University of Glasgow
DEPARTMENT OF
AEROSPACE
ENGINEERING

FLIGHT MANUAL FOR THE CONDOR UAV

By
Martin Millar & Ladislav Smrcek

Report No. 9920

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First Issue

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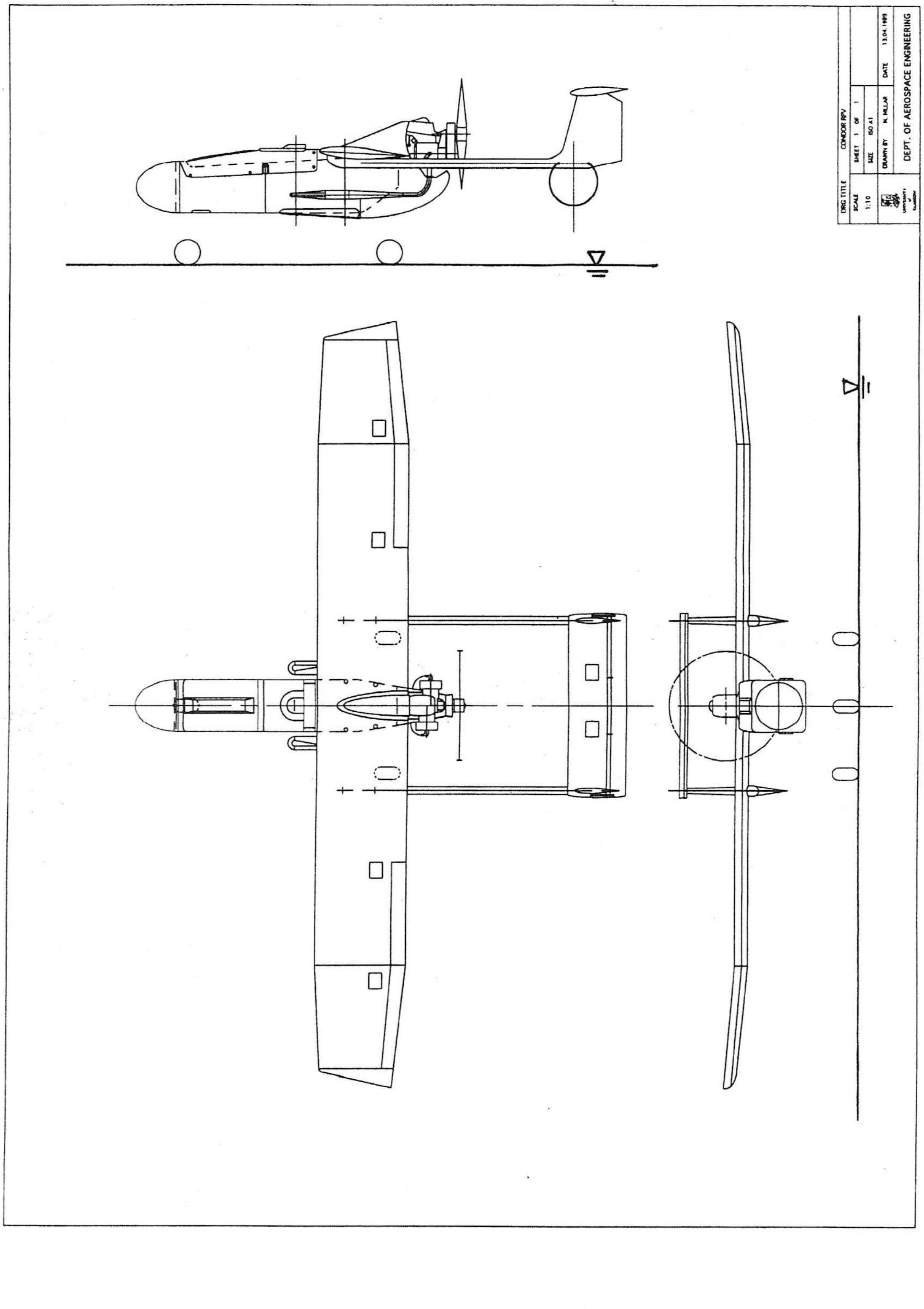
Three Plan View of UAV



Description

The Condor Unmanned Aerial Vehicle (UAV) is a Czech manufactured aircraft. The Condor has come about due to the modification of the Czech developed military UAV known as the Sojka III/TV. Modifications to the airframe, such as the implementation of rudders, an undercarriage, wing extensions, data acquisition system and flight control system mean that this new generation of the aircraft is very different to the original Sojka that it was conceived from.

