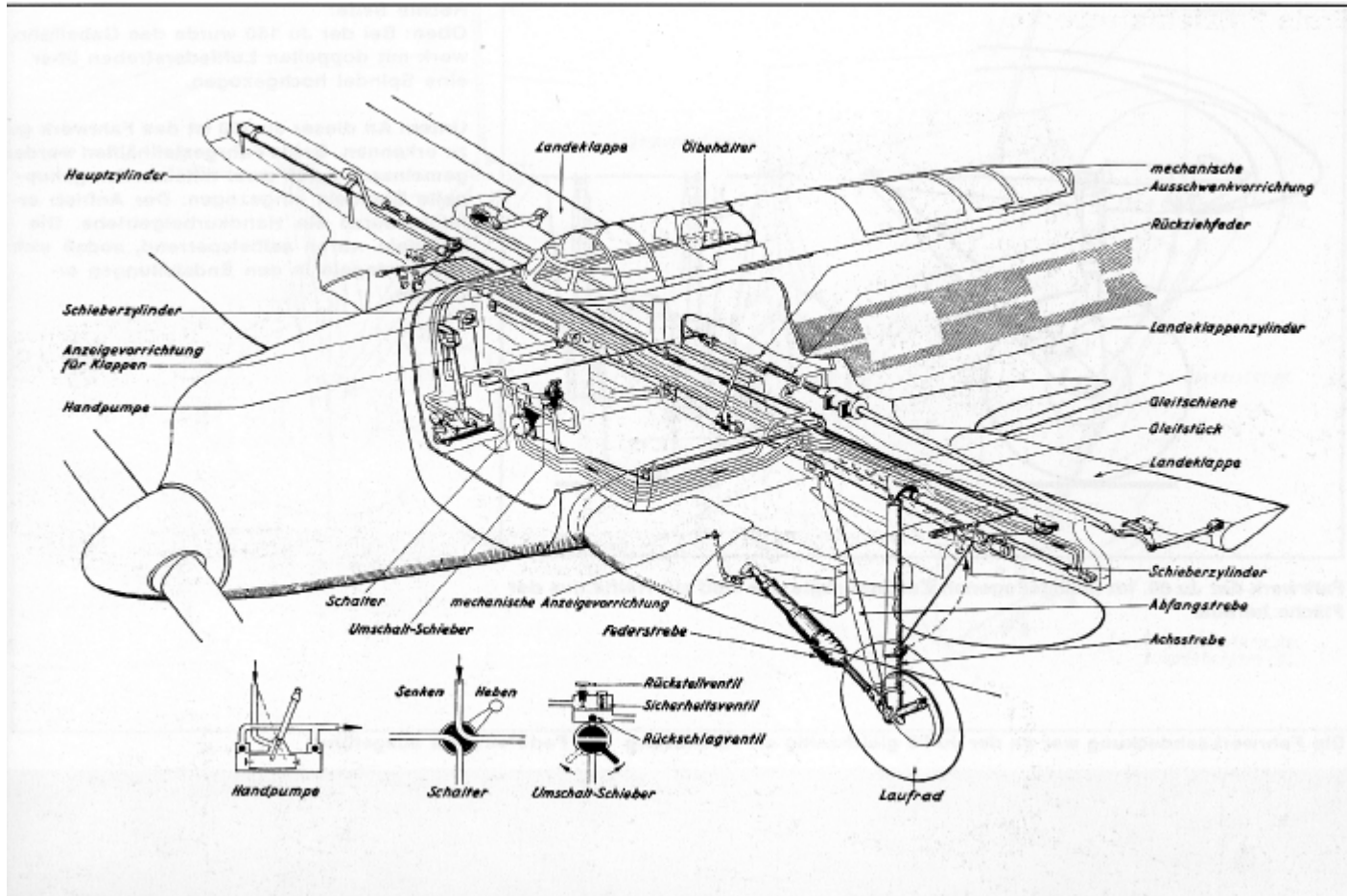
Hydraulic powered Landing Gear , He-70 , 1932

AIRBUS
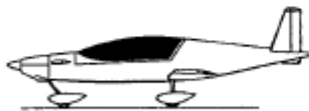
Tail Wheel - Type , Focke Wulf Fw 200 , 1936

History

Nose wheel – type
(retractable)

Tail wheel – type
(retractable)

Tandem – type
(retractable)

Nose wheel – type
(fixed)

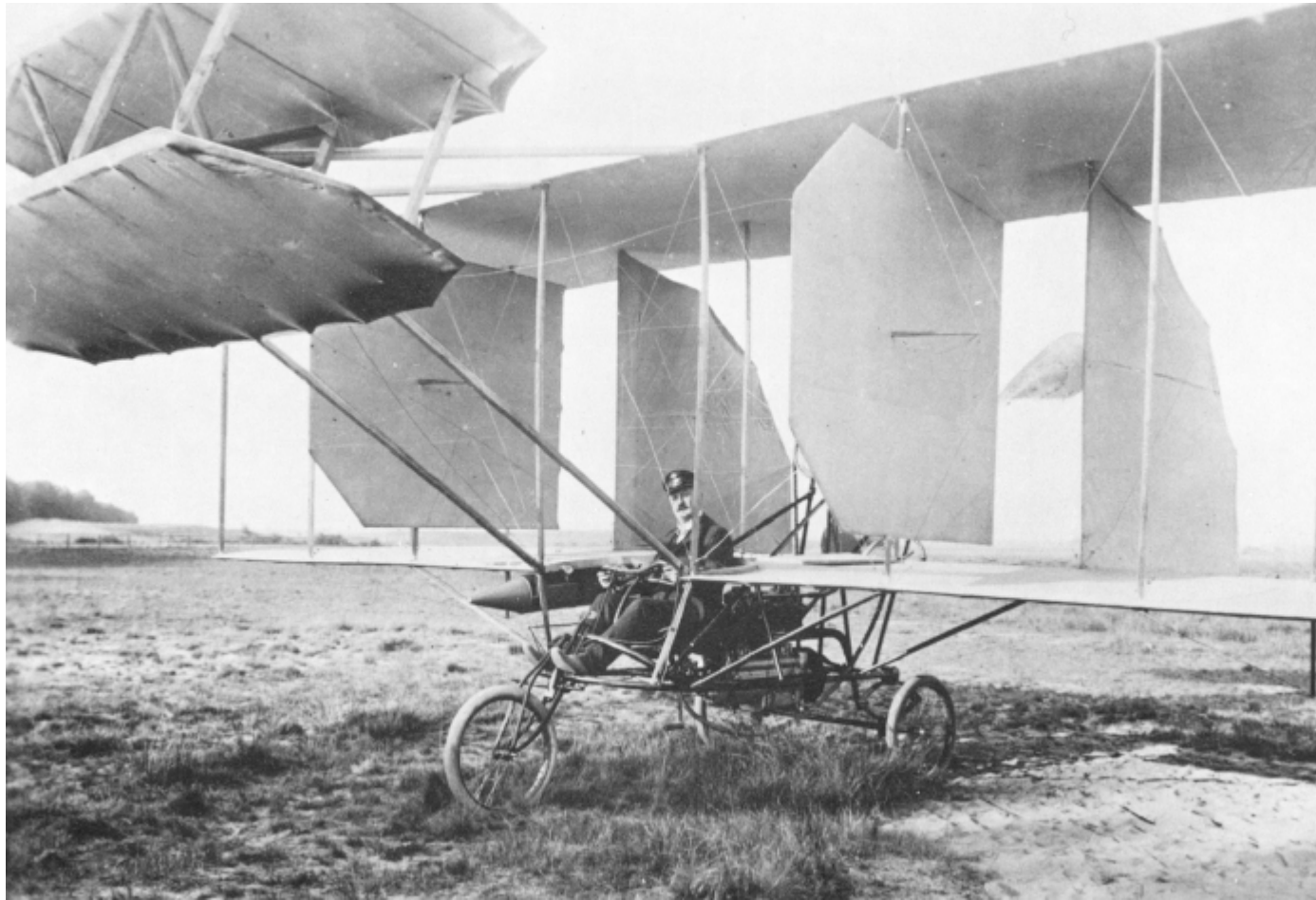Tail wheel – type
(fixed)

Overview of Landing Gear Types

History

Advantages of the NLG-Type:

- **Improved rolling characteristics**
- **Horizontal floor**
- **The Pilot has better visibility**
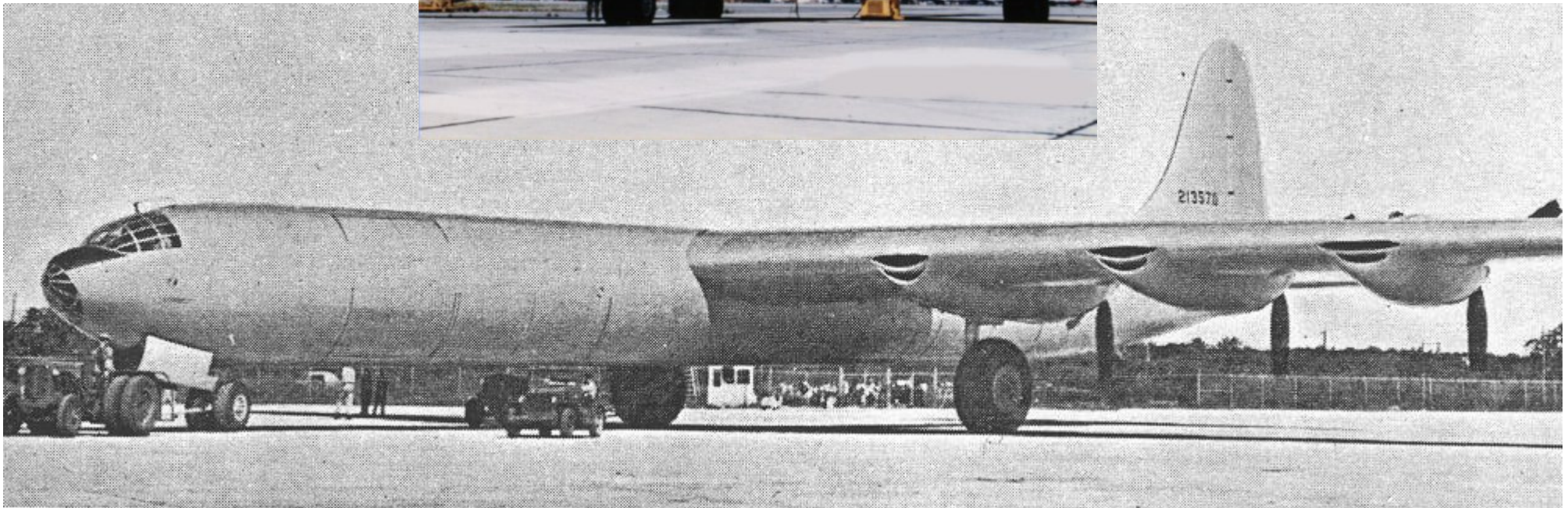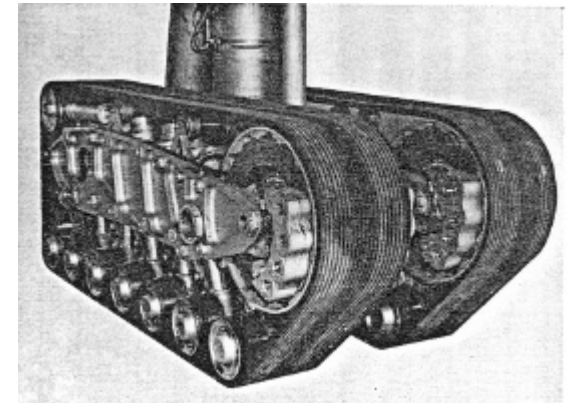- **Easier ground handling (e.g. towing)**

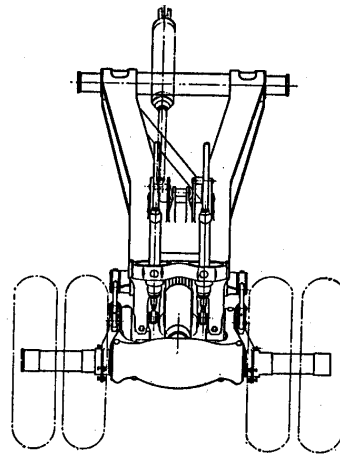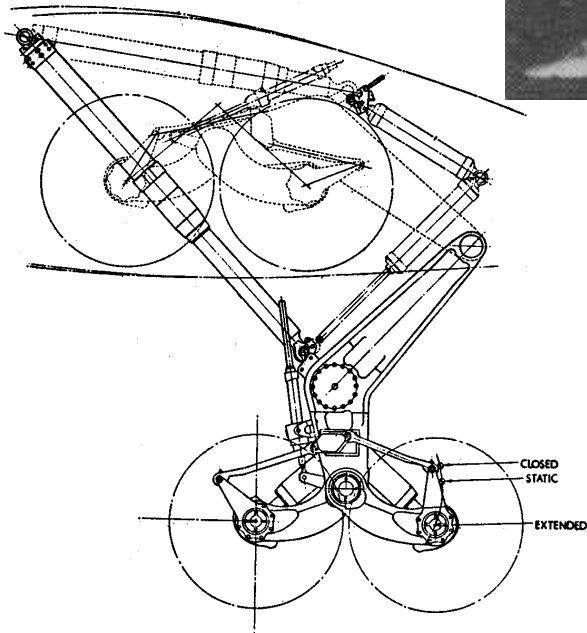**AIRBUS**

Nose Wheel-Type Landing Gear , Jatho IV , 1908

History

NLG-Type with Twin Wheels , B-29 , 1939

AIRBUS

History

NLG-Type with Single Wheels, Me 262 , 1942

Single Wheels , Convair XB-36 , 1946
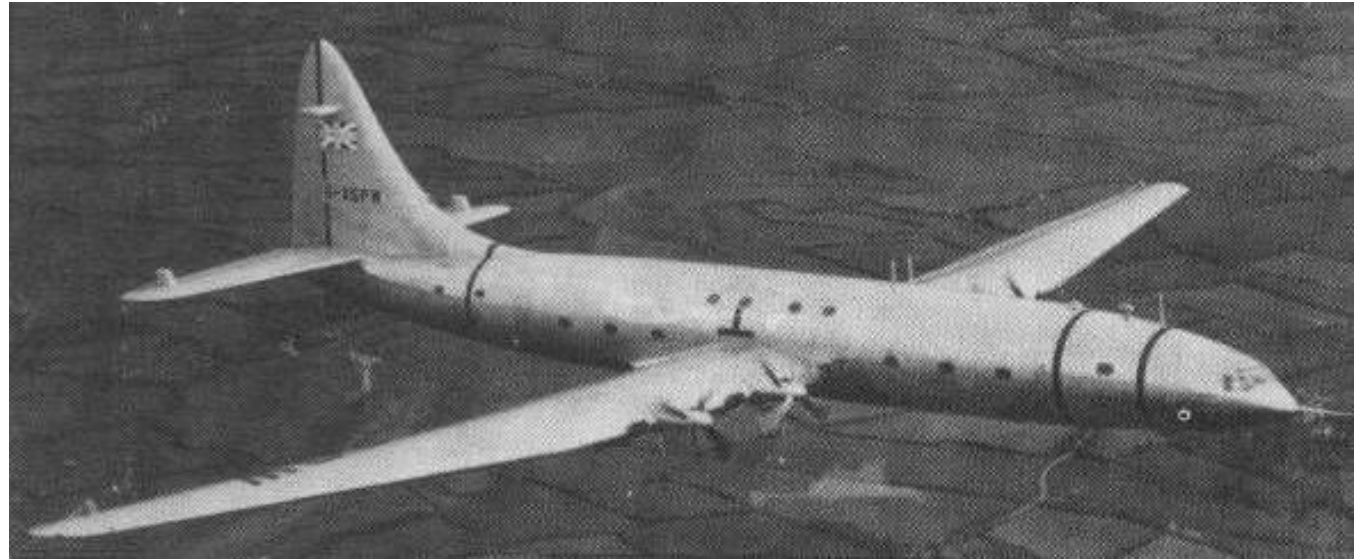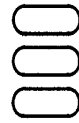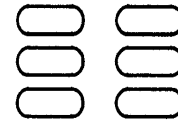
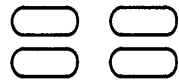8-Wheel MLG , Bristol Brabazon , 1946

AIRBUS

History

Single

Tandem

Triple

Triple Tandem
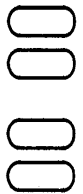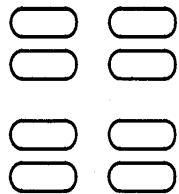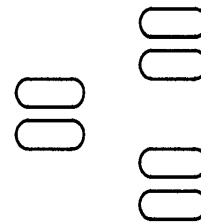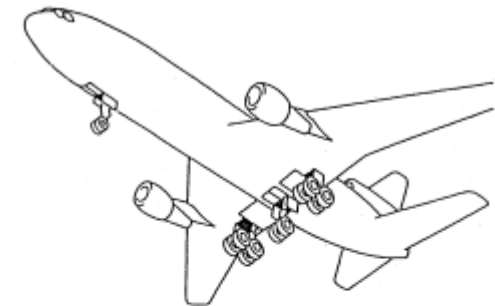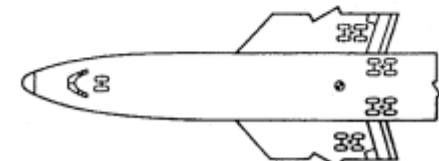
Twin

Twin Tandem

Tri–Twin Tandem

DC-10

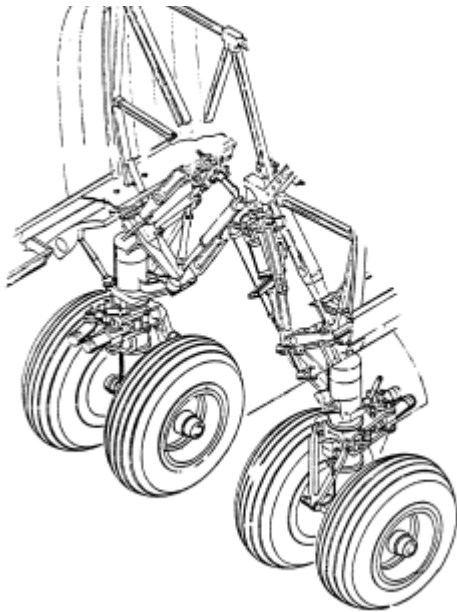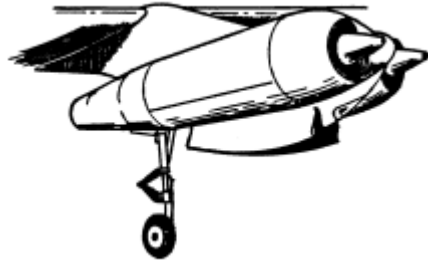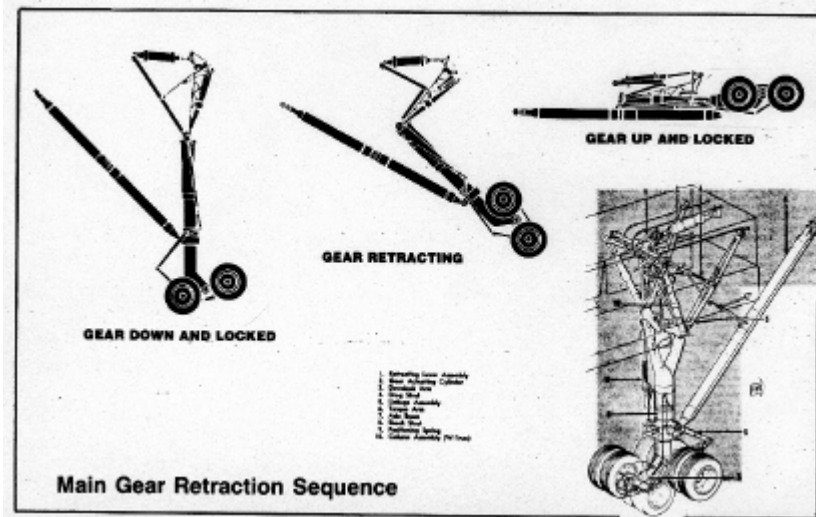Dual Twin

Dual Twin Tandem

Twin Tricycle

B 747-400

Overview Wheel Arrangements

AIRBUS

History

Tandem Gear , Boeing B-52 , 1954

History

GEAR UP AND LOCKED

GEAR RETRACTING

GEAR DOWN AND LOCKED

Main Gear Retraction Sequence
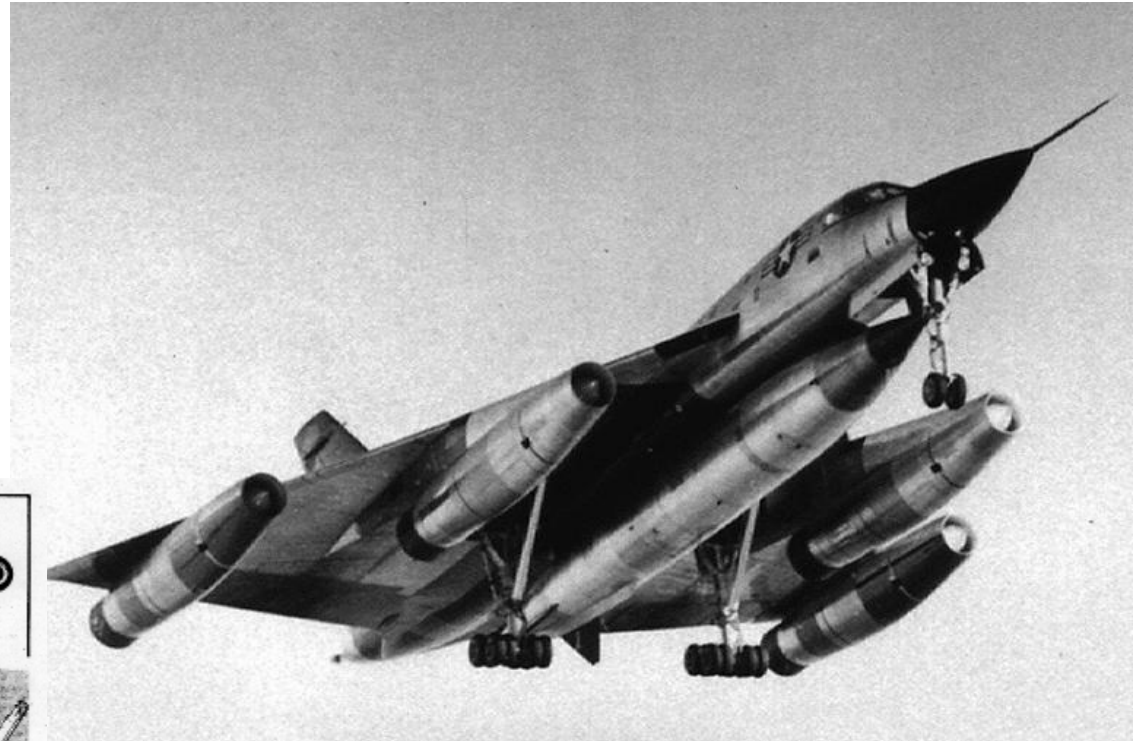
Convair B-58 , 1956
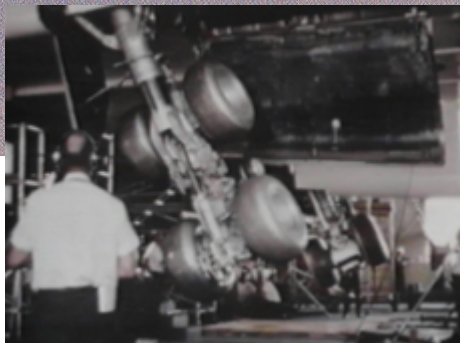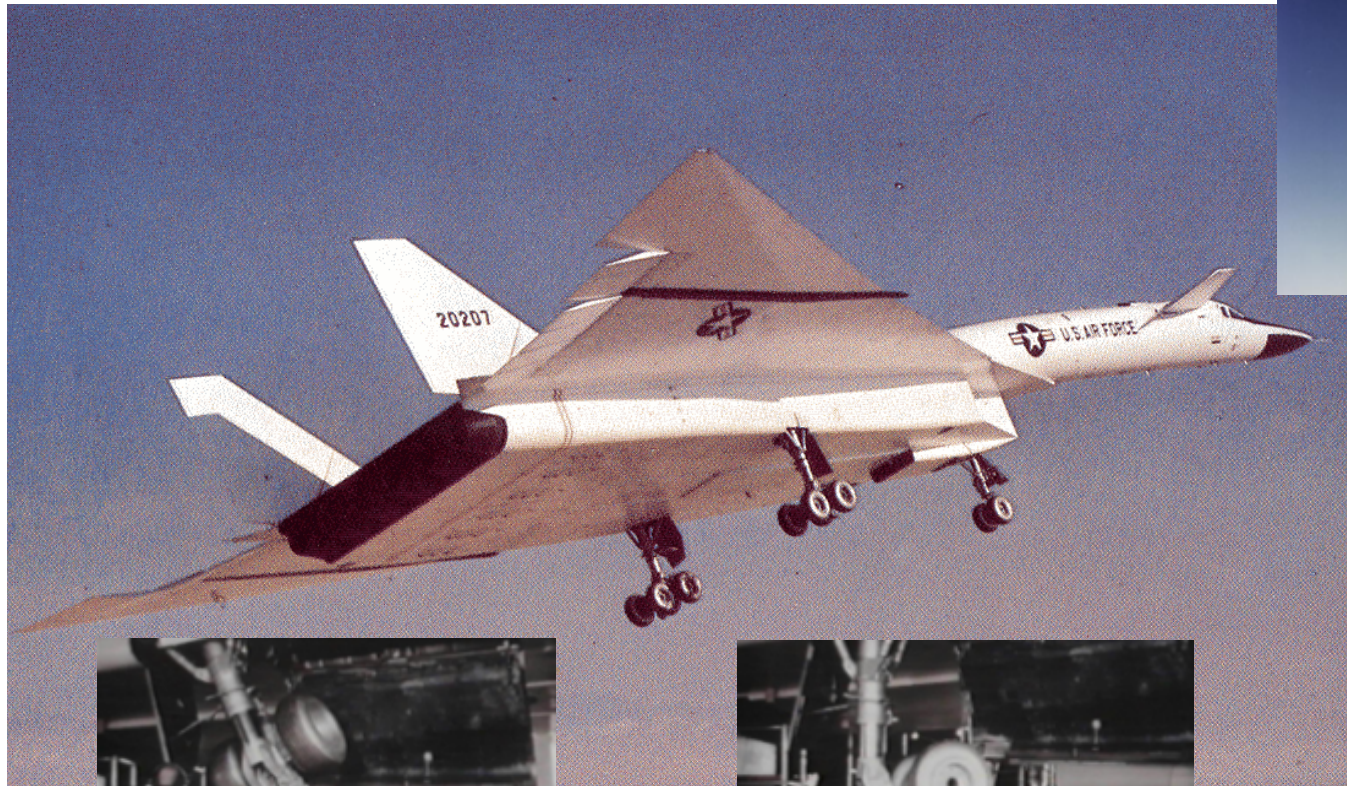
AIRBUS

History

North American XB-70 , 1964

AIRBUS

History

Lockheed C-5 Galaxy , 1968
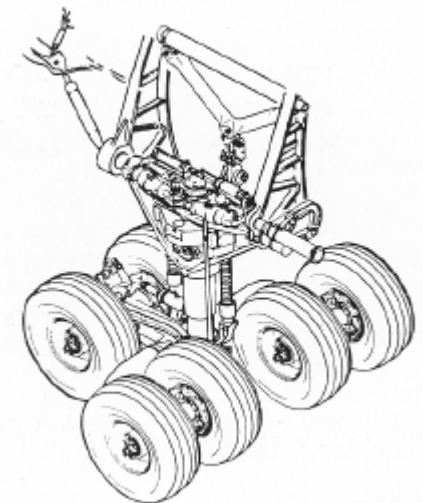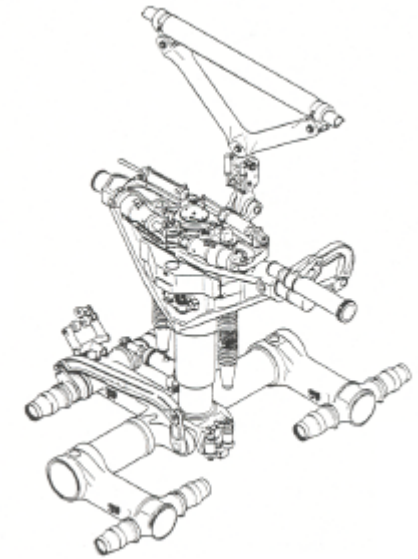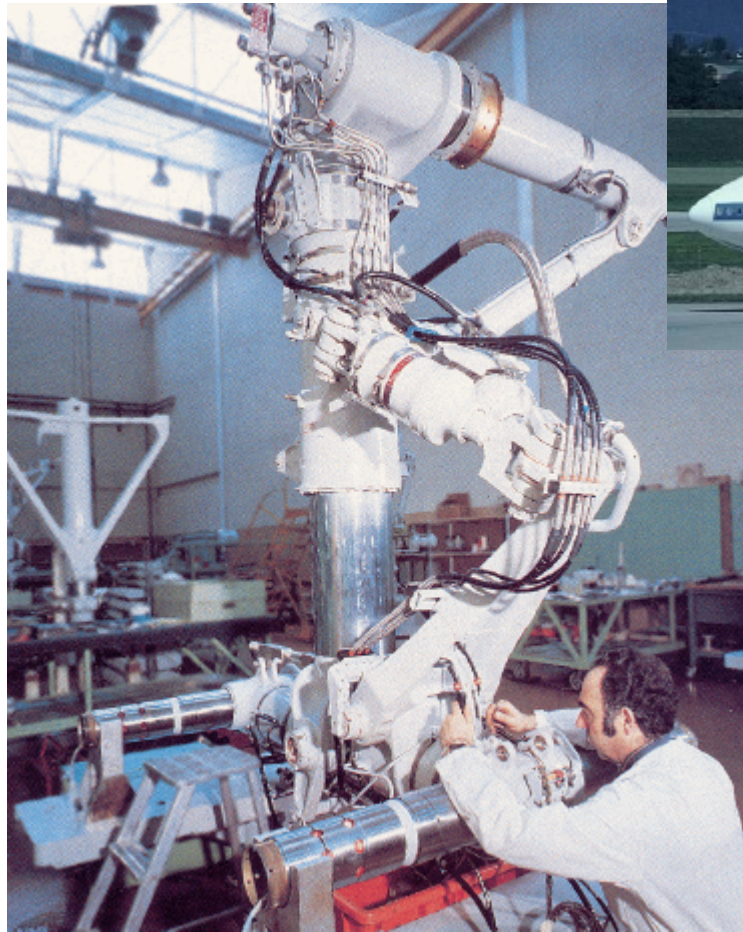
AIRBUS

History

Boeing B747-100 , 1969
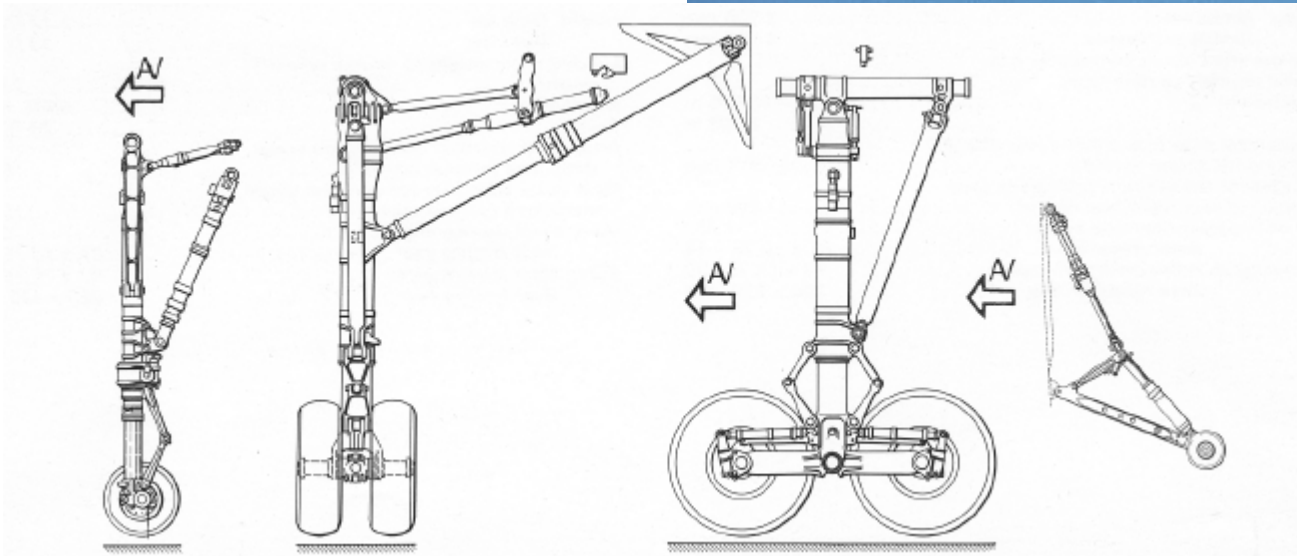
AIRBUS

History

Concorde , 1969
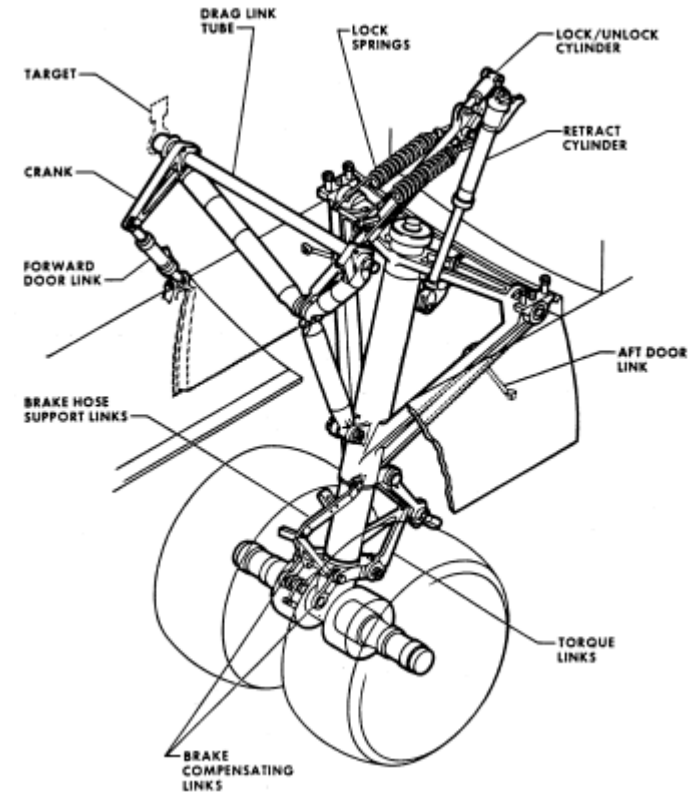
AIRBUS

McDonnell Douglas DC-10-30 , 1972

History

Airbus A320 , 1987
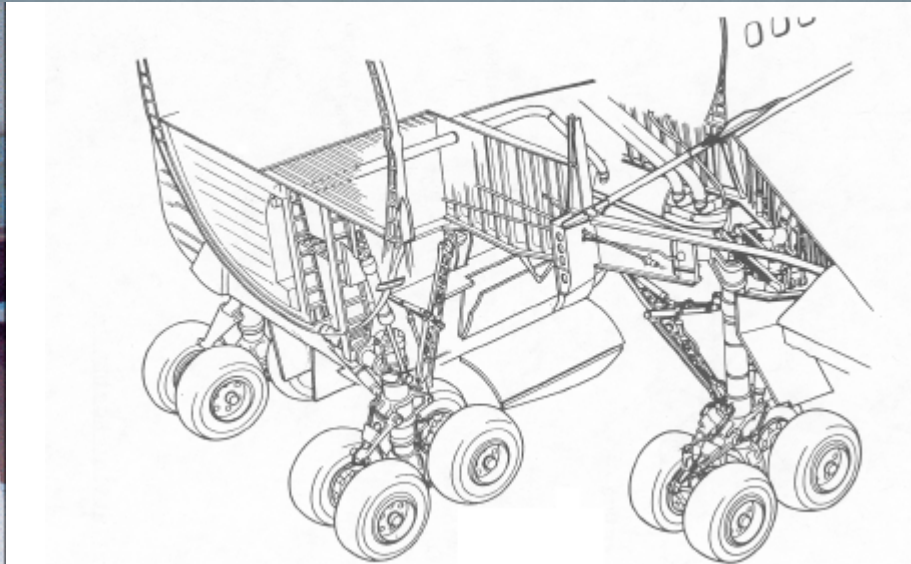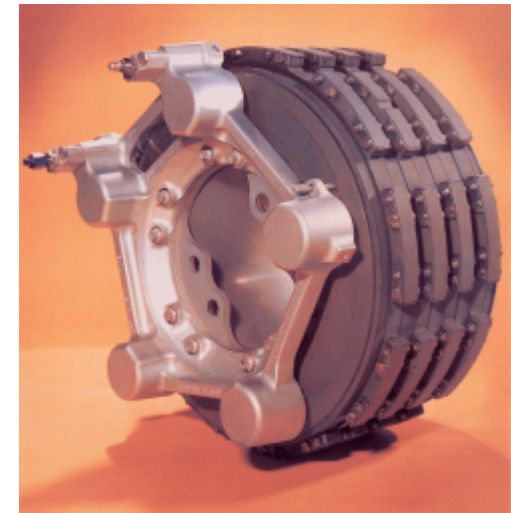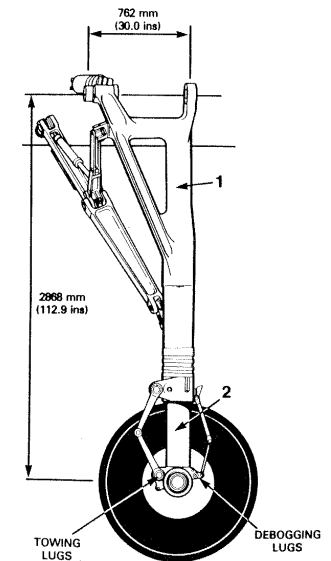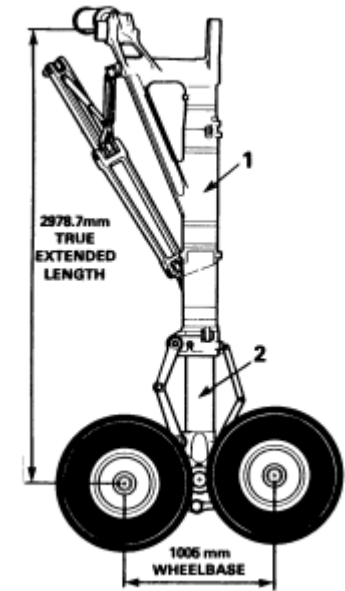
AIRBUS

History

Antonow An-225 , 1988

AIRBUS

History

The landing sequence shows the increased loads and the bogie movement

1. At initial touch-down the rear tires start to take the landing loads
2. The shock absorber starts to compress as the load increases
3. The landing loads increase on the front tires
4. The shock absorber is at its static deflection

lift from wing as A/C velocity increases relieves load on gear.

14°
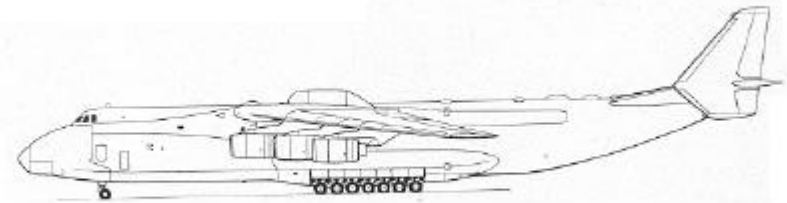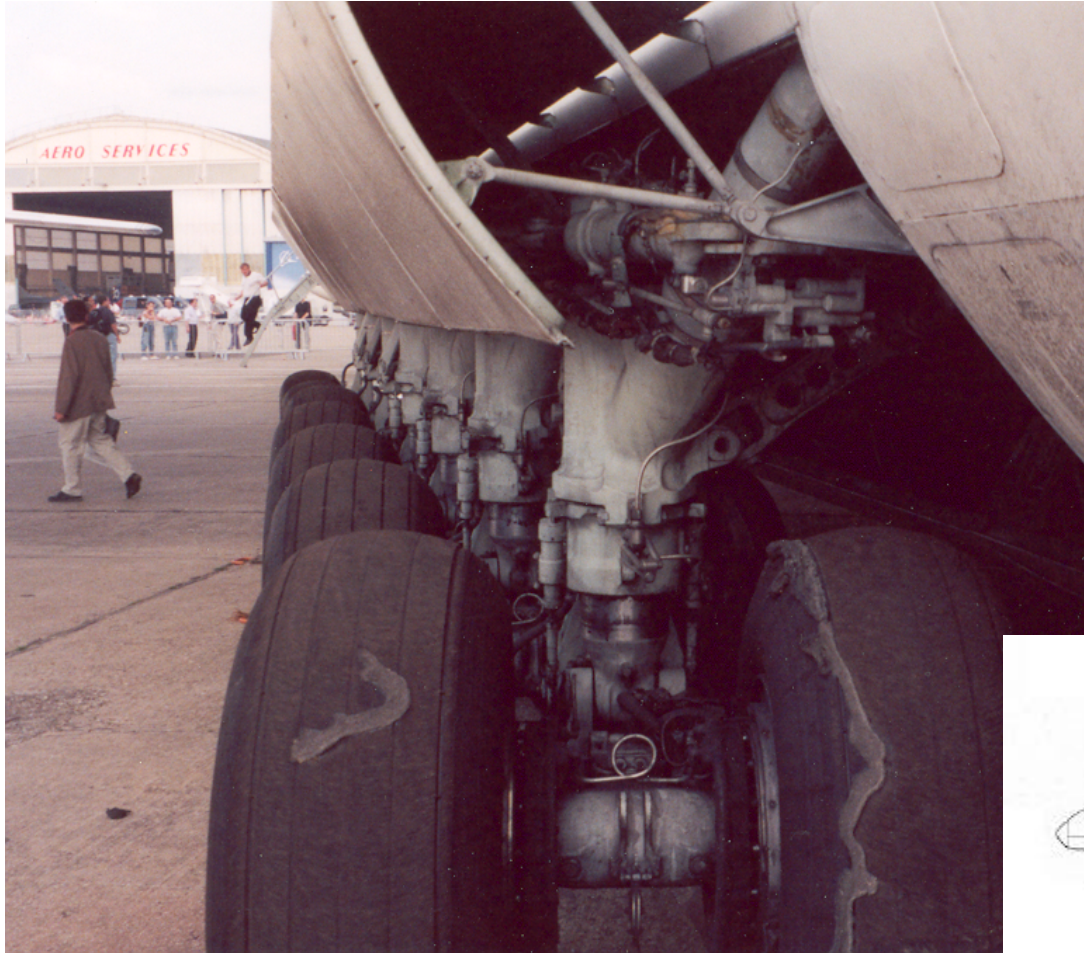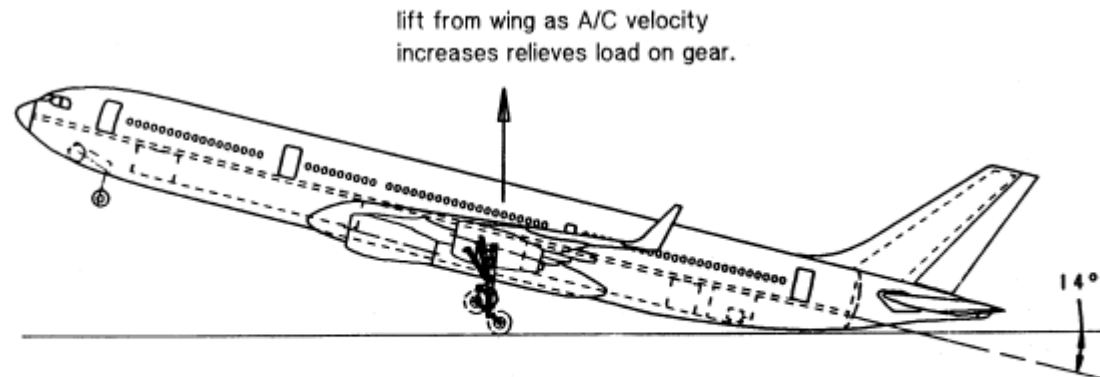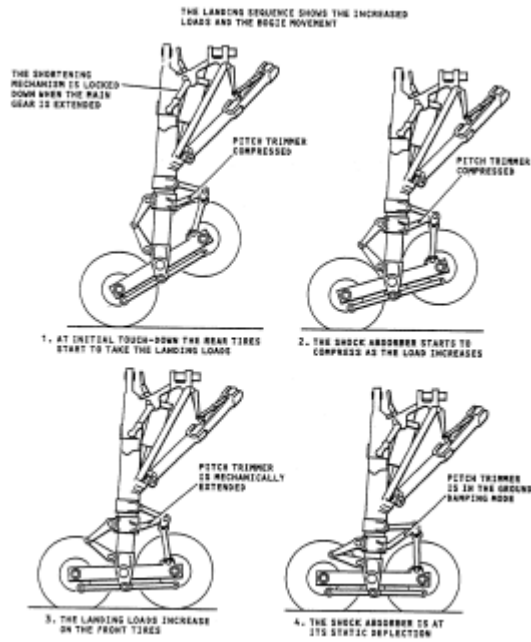
During take-off main gear acts as levered undercarriage.
As load is relieved from main gear the shock absorber extends and the bogie beam rotates about forward wheels due to the geometry of the articulation links and pitch trimmer.
A/C rotates about rear wheels only at take-off.