The Sojka III/TV was a further development of the original Sojka V system, which had both military and civilian uses in surveillance and research. However, the Condor will be primarily used as a research tool for the aerofoil analysis and design. The possibility will also exist later to collaborate with other departments within the University of Glasgow.

The research will be undertaken with the use of a wing glove which has been designed with the specific intention of gathering surface pressure distribution data on aerofoils.

This wing glove is a delicate and precise piece of equipment and should be treated accordingly. The most important thing is to ensure the wing glove is safely secured and in the correct position prior to use. Before attaching, the wing extensions should be removed and the inner ailerons disabled. The wing glove can then be slid on and secured to the attachment supports on the wing.
The pressure tubes are routed through a ducting channel in the glove interior and driven into the wing via a hole facing the free space gained by removing the right inner aileron.

The heart of the data acquisition system for the wing glove, and indeed the entire aircraft, is a laptop PC. In collaboration with a DAQ Card and LabVIEW software, the system is a classic stand-alone.
Two rotary transducers with 48 channels each cover the 30 tappings on the lower surface and the 30 tappings on the upper surface. These transducers are small enough to fit inside the wing, feeding into the DAQ Card. A pneumatic male plug makes the connection between the tubes and the transducers. This plug is a neoprene gasket and ensures no leakage. A solenoid controller is also necessary to set the stepping rate of the rotary transducer's electric motor.

TECHNICAL DESCRIPTION

The UAV Airframe

The airframe is maae with a high wing location and twin tailbooms. The wing has no dihedral. The drawing number for the wing is STV 145.200. The wing span is 5.93 m and has a gross wing area of 4.15 m^2. The tailbooms are attached to the wing. The drawing number for the tailboom is STV 145.303. The drawing number for the stabiliser is STV145.301 and the complete drawing of the elevator is number STV 145.302. The fuselage is located under the wing, the basic dimensions of which are 0.4 x 0.5 x 2 m. The drawing number for the fuselage is STV145.100 complete with

the engine and defunct landing skid. Housed in the fuselage are the fuel tank, emergency parachute system, electrical equipment and the operating equipment.

Fuselage

The fuselage is designed as a semi-laminated shell. The fuselage has front and engine partitions as well as two fuselage partitions. These partitions divide the fuselage into three parts. The base is braced with semi-ribs. The front part of the fuselage houses the payload (up to 20 kg). A TV camera can be fixed to the front partitions. The front of the fuselage is covered with a laminated fairing, which has an elliptical shape. The central part of the fuselage is used for the emergency parachute system and the flight control system.
The rear of the fuselage is closed. The fuel tank is made of laminate and has a capacity of 18.8 litres. A float in the fuel tank is used to indicate the amount of fuel remaining in the tank.
In the very back wall of the fuselage is a rectangular hole for the cooling. On the underside of the back part and engine fairing is fixed.

Wing

The wing has a basic rectangular planform and has no dihedral. The modified span is 5.93 metres. The chord is 0.7 metres. The wing profile is the NACA 2415. The wing has been designed as a sandwich shell with a foam filler. The filler is the material HEREX C 70.55. The shell is braced with two beams and ribs. The se beams are made of the glassy roving and the ribs are made of the foam sandwich and plywood. The wing is fixed to the fuselage with four bolts.
Subsequently, the tailbooms are fixed the underside of the wing, which has consoles with the connectors that allow such attachment. The ailerons are designed in the same manner as the shell, being braced ribs and made of a glassy laminate. The ailerons are fixed by two hinges (Frise's aileron). The servo-drivers for the left and right ailerons are located on the underside of the wing and in the cavity, which is covered with a metal plate during flight.