Airbus A340 , 1991

AIRBUS

Landing Gear

General Requirements:

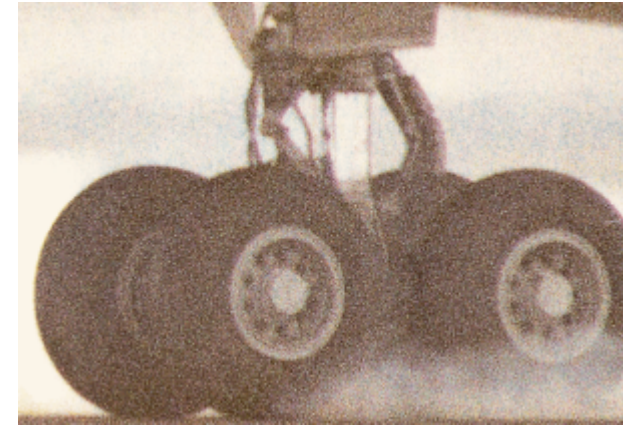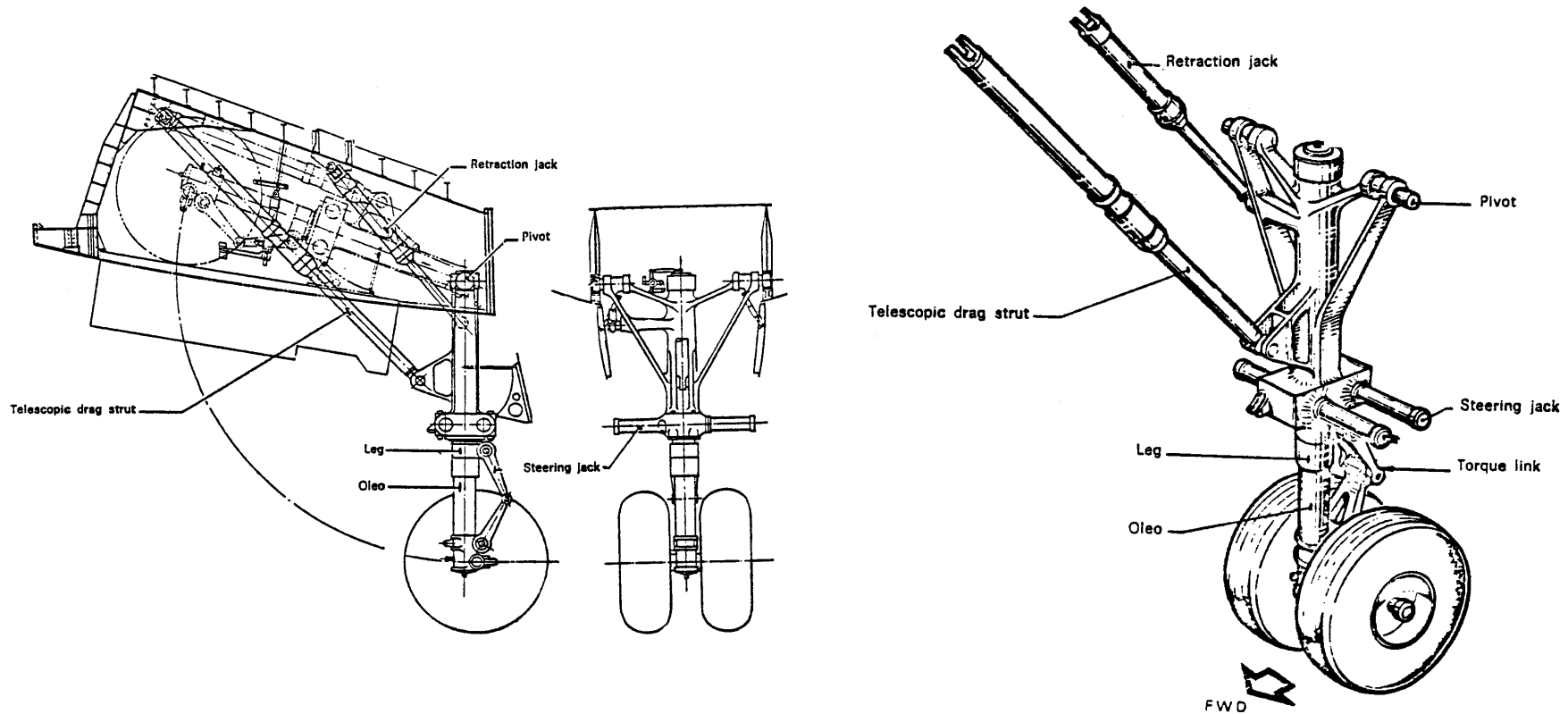- Comfortable shock absorption
- Short stopping distance (braking)
- High rolling stability during ground manoeuvring
- Small storage volume
- Low drag (specially for fixed landing gears)
- High reliability and safety
- Low maintenance
- Low weight

AIRBUS

Struts and Shock Absorbers
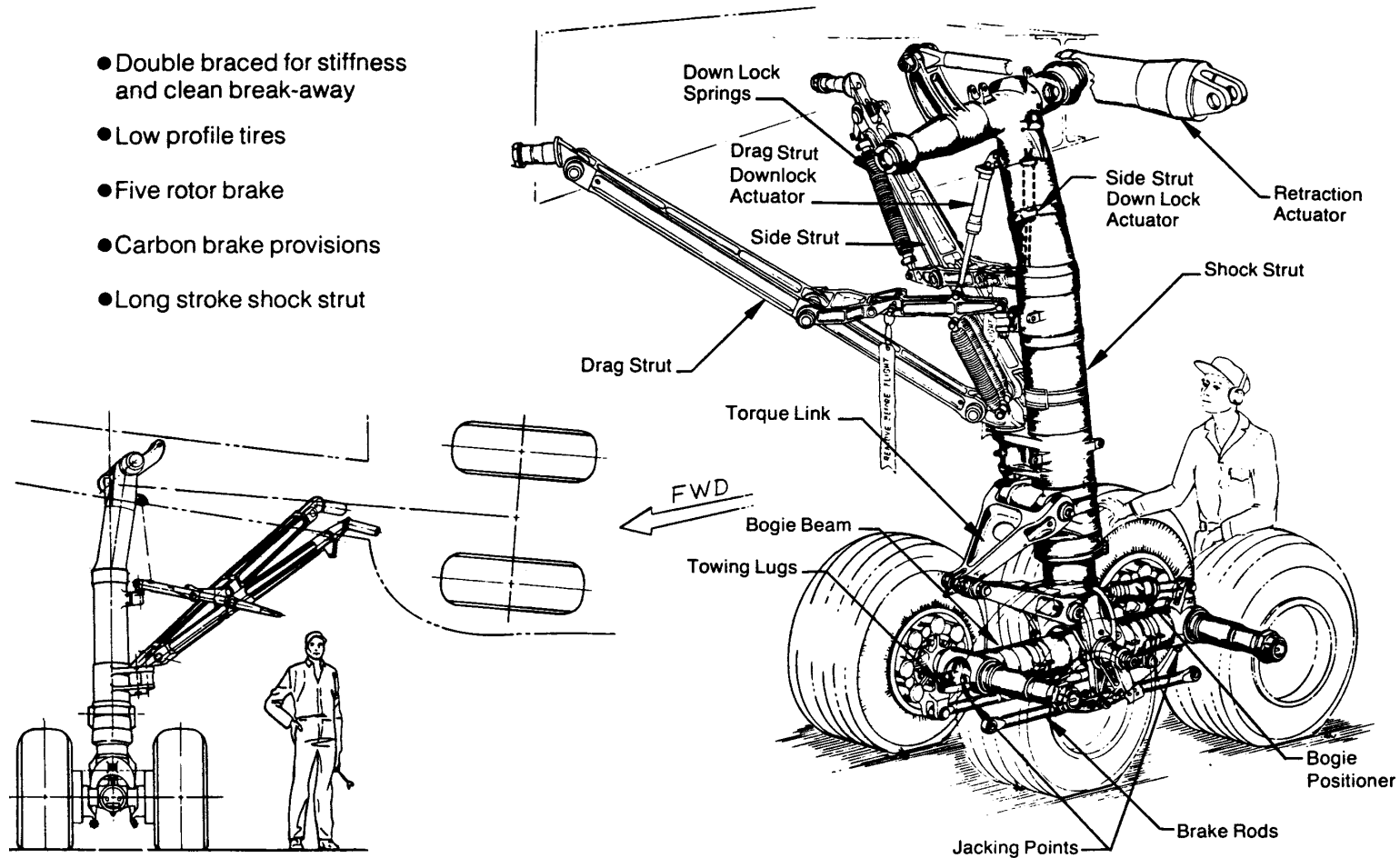
AIRBUS

Struts and Shock Absorbers
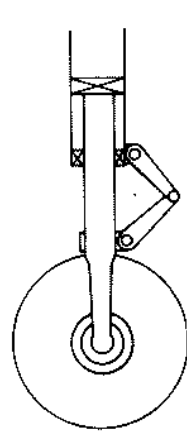

NLG (Nose Landing Gear) , Airbus A300

Struts and Shock Absorbers

- Double braced for stiffness and clean break-away
- Low profile tires
- Five rotor brake
- Carbon brake provisions
- Long stroke shock strut

Down Lock Springs

Drag Strut Downlock Actuator

Side Strut

Side Strut Down Lock Actuator

Retraction Actuator

Shock Strut

Drag Strut

Torque Link

FWD

Bogie Beam

Towing Lugs

Bogie Positioner

Brake Rods

Jacking Points

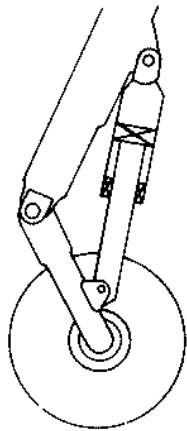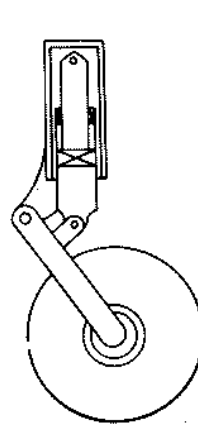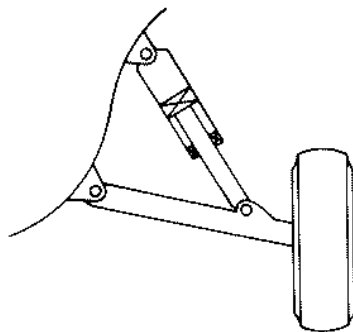## MLG (Main Landing Gear) , Boeing B767
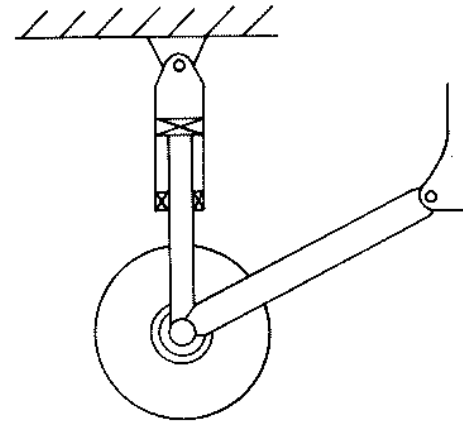
Struts and Shock Absorbers
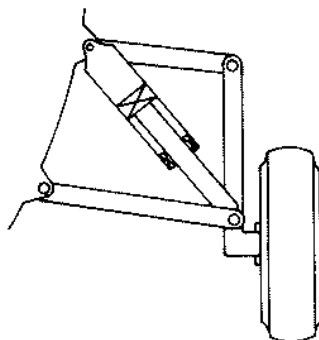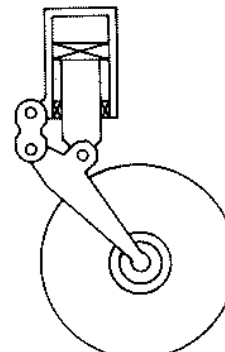

Telescopic   Lever suspension   Forward lever
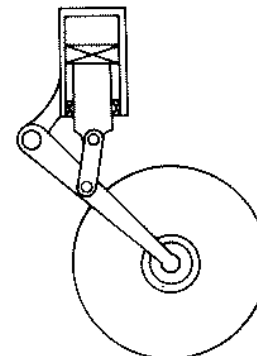
Sideways lever   Deformable quadrilateral   Semi-articulated

Overview Strut-Types

AIRBUS

Struts and Shock Absorbers
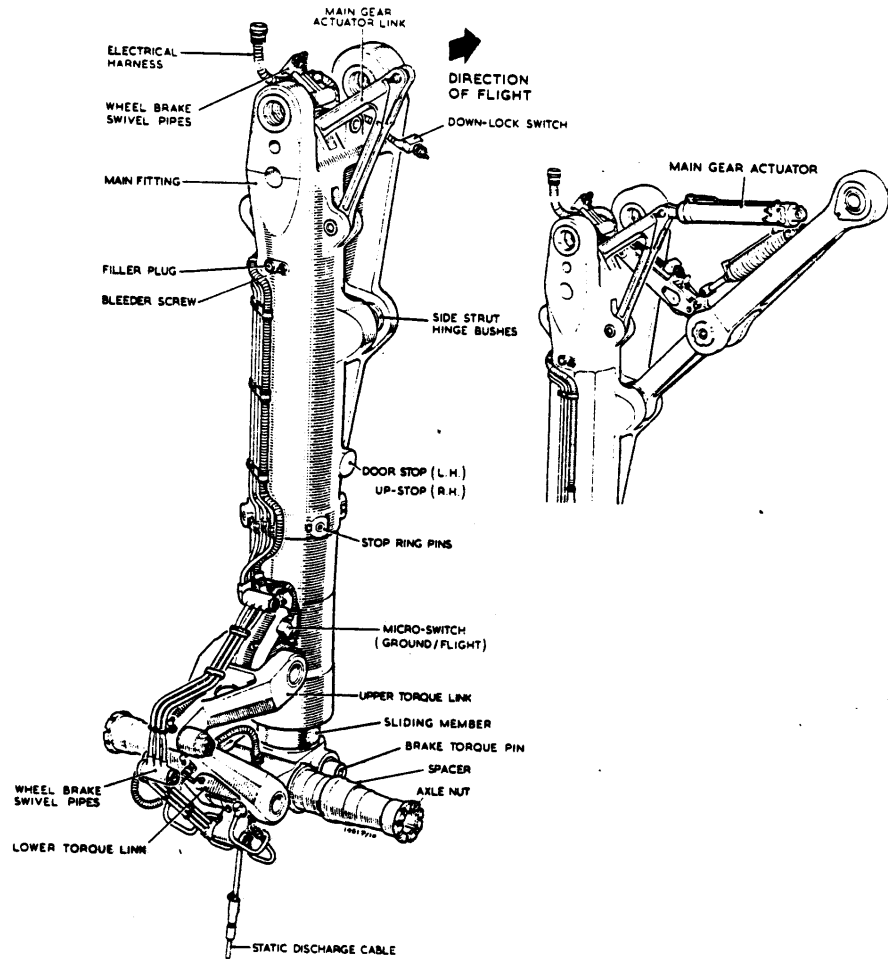
Telescopic-type MLG , Fokker F-28

AIRBUS

Struts and Shock Absorbers
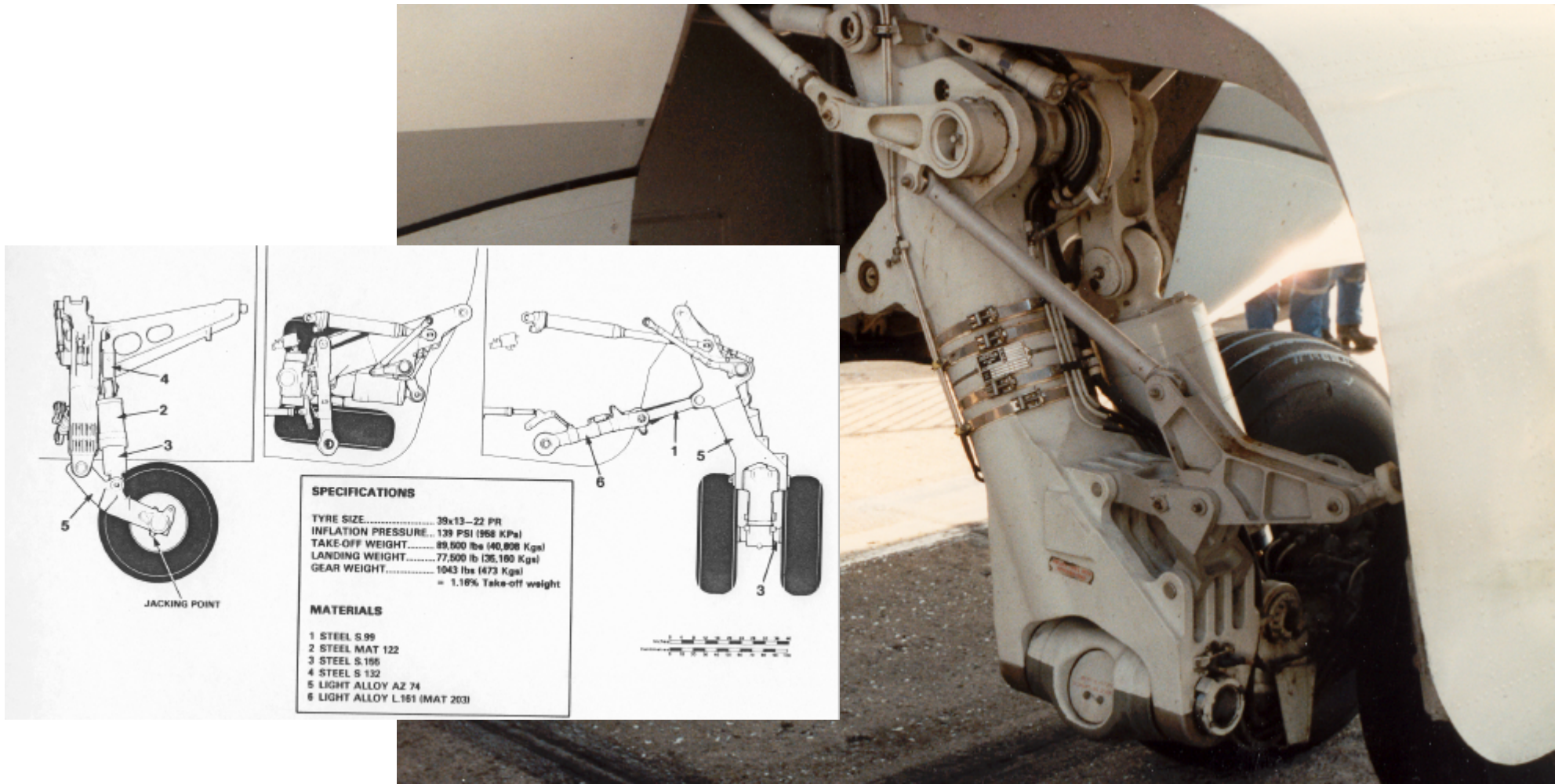
Lever-type MLG , BAe 146

AIRBUS

Struts and Shock Absorbers

Semi-lever-type MLG , TU 154

✈ AIRBUS

Struts and Shock Absorbers
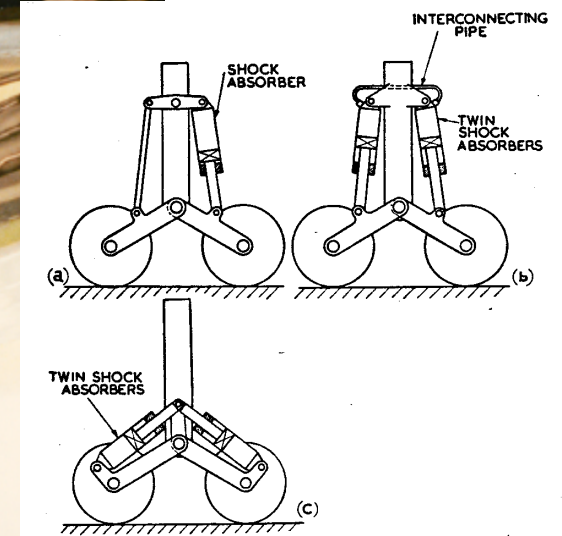
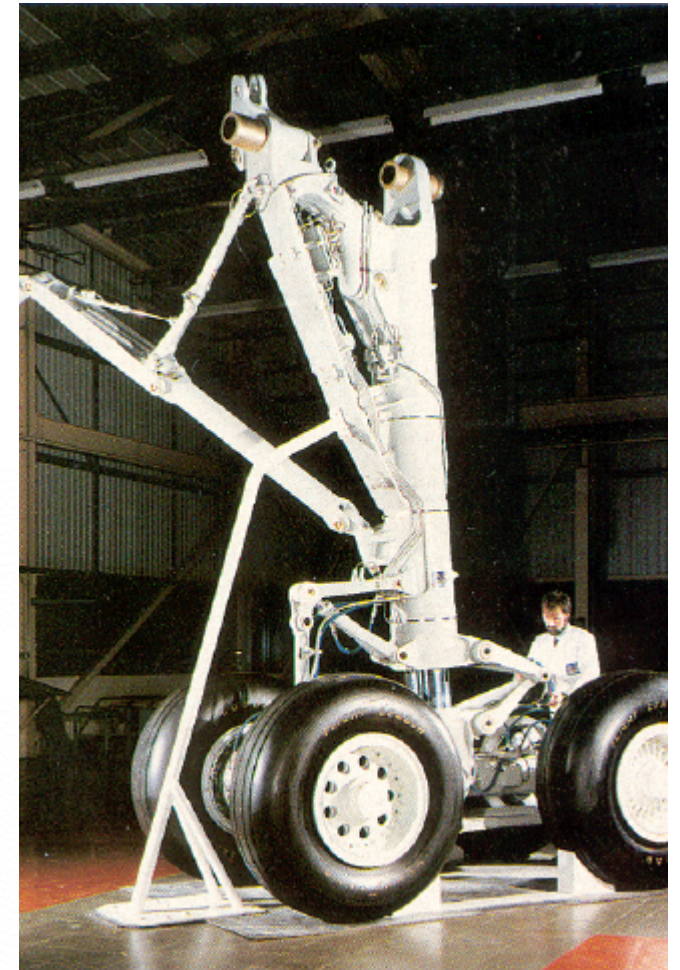4 Wheel MLG , Caravelle

AIRBUS

Struts and Shock Absorbers
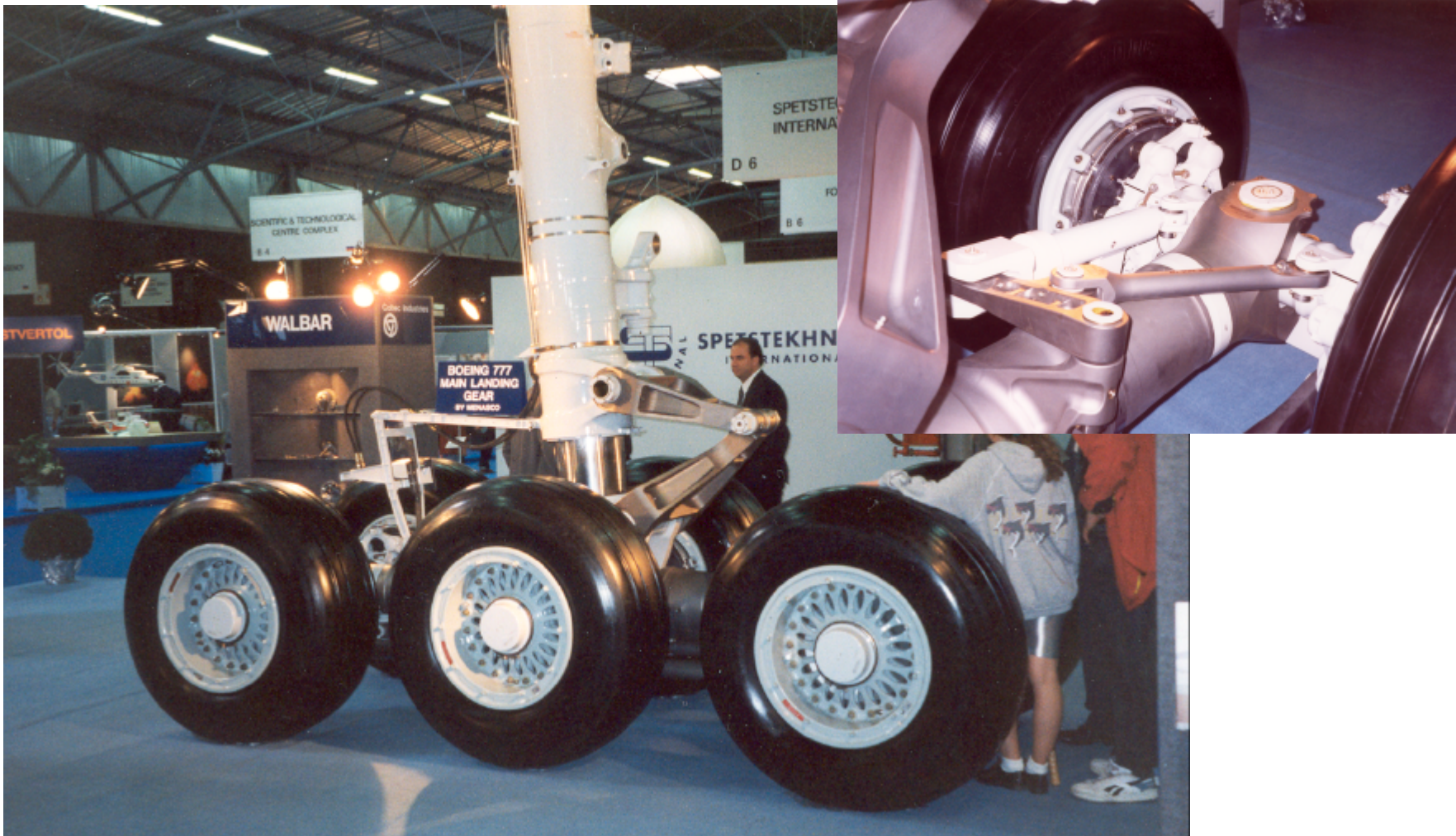

MLG , A300

MLG , A310

MLG , A340

AIRBUS

Struts and Shock Absorbers

MLG with Steering , B777

Struts and Shock Absorbers

Aermacchi / Embraer AMX

Struts and Shock Absorbers

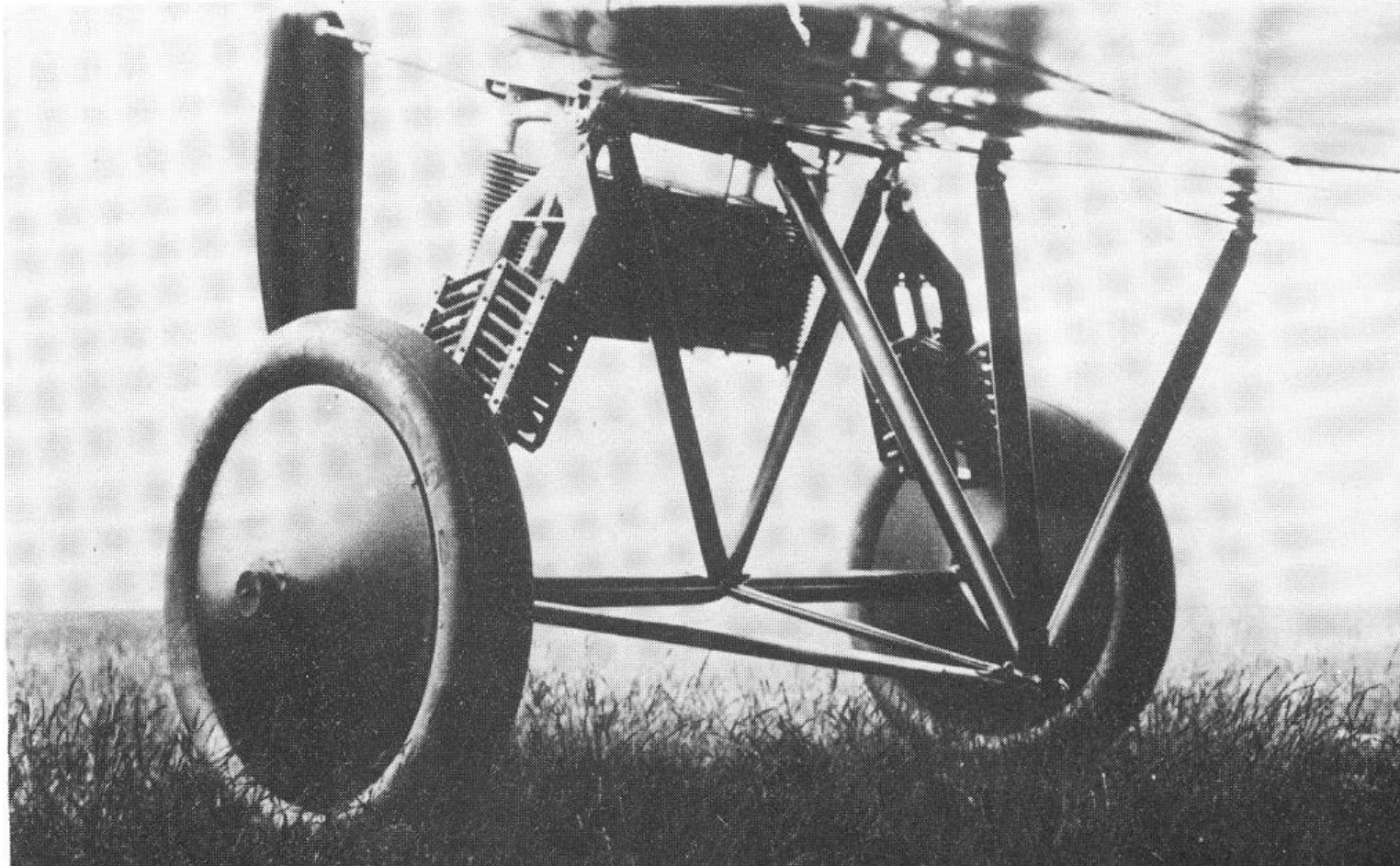EF 2000 - Typhoon

Struts and Shock Absorbers

Lockheed Martin F-16
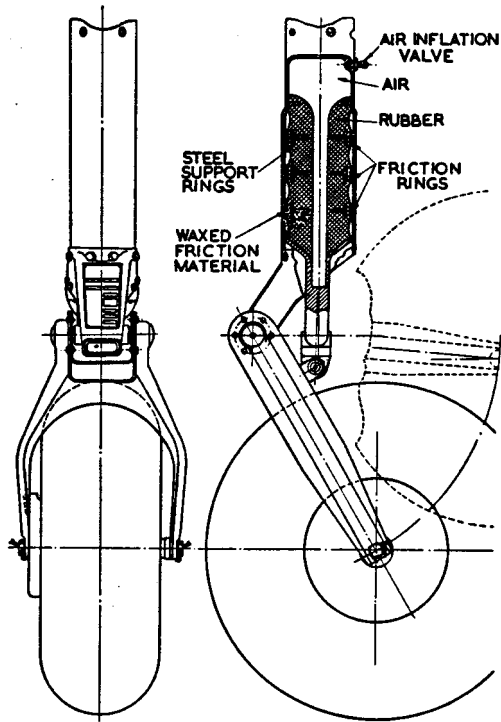
AIRBUS

Struts and Shock Absorbers

Boeing F-18
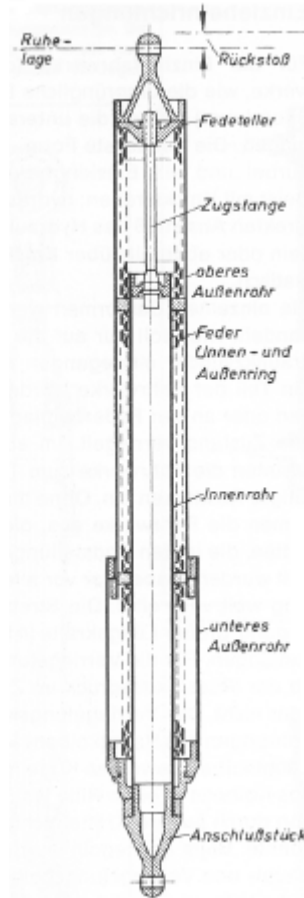
Struts and Shock Absorbers

Rubber Shock Absorber

Struts and Shock Absorbers

Rubber

Spring

Oleo

Struts and Shock Absorbers

(a) Unseparated oleo with positive recoil control

(b) Unseparated oleo with three level damping position dependent

(c) Separator type oleo

(d) Two-stage shock absorber
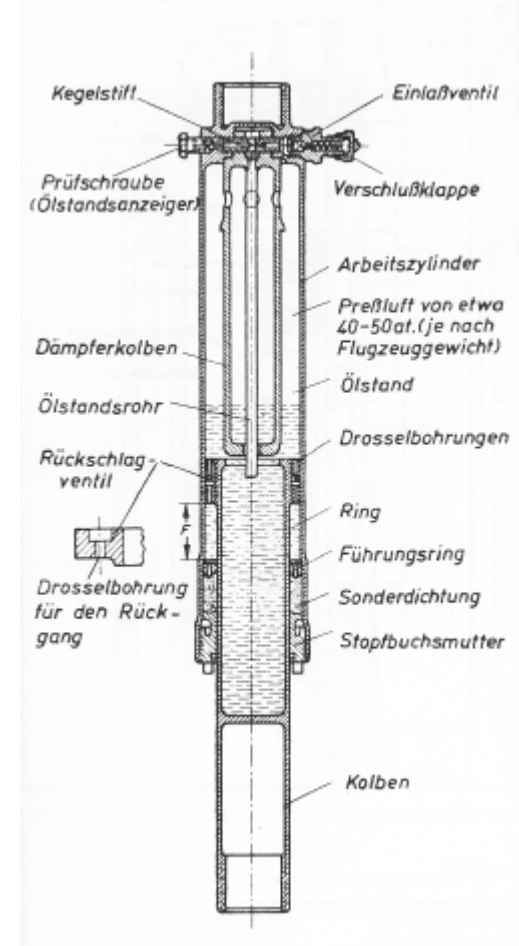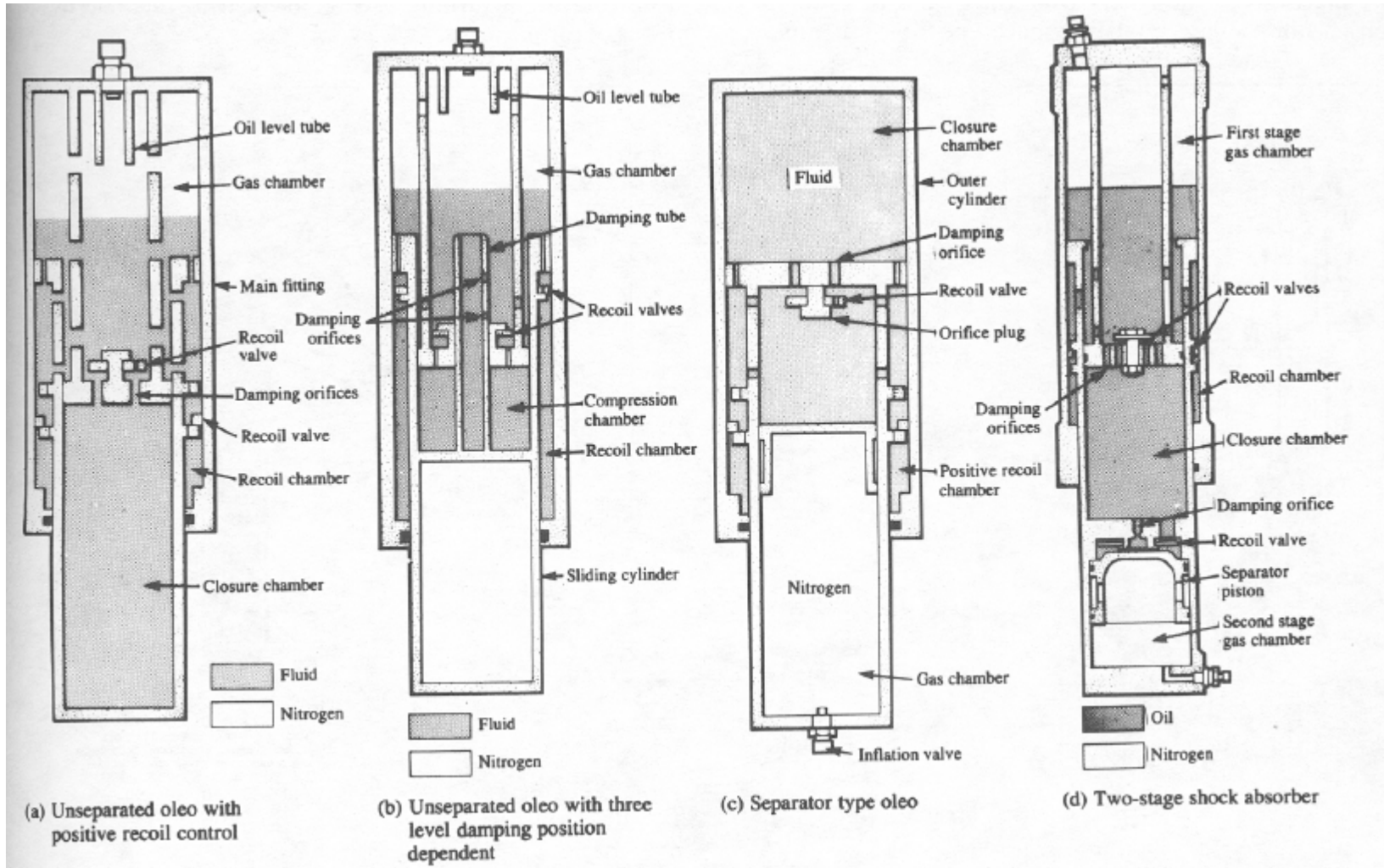
Oleo-Types
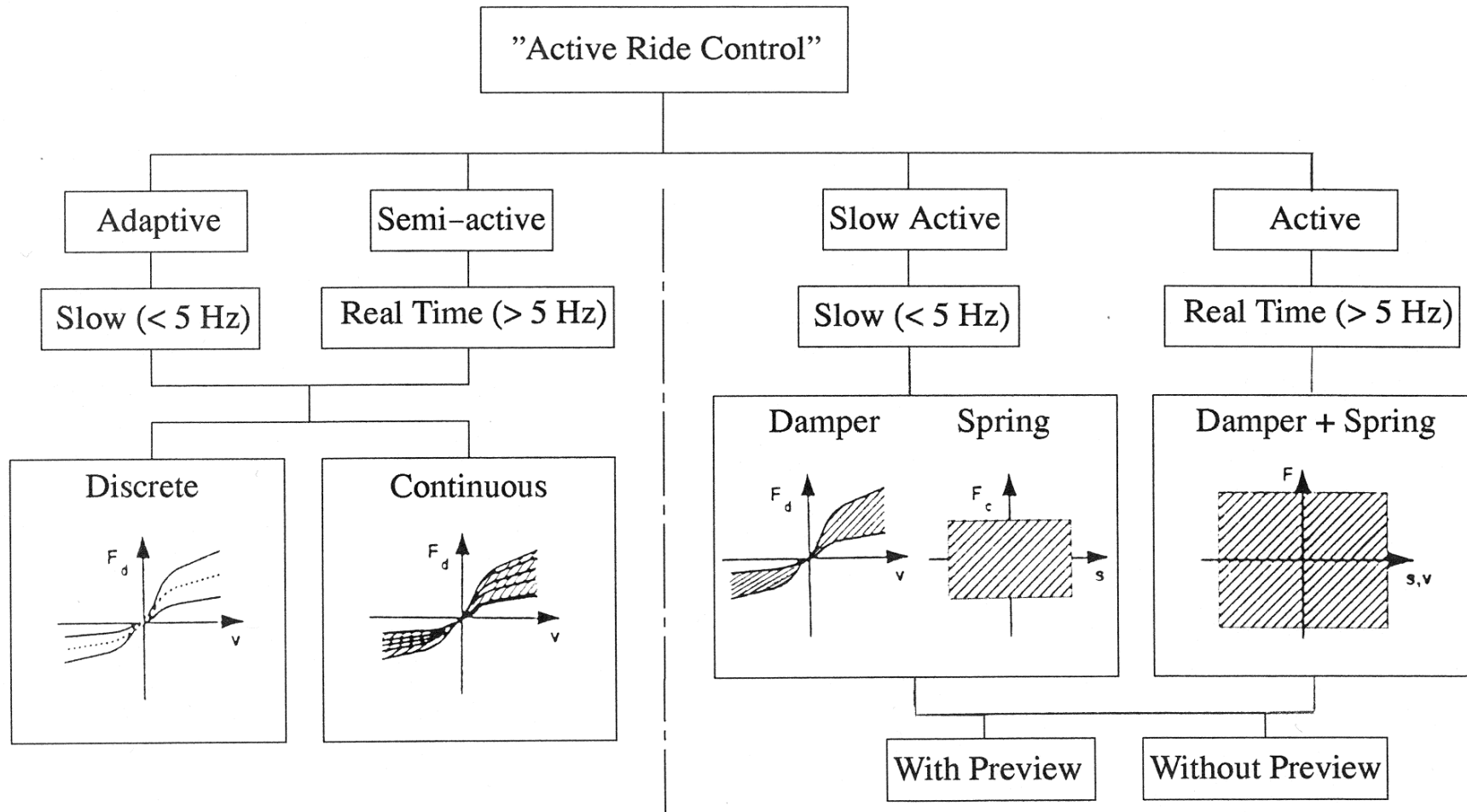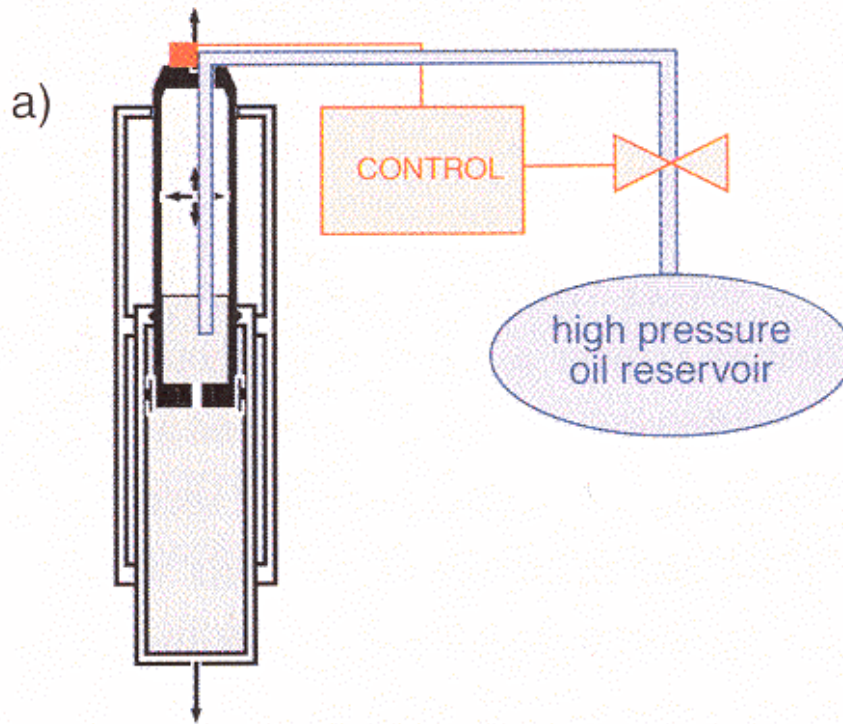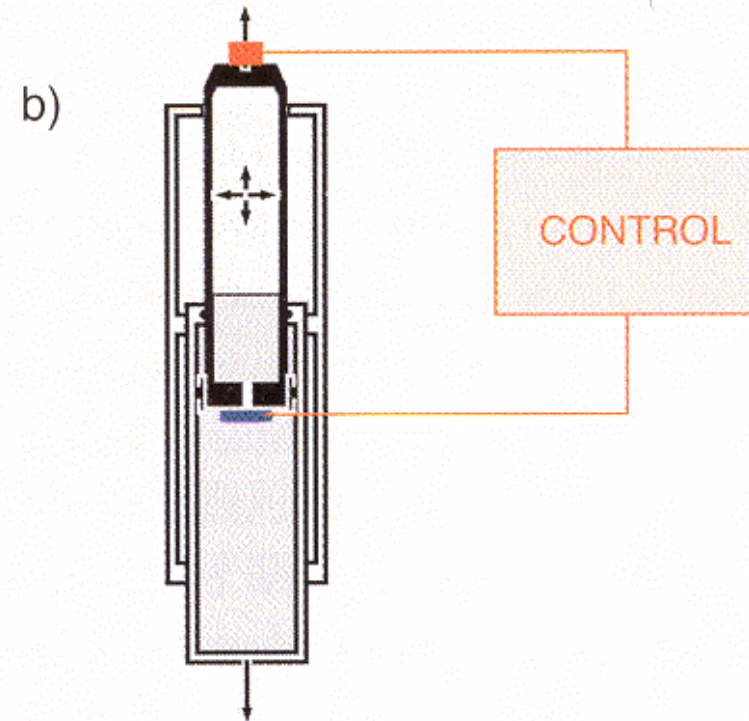
Struts and Shock Absorbers
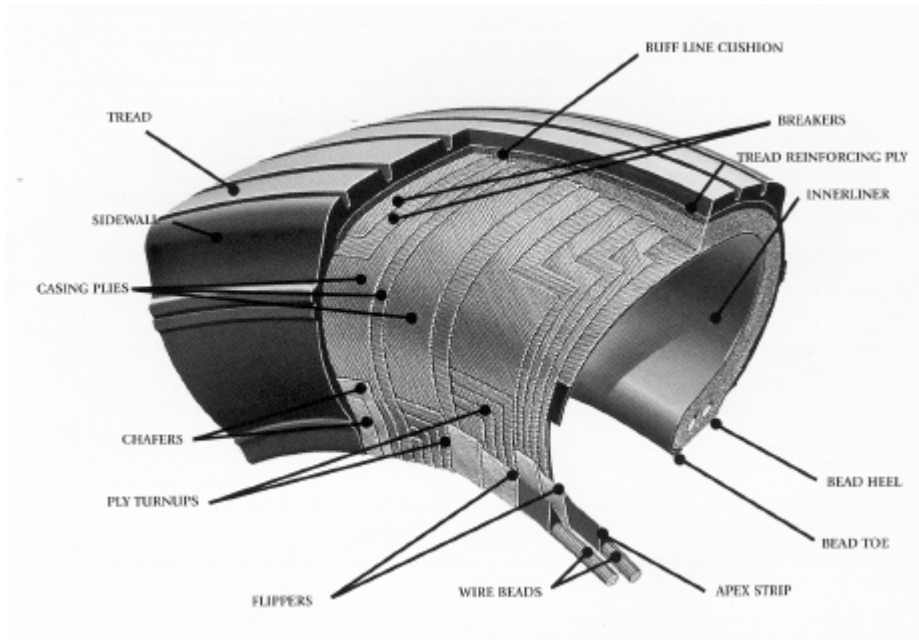
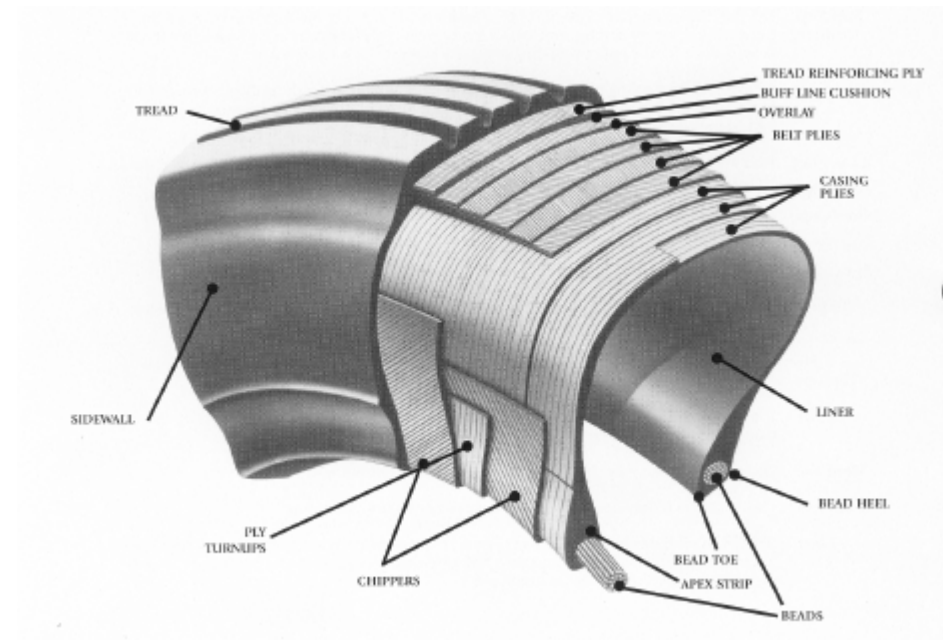# *Struts and Shock Absorbers*