Tailboom

The UAV is designed with twin tailbooms, which are attached to the stabiliser with the elevator.
These tailbooms are of conical shape and composed of carbon fibre. On the right hand side of the tailboom is a cavity for the connector assembly. An inspection door covers this cavity.
The original Sojka RPV was designed with the use of rudders, these have been implemented onto the new Condor UAV. The tailbooms are fixed to the wing via the tube boxes that are fixed to the underside of the wing by a couple of M6 bolts. The tailbooms are then secured with a pin with a diameter of 6 mm. This is in turn secured with a wire fastener.
In the starboard tailboom is the cable connector for the servo-motor which operates the elevator. The front part of the tailboom has an aerodynamic cover.

Tail

The tail consists of the stabiliser and elevator. The stabiliser is designed as shell and is made of a glassy laminate and a foam filler, braced with two spars. The stabiliser is fixed to the vertical tail by way of four M5 bolts.
The elevator is designed as a glassy laminated shell and braced with ribs comprised of foam. The elevator is attached to two hinges and the servo-motor for this is housed in a cavity on the underside of the stabiliser. During flight this cavity is covered with a metal cover and secured with 3x M4 bolts.

Technical data:

Wing Span:	5.93 m (19.46 ft.)	
Length:	4.07 m (13.35 ft)	
Height:	To be determined	
Wing Aspect Ratio:	8.47	
Wing Area:	4.15 m^2 (44.65 sq.ft)	
Wing Chord:	0.7 m (2.30 ft.)	
Max. Take-Off Weight:	145 kg (319.66 lb.)	
Max. Wing Load:	50.52 kg/m^2 (11.72 lb/ft^2)	
Aerofoil:	NACA 2415	
Airspeed Range:	100 km/h to 180 km/h (200 km/h for short period)	
Engine:	Ustav Pro Vyzkum Motorovych Vozidel M115, 2 stroke, 4 cylinder (20.5 kW at 6500 rpm)	
Propeller:	Vrtule V125R	
Manoeuvring Load Factor:	n = +4 to –4(normal speed range) n = +2 to –2(at 200 km/h)	
Aileron Range:	+12 to –15 degrees	
Elevator Range:	+12 to –15 degrees	
Max. Transportation Speeds:	30 km/h	on the road
	15 km/h	on the runway
	5 km/h	on the ground
Moments of Inertia:	I_X = 26,483 $kg.m^2$ I_Y = 99,844 $kg.m^2$ I_Z = 66,483 $kg.m^2$	

Operating Limitations

PERMITTED OPERATIONS

The Condor is a civilian operated vehicle UAV and under such conditions, has to abide by the laws and rules laid down by the British Civil Aviation Authority (CAA). The RPV will need to comply with the Air Navigation Order, with exceptions granted on the basis of limited usage.
The Condor UAV has to abide by the following:

Prohibition from flying:

1. in contrc lled airspace or in an aerodrome traffic zone, except with the permission of the relevant air traffic control unit;

2. at a height exceeding 400 feet above ground level;

3. for aerial work (i.e. for hire or reward) without the Authority's permission:
   - not beyond 1000 metres from the operator, or visual range if less;
   - not within 500 metres of any congested area of a city, town or settlement;
   - not within 500 metres of any person, vehicle or structure, except during take-off and landing when the distance can be reduced for person necessarily present for the safe operation of the UAV;
   - not without a serviceable mechanism that will land the UAV in the event of a failure of its control system or radio link;
   - not without the operator of the UAV ensuring that any load carried by the UAV is properly secured.