Active Control   Semi-active Damping

Tyres, Wheels & Brakes

Brake

Tyre

Wheel

Brake
Discs

AIRBUS
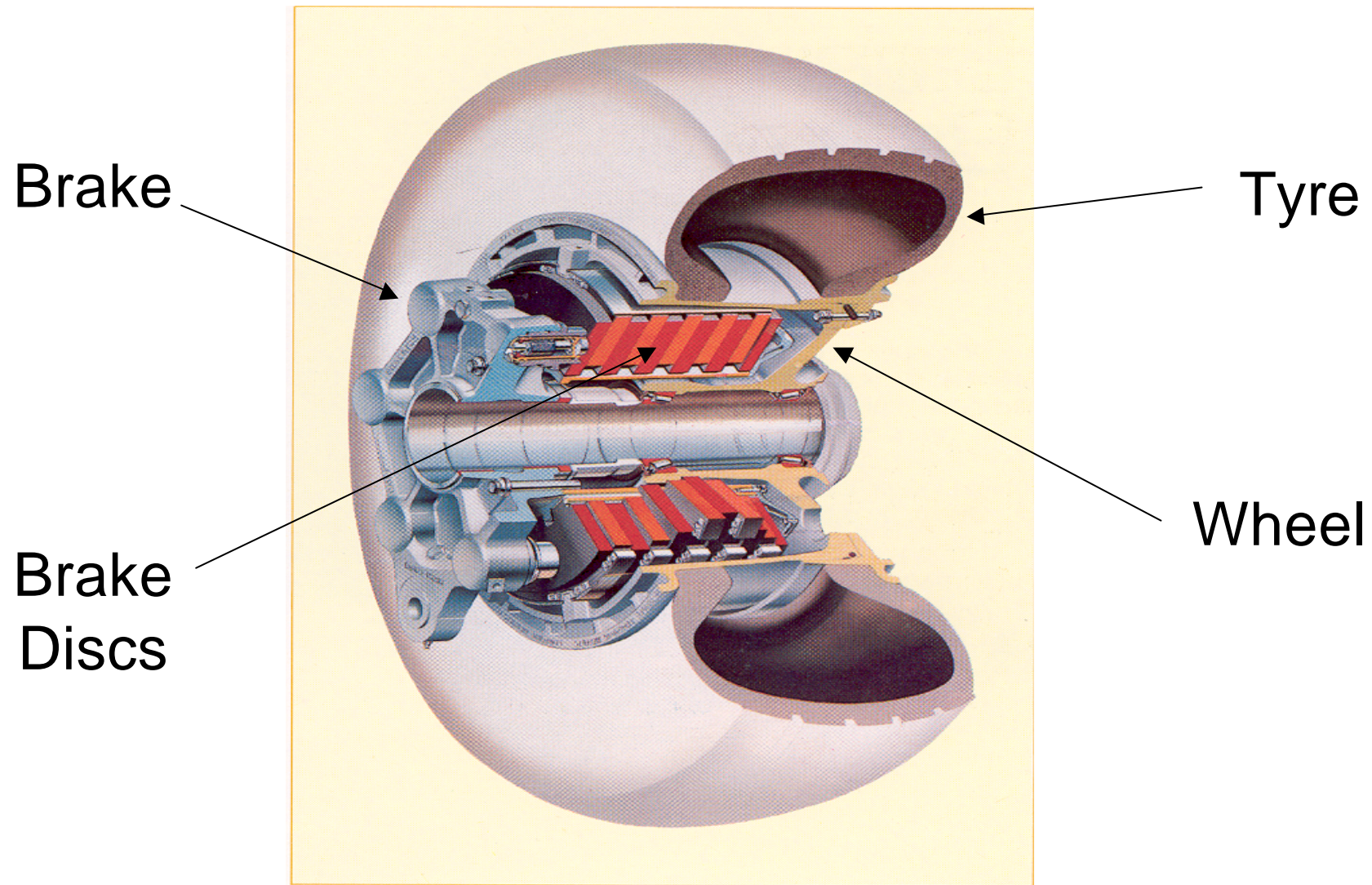
Tyres, Wheels & Brakes

Bias Tyre

Radial Tyre

AIRBUS

Tyres, Wheels & Brakes

MICHELIN NZG RADIAL CONSTRUCTION

1 Crown protection ply
4 Casing plies
7 Crown plies
2 High tensile fibre bead wires
Source: Michelin

NZG = Nearly Zero Growth
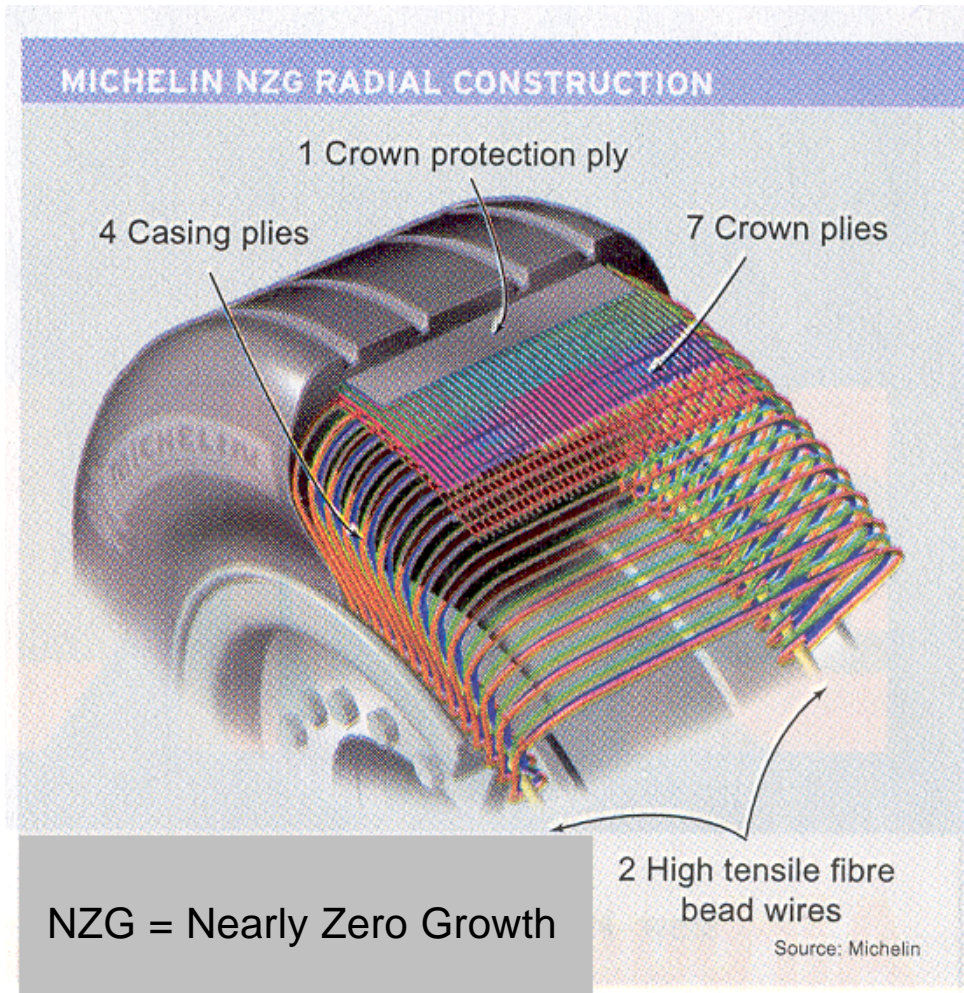
TABLE 1- TYRE CONSTRUCTION DESIGN COMPARISON

	Bias	Radial	NZG Radial
Bead wires	6	2	2
Casing plies	18	7	4
Crown plies	0	9	7
Crown protection plies	2	1	1
Tread groves	5-6	4	4

Source: Michelin

TABLE 2 - TYRE COMPARISON FROM 0-100M/SEC (0-195KT)

	Radius increase		
Tyre type	Centrifugal force	Inflation	Total
Bias	+4%	+8%	+12%
Radial	+2%	+6%	+8%
NZG Radial	+1%	+2%	+3%

Source: Michelin

NZG Tyre

AIRBUS

Tyres, Wheels & Brakes

ROTOR ALIGNMENT GUIDE

INFLATION VALVE NO EXTENSION REQUIRED

WHEEL BEARINGS

BEARING GREASE SEALS

WHEEL TIE BOLTS

PRESSURE RELIEF VALVE

HEAT SHIELD

THERMAL FUSE SCREW ACCESSIBLE WITHOUT REMOVING TIRE

ROTOR DRIVE KEYS

HEAT SHIELD SCREWS, RETAINERS AND NUTS

NLG

MLG

Wheels

AIRBUS

Tyres, Wheels & Brakes

Pre-rotated Wheels

Tyres, Wheels & Brakes
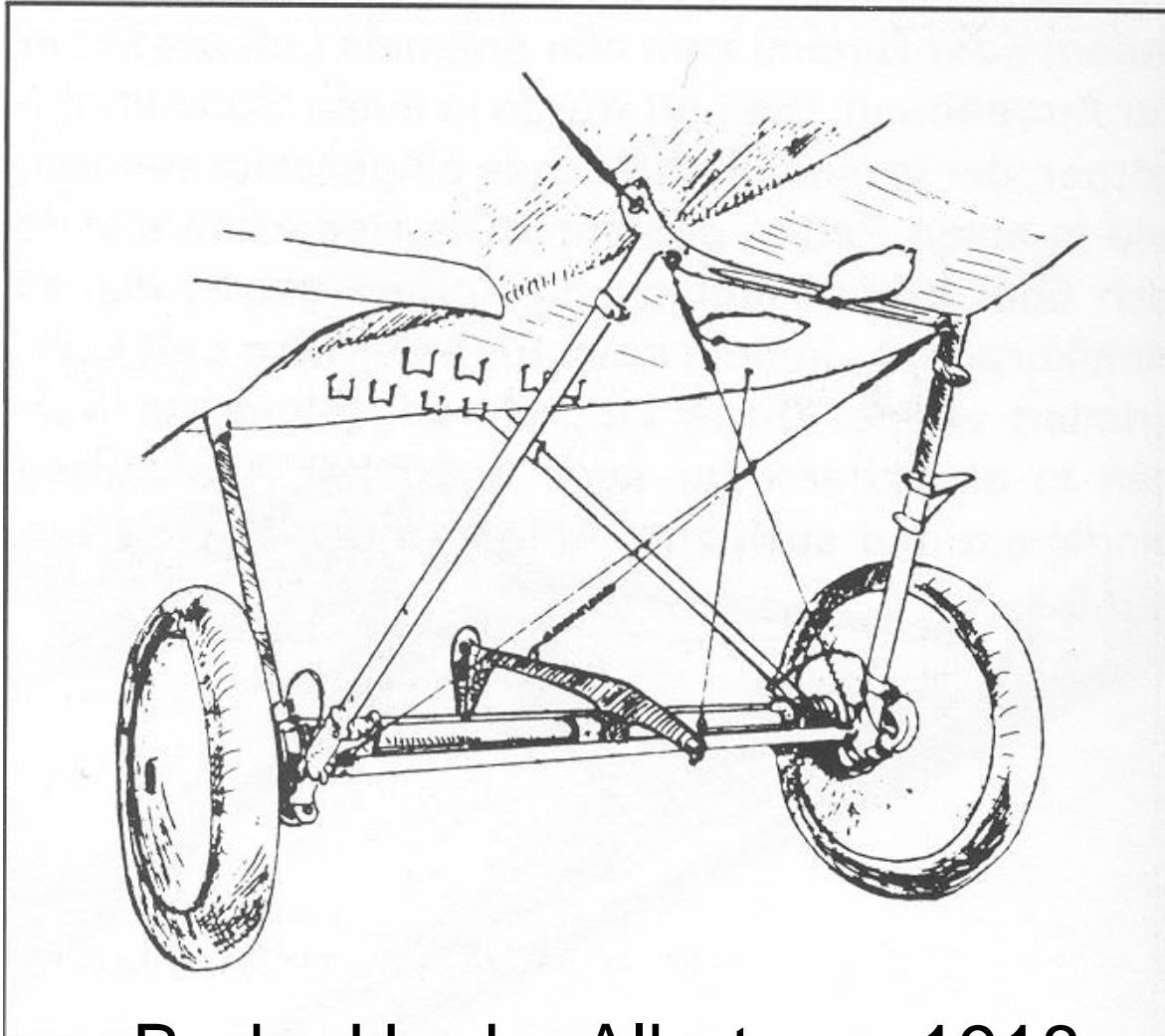
Brake Hook , Albatros , 1918

AIRBUS

Tyres, Wheels & Brakes
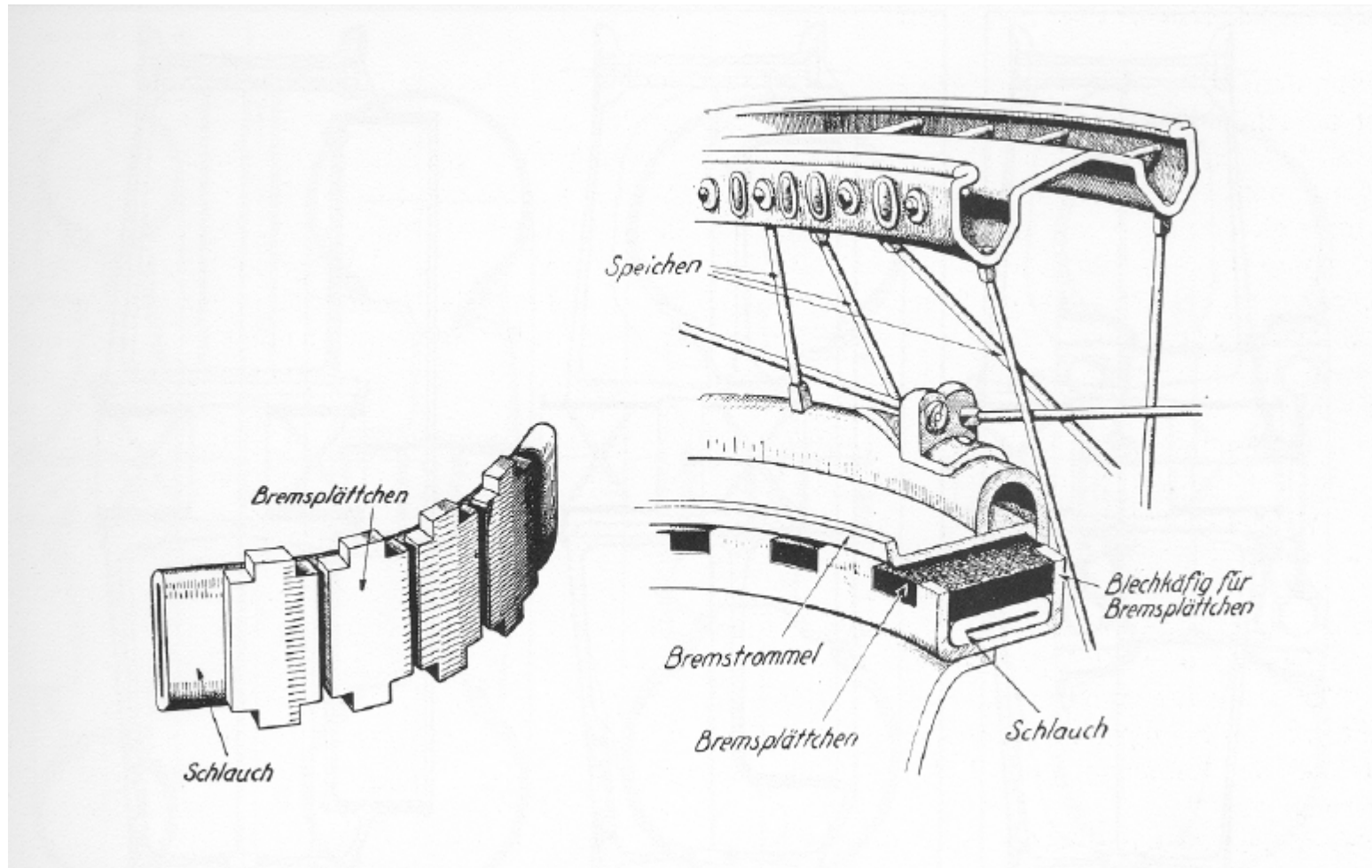
Palmer - Brake Tube

Tyres, Wheels & Brakes
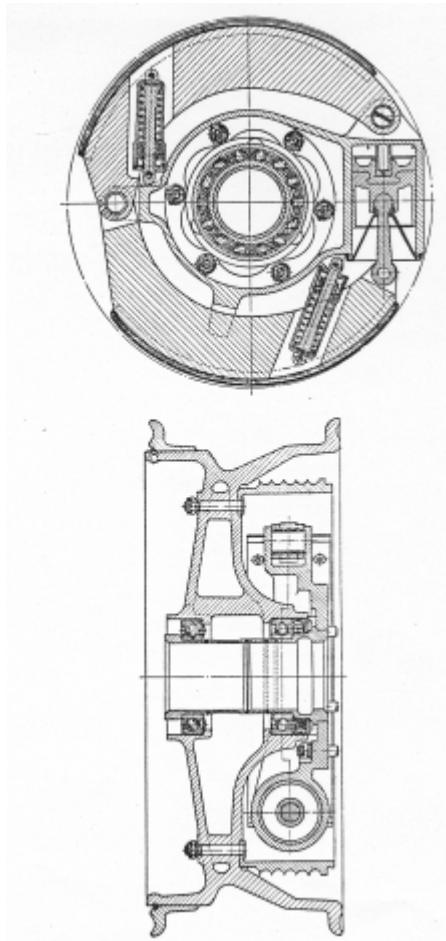
Drum Brake

Multi-disc Steel Brake

AIRBUS

Tyres, Wheels & Brakes

**4 Rotor and
5 Stator C/C**

Wear Pin

**Temperatur
Sensor**

**Piston
Housing**

Brake Piston

WEAR RATE

TAXI ENERGY RANGE

HIGH ENERGY RANGE

SERVICE ENERGY RANGE

STEEL

CARBON

KINETIC ENERGY
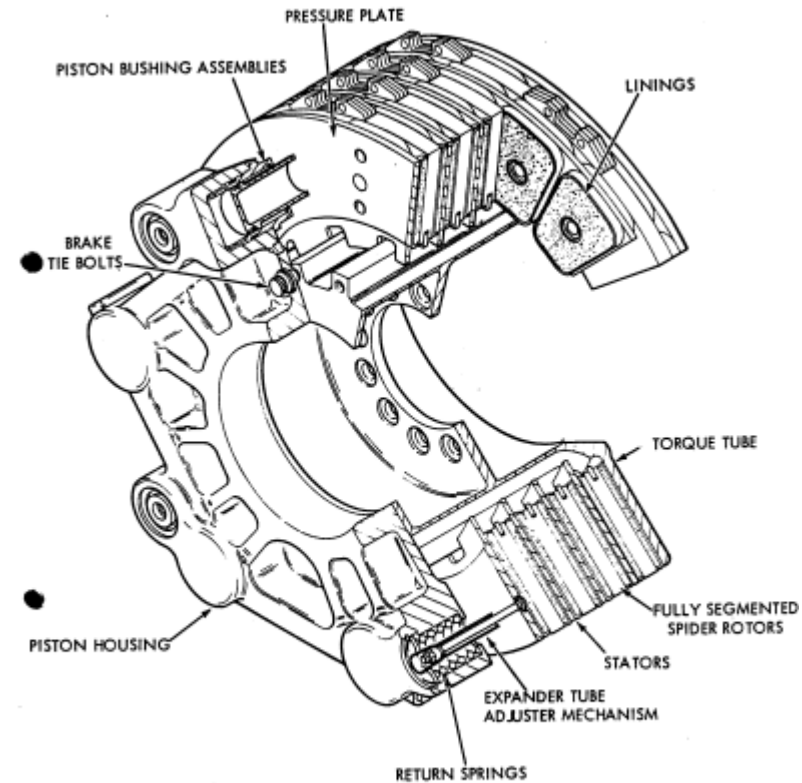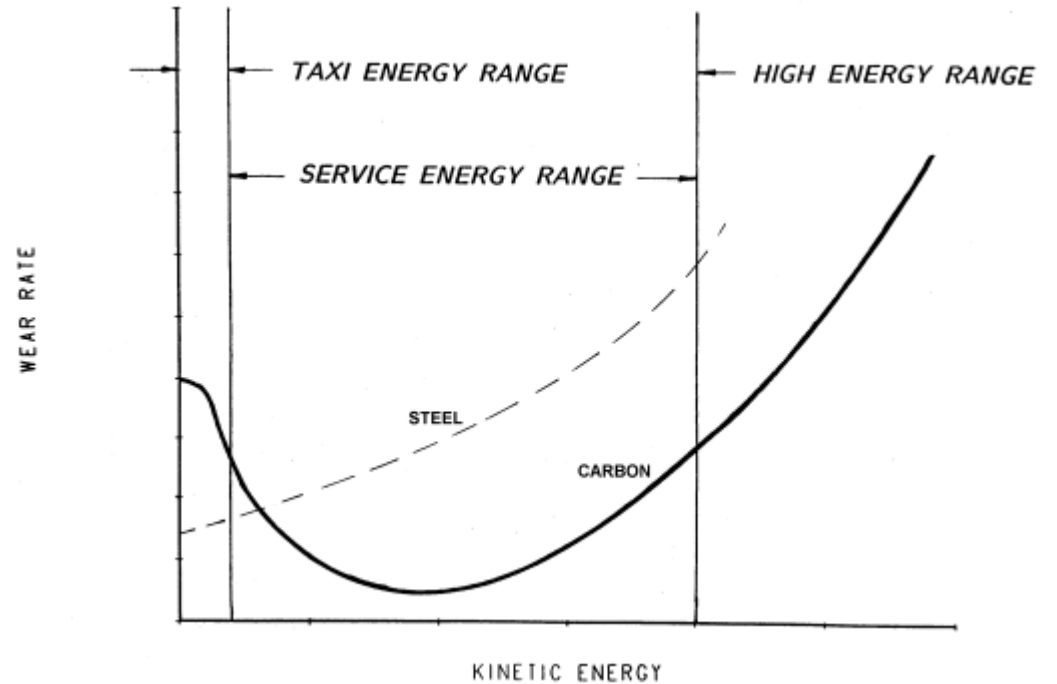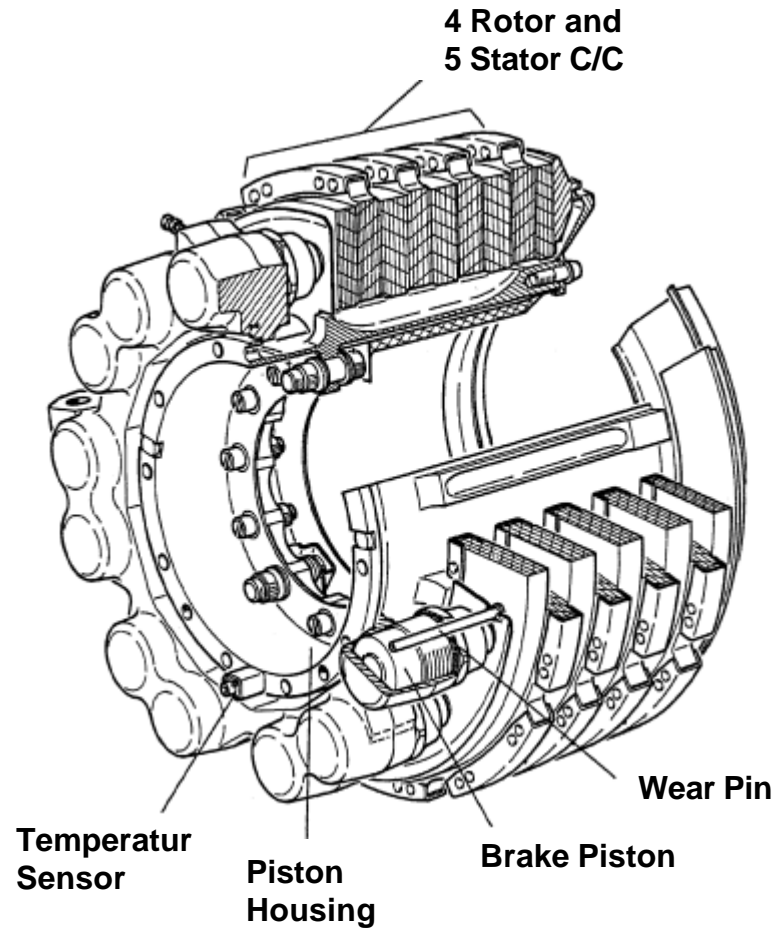
Carbon Brake

Braking system

From brake
control valve

Modulator

reservoir
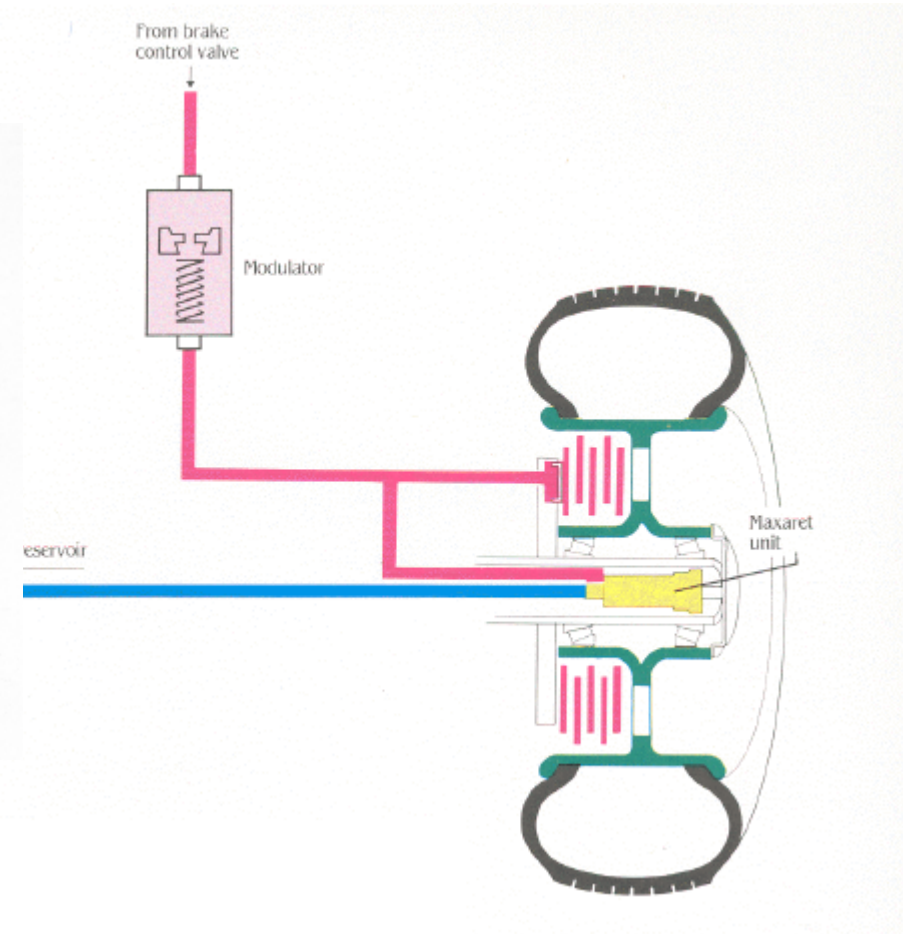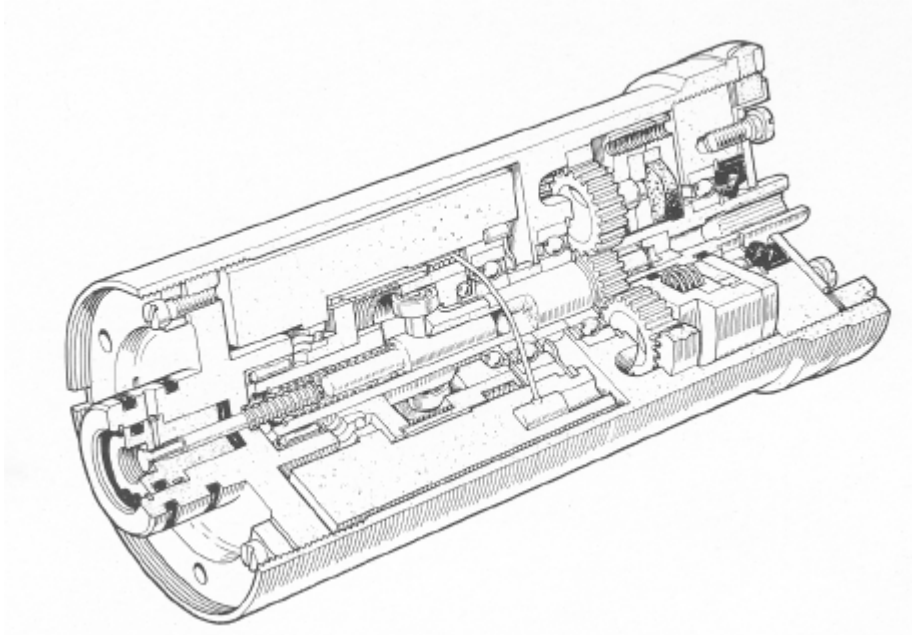
Maxaret
unit

Dunlop Maxaret , 1948

AIRBUS

Braking system

Brake Failure

Braking system
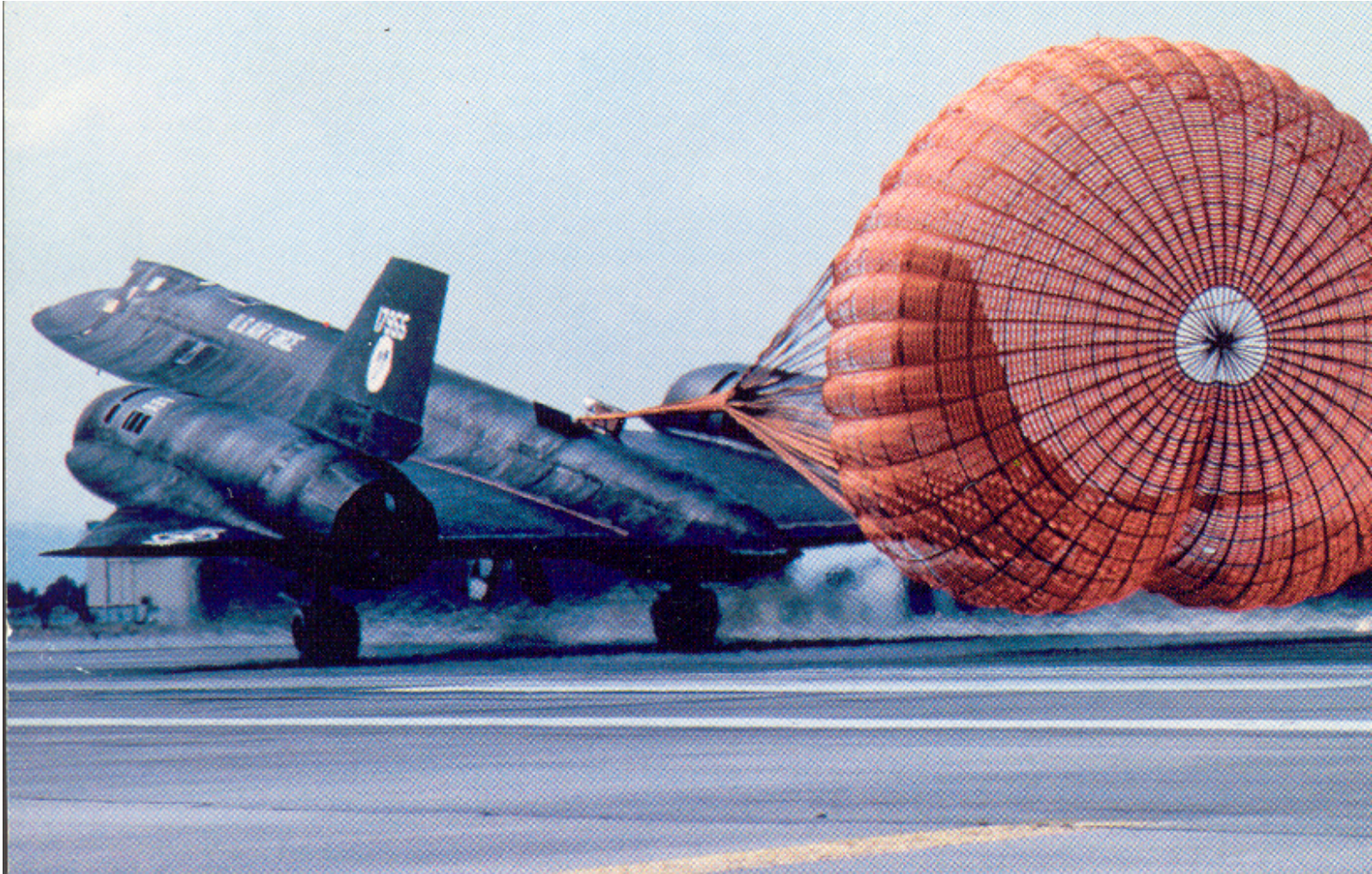
Braking Parachute , Lockheed SR-71

AIRBUS

Braking system

Aircraft Carrier Operations

AIRBUS

Braking system

Aircraft Carrier Operations

AIRBUS

Steering system

Basic steering actuation mechanisms:
- BANANA LINKAGE
- BANANA LINKAGE WITH MOVING BODY ACTUATOR
- MOVING BODY ACTUATOR
- OSCILLATING CYLINDER
- TWIN ACTUATOR
- BASIC STEERING ACTUATION MECHANISMS

Steering mechanism labels:
- CABLE INPUT THROUGH TRUNNIONS
- INPUT QUADRANT
- RACK
- STEERING VALVE
- BAULK RING
- DIFFERENTIAL LEVER AND CRANK ASSEMBLY
- SHUT-OFF VALVE
- STEERING COLLAR
- FOLLOW-UP SPRING BOX
- STEERING ACTUATOR
- TORQUE LINKS
- FORWARD
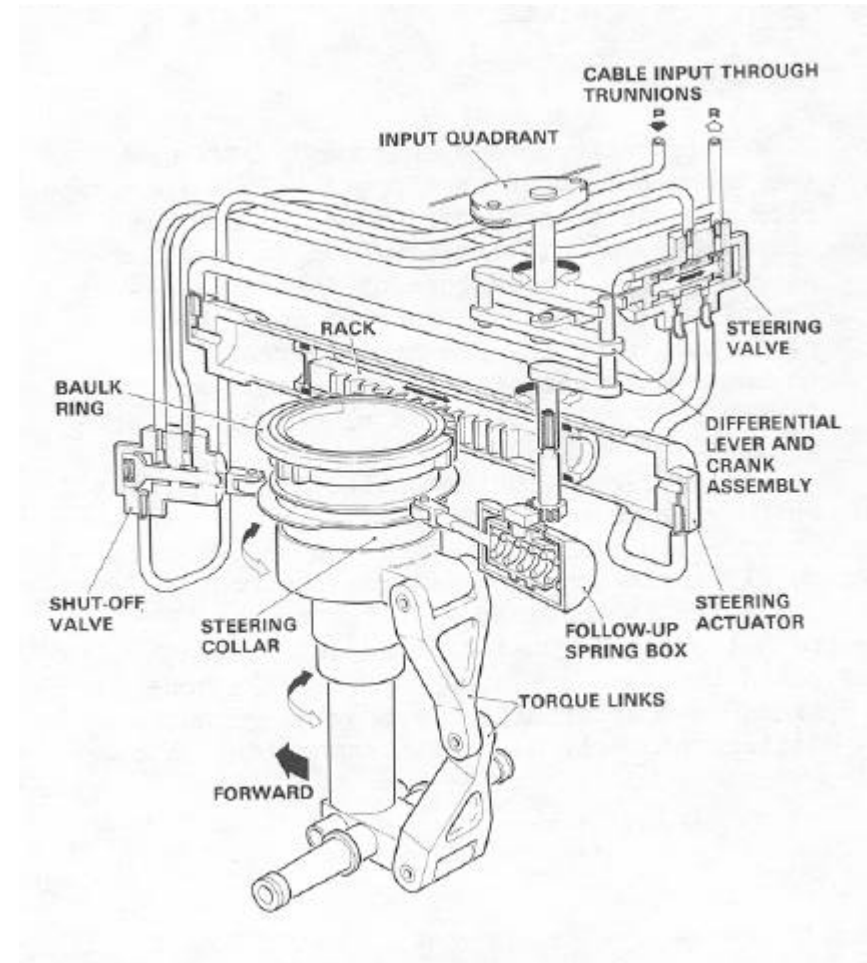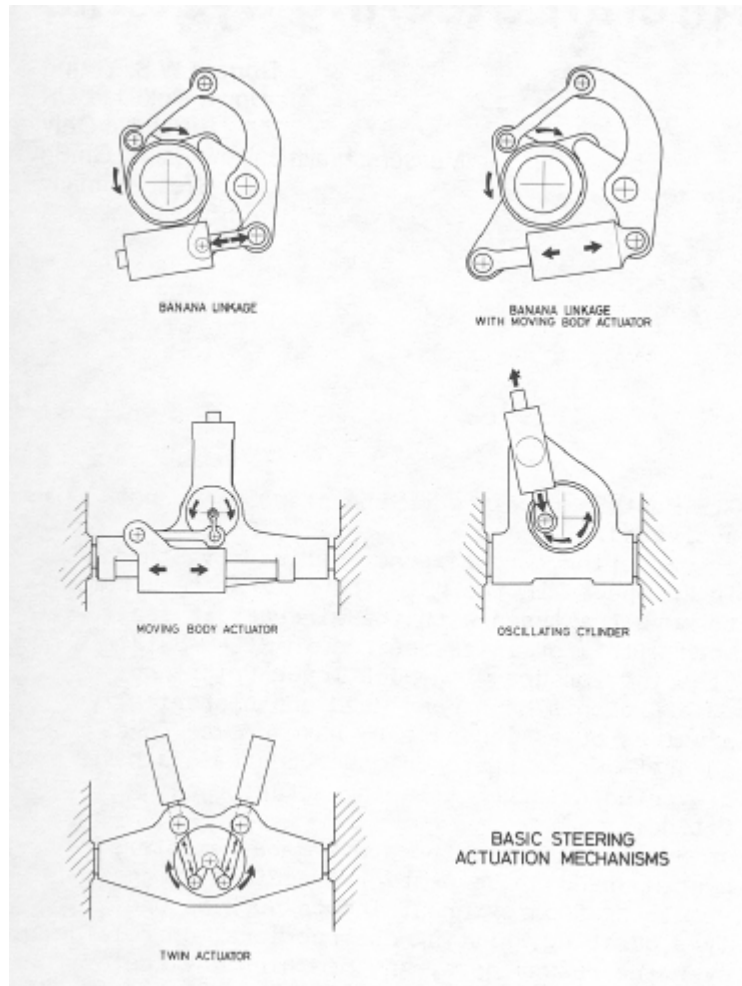
Steering Mechanism

AIRBUS

Actuation system

Landing Gear Retraction, Boeing 747

AIRBUS

Tests and Certification

- **Landing Gear Certification is part of the Aircraft Certification**
- **Test are performed at the Suppliers facilities**
- **Normally 4 Prototypes are simultanously used for:**
    1. **Performance Test**
    2. **Fatigue Test**
    3. **Strength Test**
    4. **Drop Test**

AIRBUS

Tests and Certification
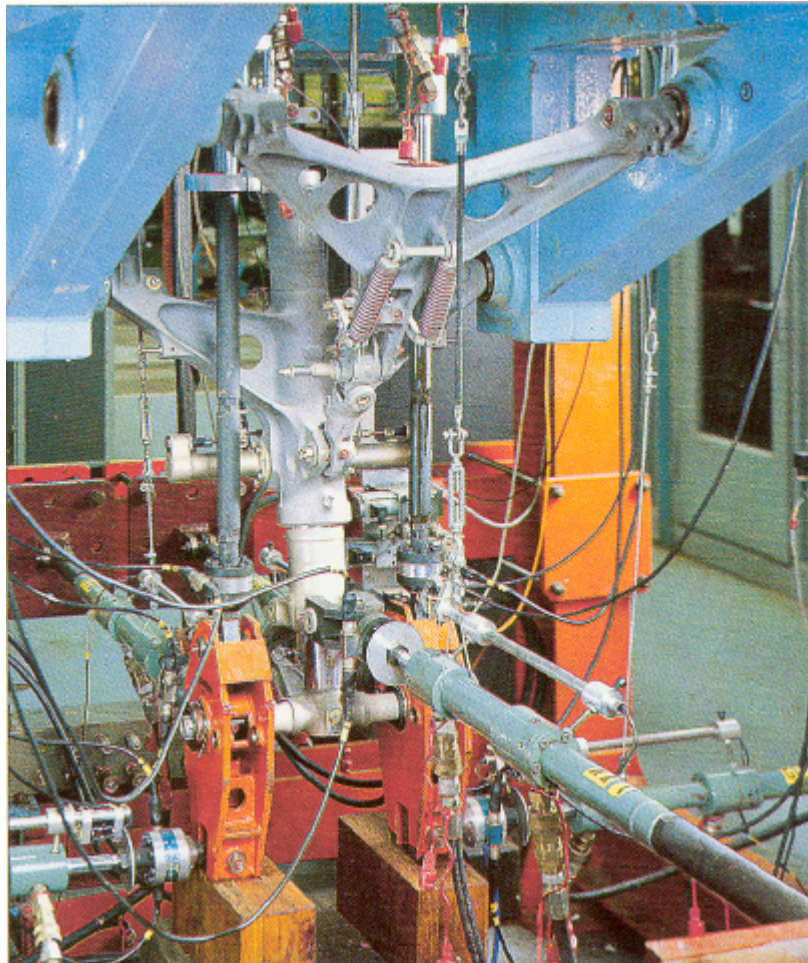
Fatigue Test

Strength Test

AIRBUS

Tests and Certification

Drop Test , MLG , A310

AIRBUS

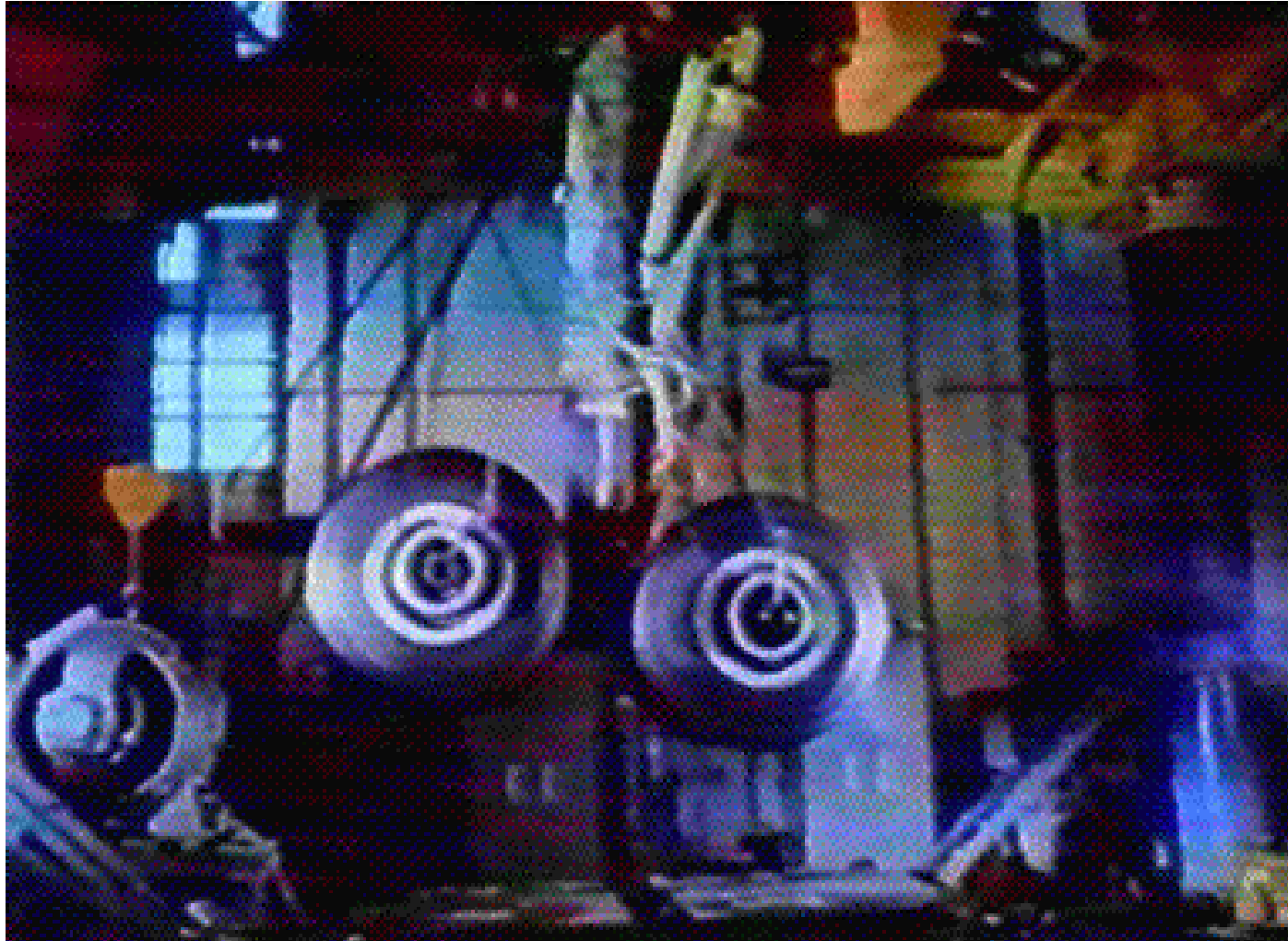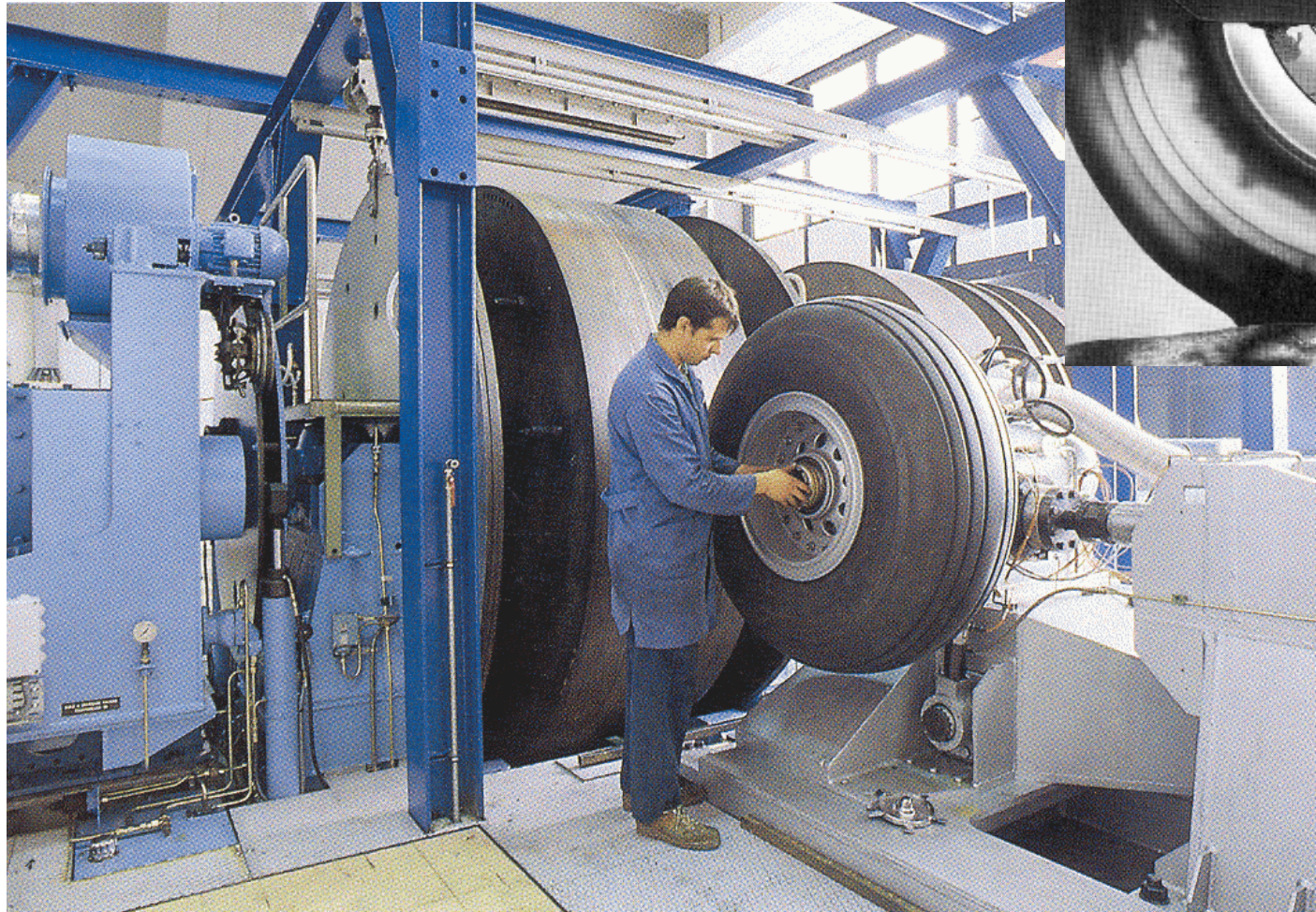# *Tests and Certification*

Rejected Take-off , B777

AIRBUS

Tests and Certification

Dynamometer

Tests and Certification
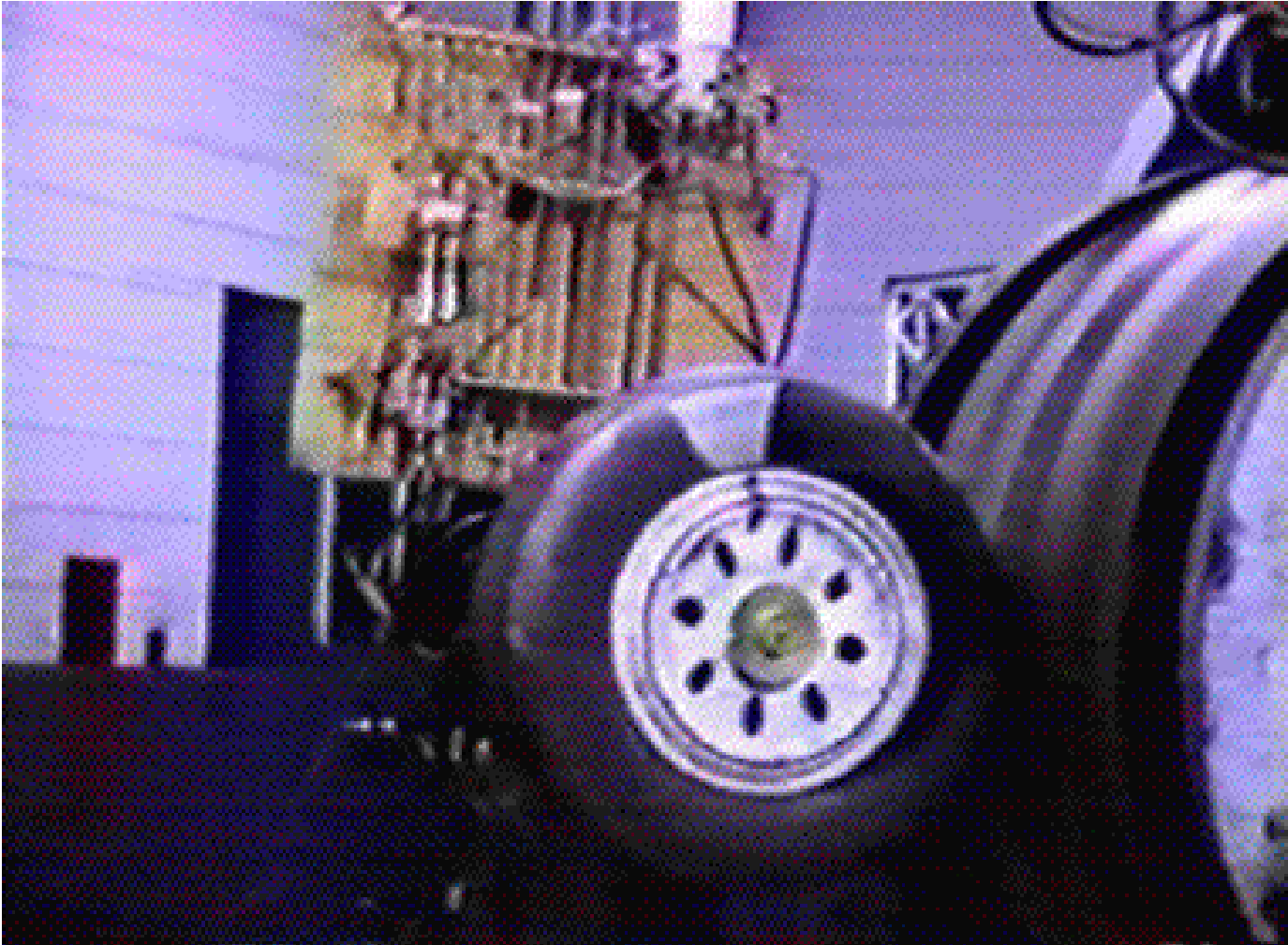
Over-load Tyre Test

AIRBUS

Tests and Certification

Tyre Failure

AIRBUS

Tests and Certification
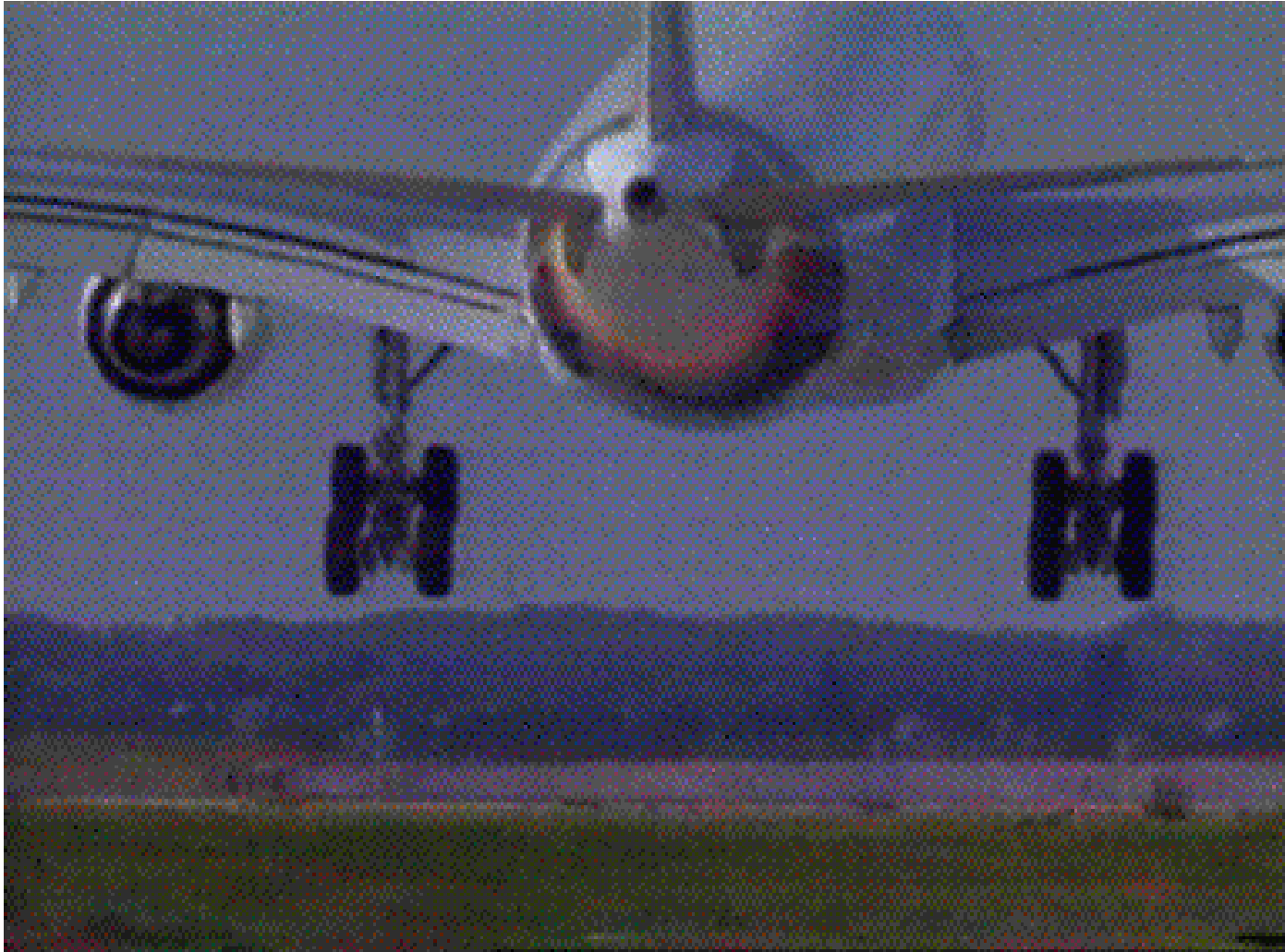
Normal Landing , A330

AIRBUS
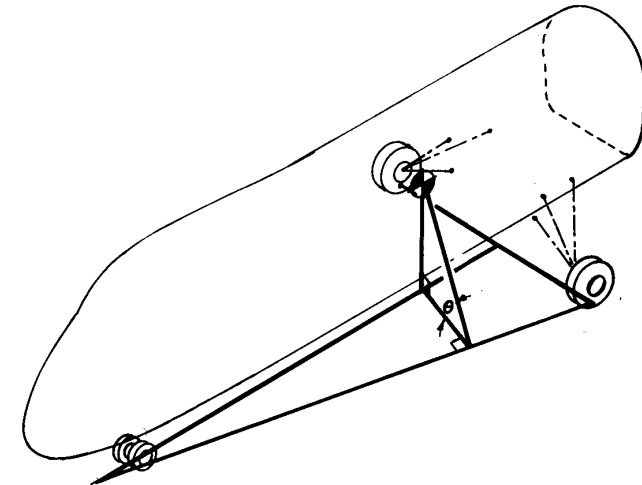
Tests and Certification

Landing under adverse Conditions , B747-400

AIRBUS

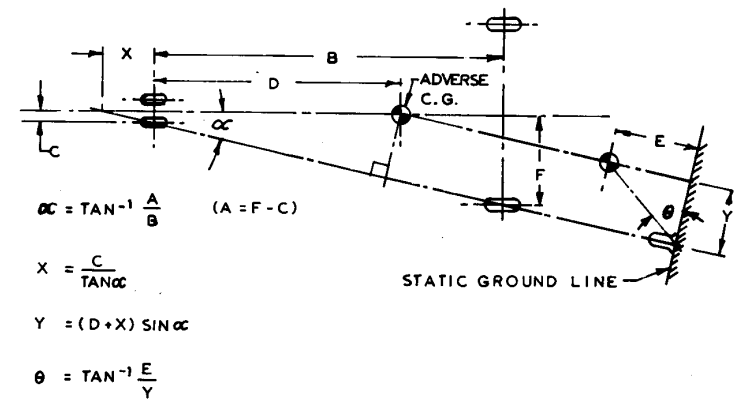# *Tests and Certification*

One Engine out Take-off, A340

AIRBUS

Landing Gear Design

NOTE : $P_n + n_s P_m = W$

n_s = NO. OF M GEAR S

$n_s = 2$ FOR MOST AIRPLANES

$n_s = 3$ DC 10-30 $n_s = 4$ B747

$\alpha = TAN^{-1} \dfrac{A}{B}$ $(A = F - C)$

$X = \dfrac{C}{TAN\alpha}$

$Y = (D + X) SIN\alpha$

$\theta = TAN^{-1} \dfrac{E}{Y}$

STATIC GROUND LINE

ADVERSE C.G.

AIRBUS

Landing Gear Design
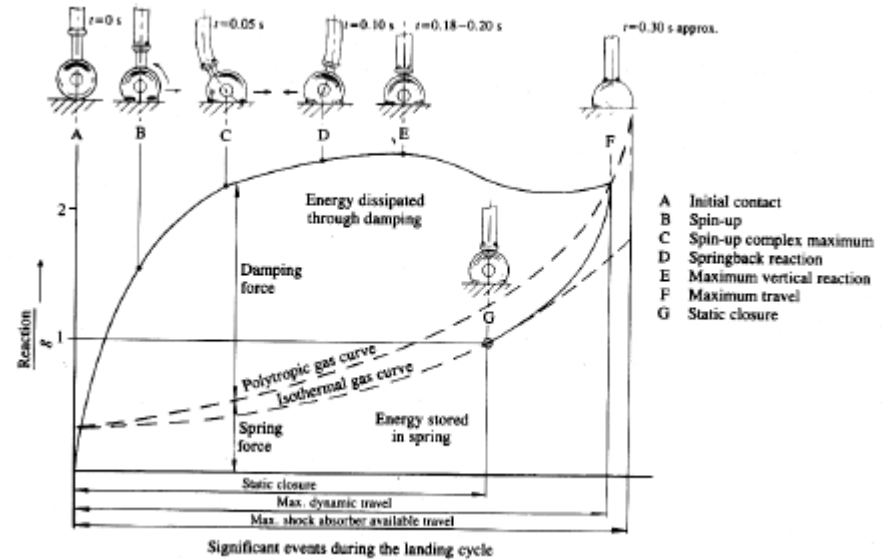
Sprung mass

Shock absorber
and spring

Shock absorber
damper

Shock absorber
travel

Unsprung mass
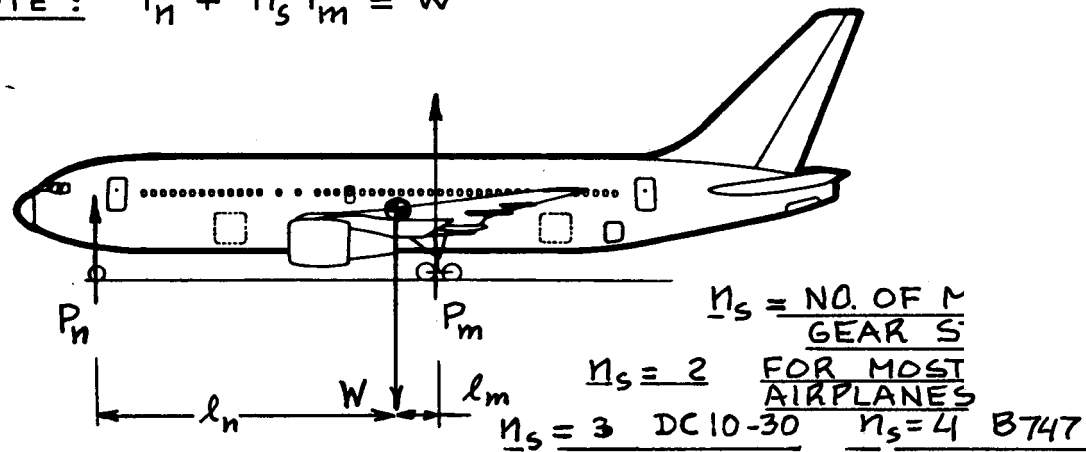
Tyre
travel
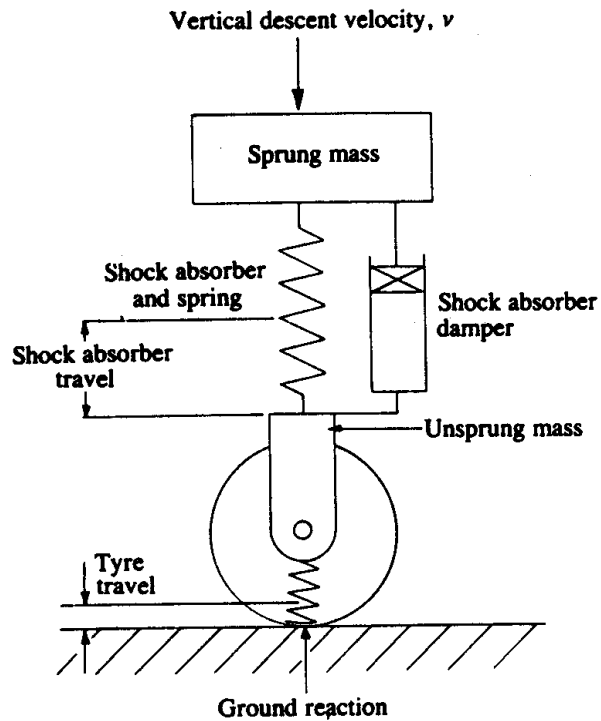
Ground reaction

Reaction factor, $\lambda = \dfrac{\text{Ground reaction}}{\text{Associated mass} \times g}$

$\text{Energy} = \frac{1}{2}\,mv^2$

$= \lambda.m.g$ [shock absorber travel $\times$
shock absorber efficiency $+$
tyre travel $\times$ tyre efficiency]

Significant events during the landing cycle

A   Initial contact
B   Spin-up
C   Spin-up complex maximum
D   Springback reaction
E   Maximum vertical reaction
F   Maximum travel
G   Static closure

$(S_t \times n_t \times NW) + (S \times n_s \times NW) = \qquad WV^2/2g \quad + \quad (W-L)(S+S_t)$

  tire energy   strut energy   kinetic energy   potential energy
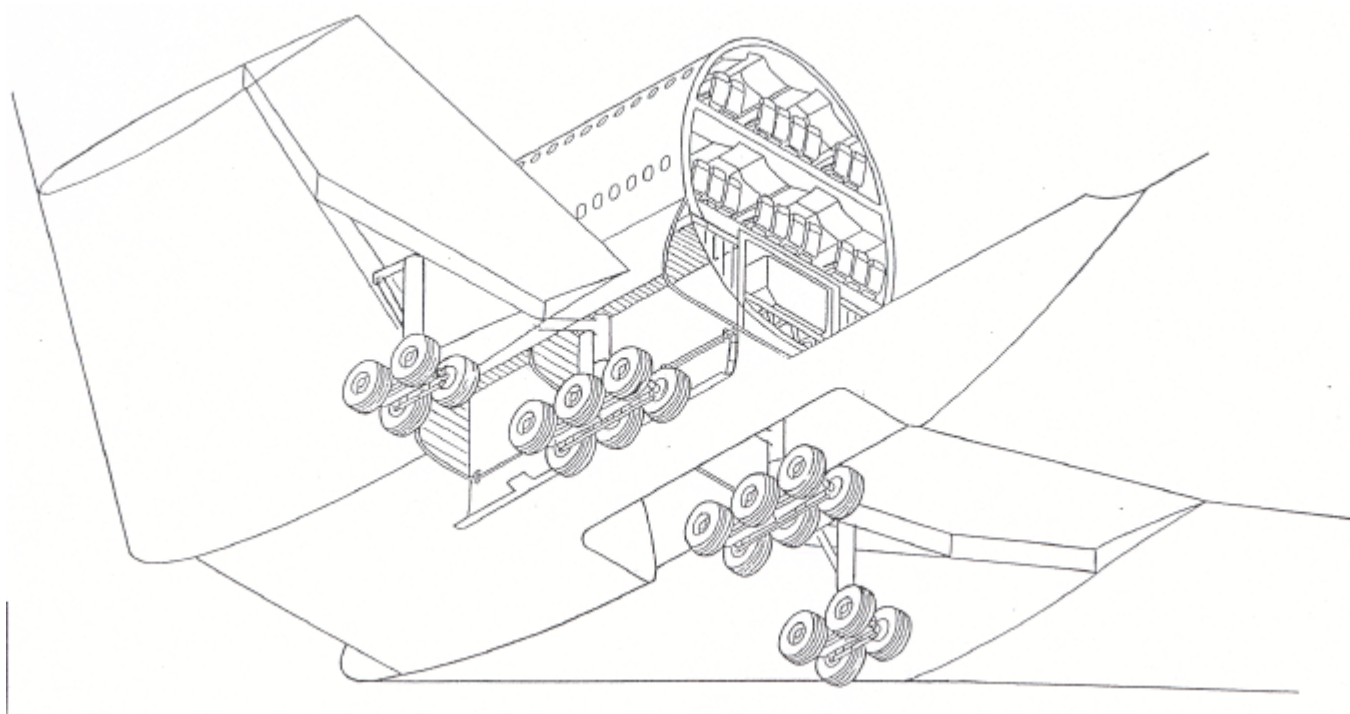
where

S_t = tire deflection under N times static load, ft
S = vertical wheel travel, ft (unknown)
n_t = tire efficiency, generally assumed to be 0.47
n_s = shock strut efficiency (assumed initially as 0.80 on an oleo-pneumatic
   strut)
N = reaction factor
W = aircraft weight, lb
L = lift, lb
V = sink speed, ft/sec

AIRBUS

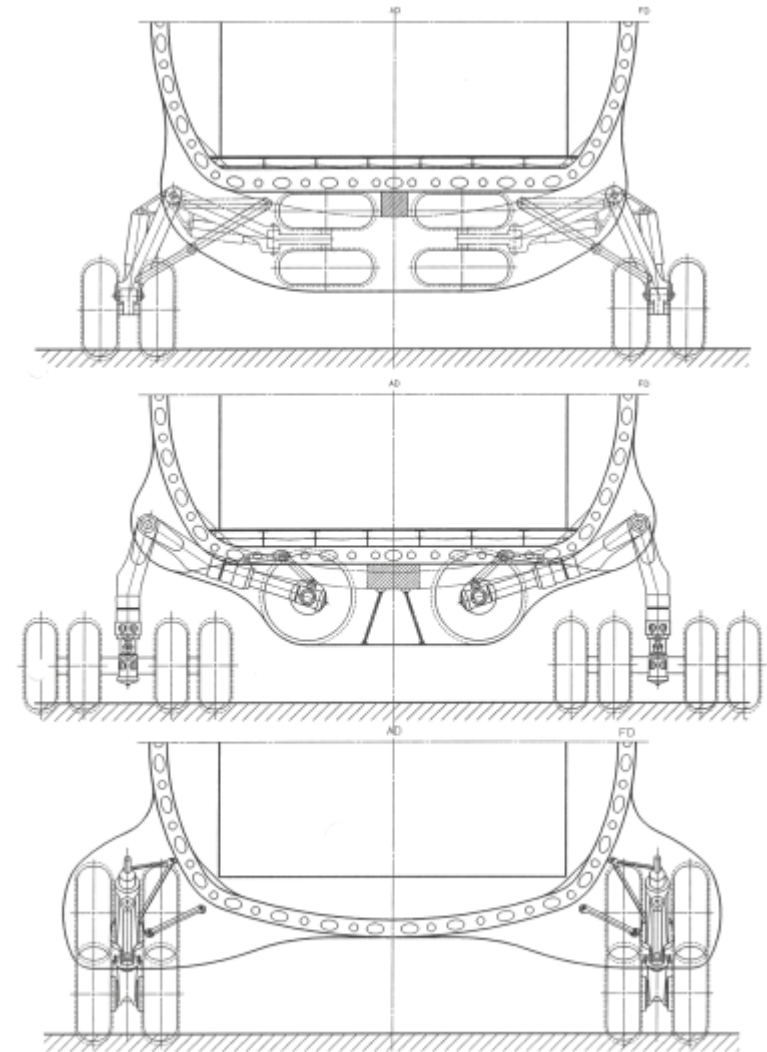# *Landing Gear Design*

Airbus A380-800

⚙ *AIRBUS*

Landing Gear Design

Airbus A380-800

AIRBUS

Landing Gear Design
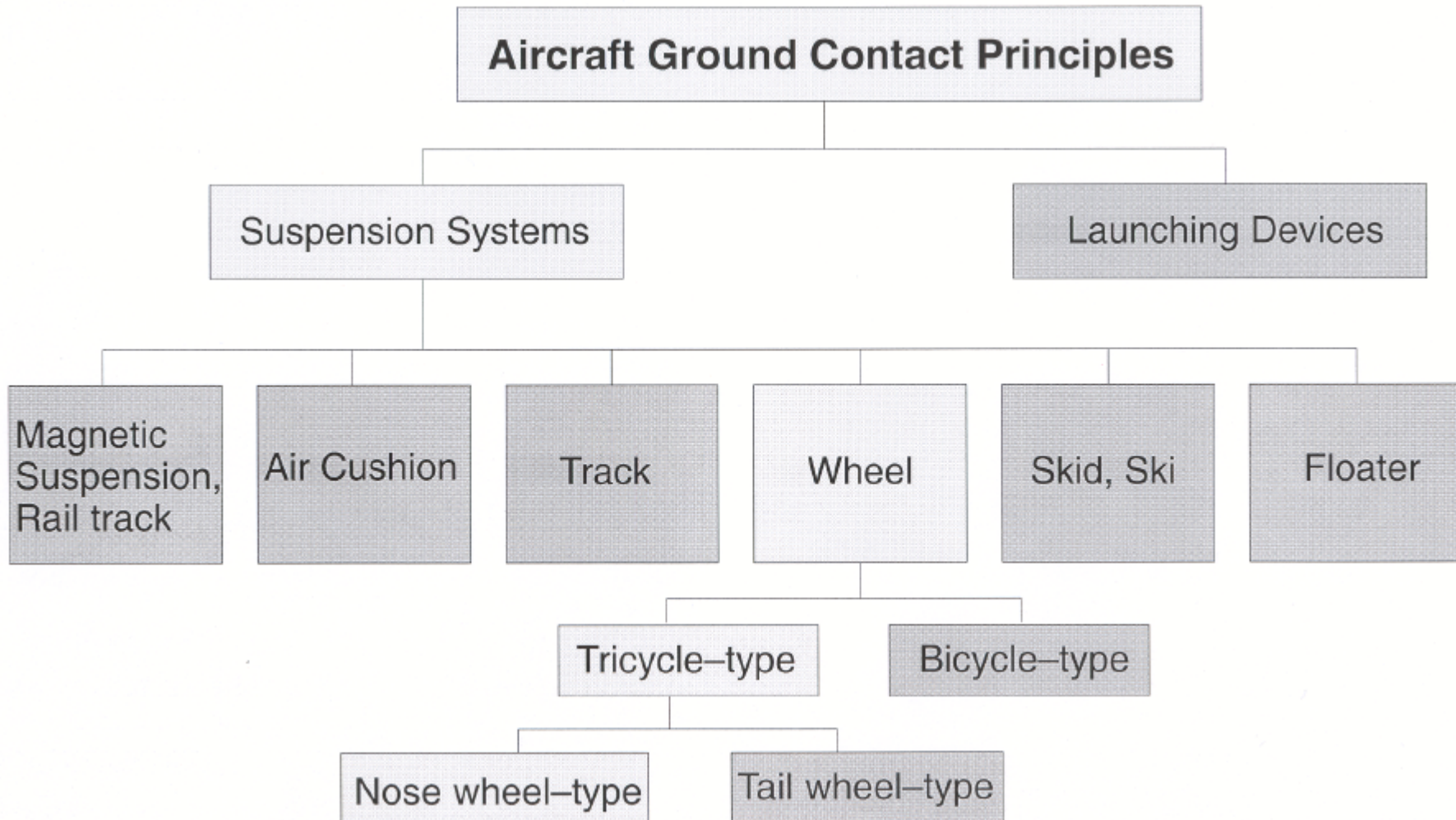

Airbus A400M

AIRBUS

Future Trends

- **Smart Shock Absorbers**
- **Integrated Control Units**
- **Improved Materials for Struts and Brakes**
- **Maintenance-free components**
- **More electrical Actuation**
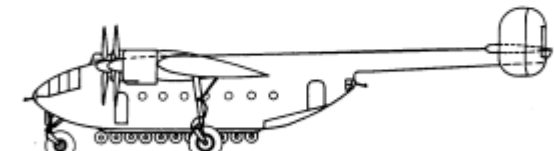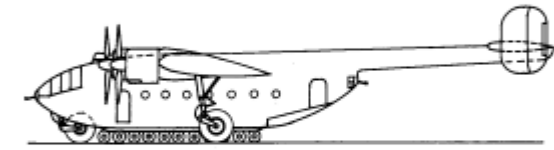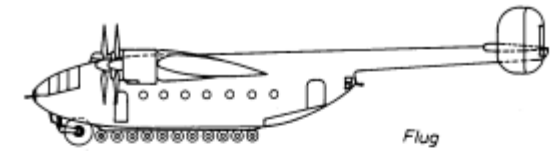
AIRBUS

Special Purpose Undercarrige

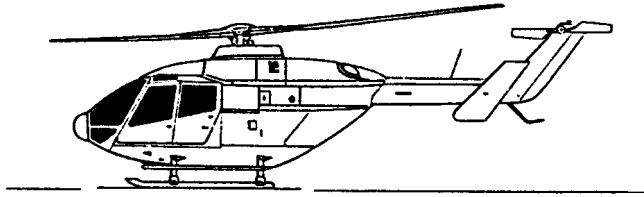## Otto Lilienthal , 1895

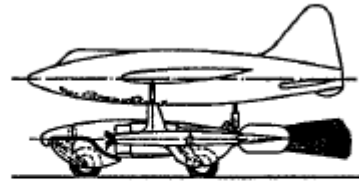# *Special Purpose Undercarrige*

AIRBUS

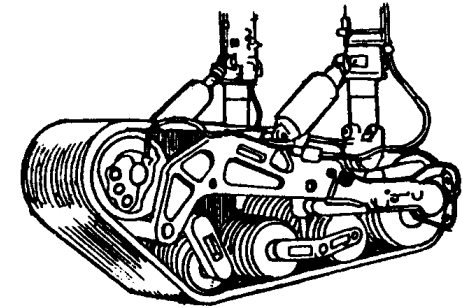# *Special Purpose Undercarrige*

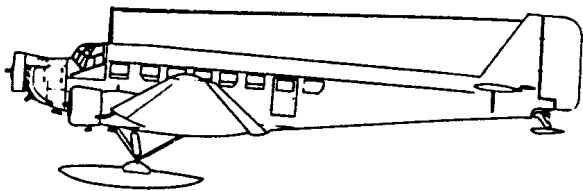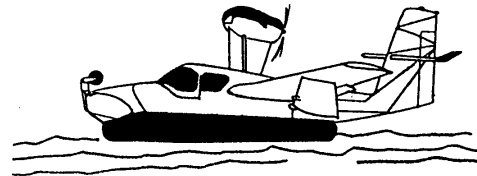Multi-wheel arrangement , Ar 232
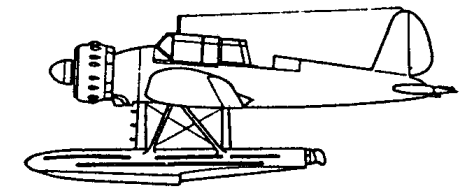
Special Purpose Undercarrige
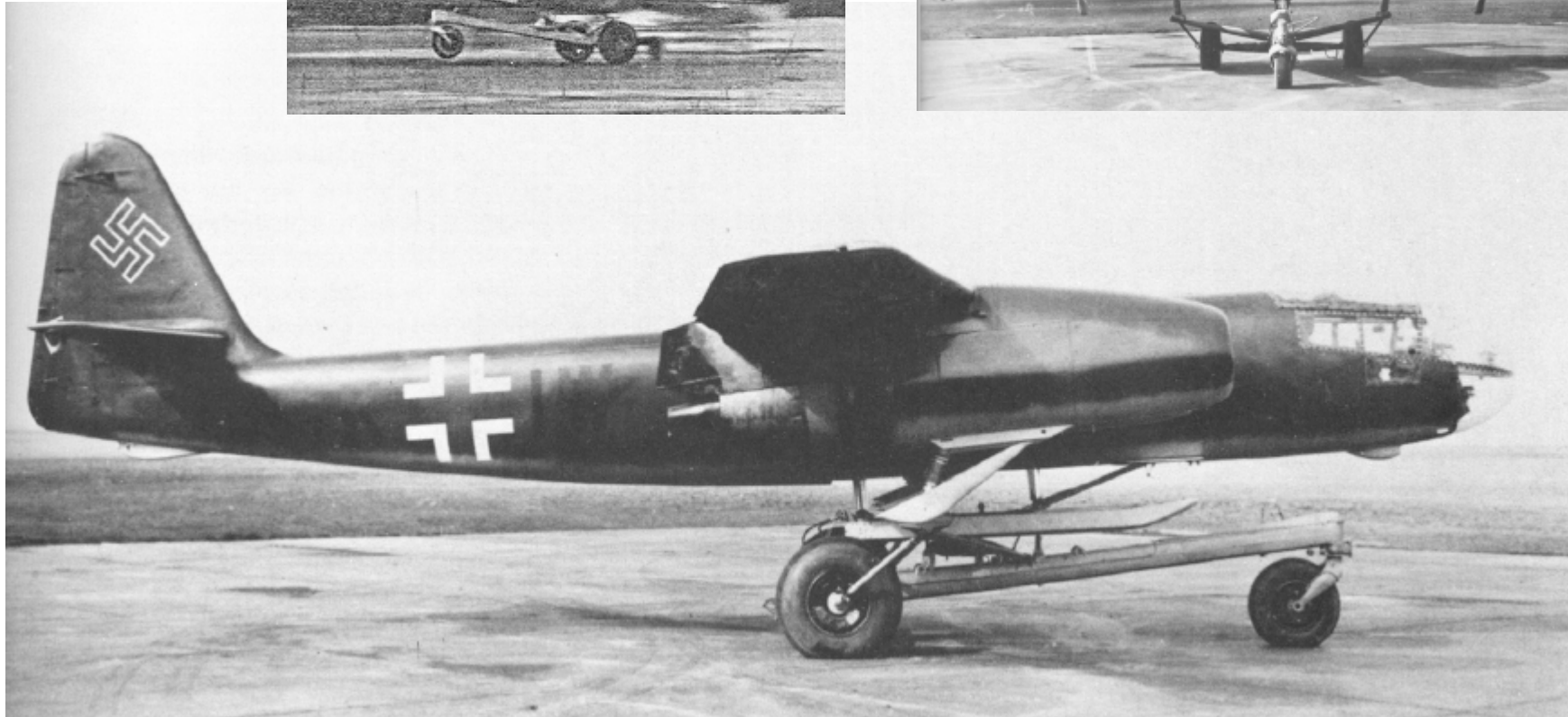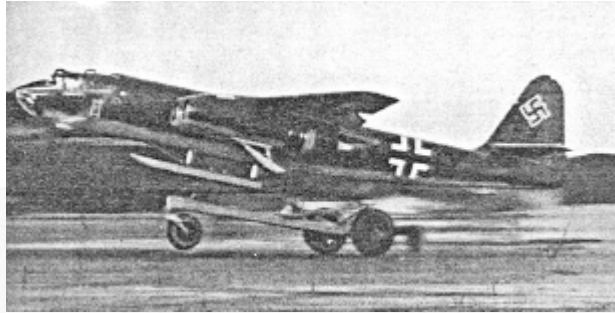
Skid

Take-off Trolley

Track

Ski

Air Cushion

Floater

Aircraft Ground Contact Devices

Special Purpose Undercarrige

Skid , EC-135

AIRBUS

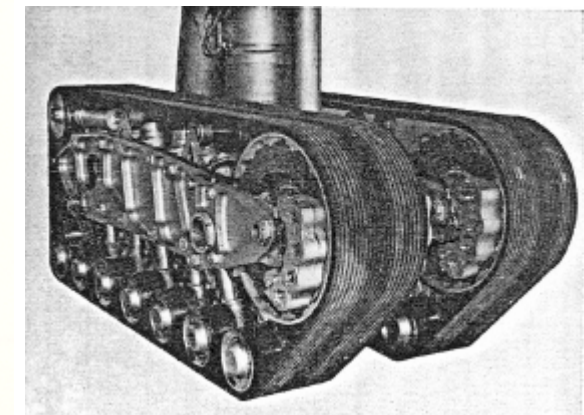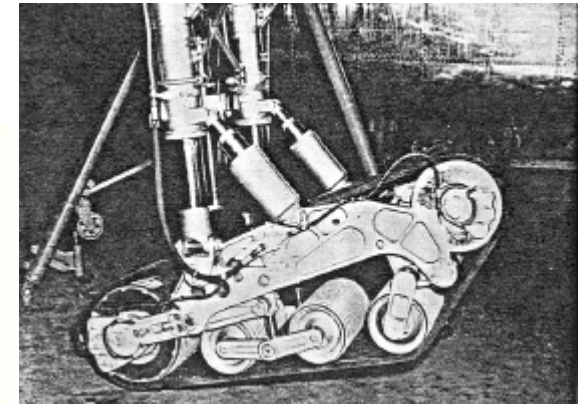# *Special Purpose Undercarrige*

Take-off trolley , Ar 234

AIRBUS

Special Purpose Undercarrige

Tracked Gear

Special Purpose Undercarrige

Skies

AIRBUS

Special Purpose Undercarrige

Aircraft Ground Contact Devices

AIRBUS

Special Purpose Undercarrige

Ekranoplan

AIRBUS

Special Purpose Undercarrige

Seaplane - Amphibian

AIRBUS

The End

AIRBUS