ENGINE LIMITATIONS

Engine

Engine Model	M115VR
Engine Type	Two stroke flat air cooled
No. of Cylinders	2 – opposed
Stroke/Bore (mm)	52/62
Displacement (cm^3)	314
Compression Ratio	11:1
Max. Power (kW/rpm)	7000

RPM Limitations

Maximum RPM	7500 RPM
Maximum Continuous RPM	6400 RPM
Idle RPM	2200 RPM
Take-Off:	To be determined
Cruise Setting:	To be determined

Lubrication

A mixture of fuel and oil

Fuel

The recommended fuel is AB 96 - Super

Fuel Consumption

Travel Mode (4400 rpm) kg/hr	5.94

Cylinder Head Temperature

Max. Cylinder Head Temperature:	200 °C
Recommended Cylinder Head Range:	120 °C

Carburettor

Type	Membrane
Diameter of Diffuser (mm)	26
Main Nozzle	115
Diameter of Throttle (mm)	32

Electrical System

Ignition	via 12V Battery
Ignition Coil	PAL 443 212 214 300
Spark Plug Cable	ZSILE 1.34 mm^2
Spark Plug	PAL NR 12 YC – Summer PAL NR 9 YC – Winter
Alternator	PAL 28V / 35A No. 443 113 516 840
Wedge-Shaped Belt for Alternator	10 x 500 mm
Fuel Pump	Pierburg 12V / 0.2 bar No. 7.20788.01

AIRSPEED LIMITATIONS AND LIMIT LOAD FACTORS
(See Flight Envelopes Calculations, Appendix A)

Manoeuvre Design Speed:		
V_A = 155 km/h	84 knots	97 mph
Flap Design Speed:		
V_F = 140 km/h	76 knots	88 mph
Cruise Speed		
V_C = 160 km/h	81 knots	100 mph
Design Dive Speed:		
V_D = 225 km/h	121 knots	141 mph
Maximum tall Speed:		
V_{S1} = 79 km/h	43 knots	49 mph
Minimum Stall Speed:		
V_{S0} = 76 km/h	41 knots	48 mph

The following acceleration forces may not be exceeded:

at manoeuvring design speed	+3.8	
at design dive speed	+3.8	
at cruising speed	+5.82	-3.82

GROUND CREW

The necessary minimum number of people for maintaining and operating the whole system is four, although more are recommended:

- UAV pilot – operator
- UAV engineer
- Two Assembly Personnel

WEIGHTS

(d.n. – Drawing Number)

Airframe Empty Weight (no engine) (d.n. STV 154.001)	50.4 kg
Wing (d.n. STV 145.200)	
2 x Boom Attachments (d.n. STV 145.304)	
2 x Coverings (d.n. STV 145.305)	Max. 16.9 kg
2 x Wing Extensions	Max. 7.5 kg
Stabiliser (d.n. STV 145.301)	
Elevator (d.n. STV 145.302)	Max. 3.2 kg
Left Tailboom (d.n. STV 145.303)	
+ Metal Wires (d.n. 145.306)	Max. 2.7 kg
Right Tailboom (d.n. STV 145.303)	
+ Metal Wires (d.n. STV 145.306)	Max. 2.7 kg
Fuselage (d.n. STV 145.100)	
Tank (d.n. STV 145.610-01)	Max. 21.5 kg
Engine Mount (d.n. STV 145.603)	Max. 3.4 kg
Dry Engine with Reduction Gear Unit & Prop. Flange	19.4 kg
Alternator PAL 443 113 516 840	4.5 kg
Exhaust sockets	2.6 kg
Propeller V 125 B, 850 mm Diameter	1.0 kg
General Weight	27.5 kg

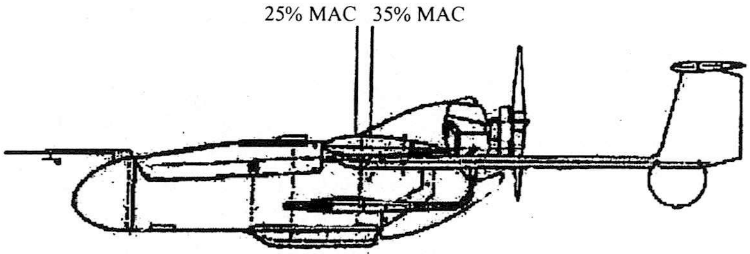
Emergency Parachute	10.3 kg

CENTRE OF GRAVITY AT FLIGHT WEIGHT

The approved range of centre of gravity positions during flight is

25% MAC to 35% MAC

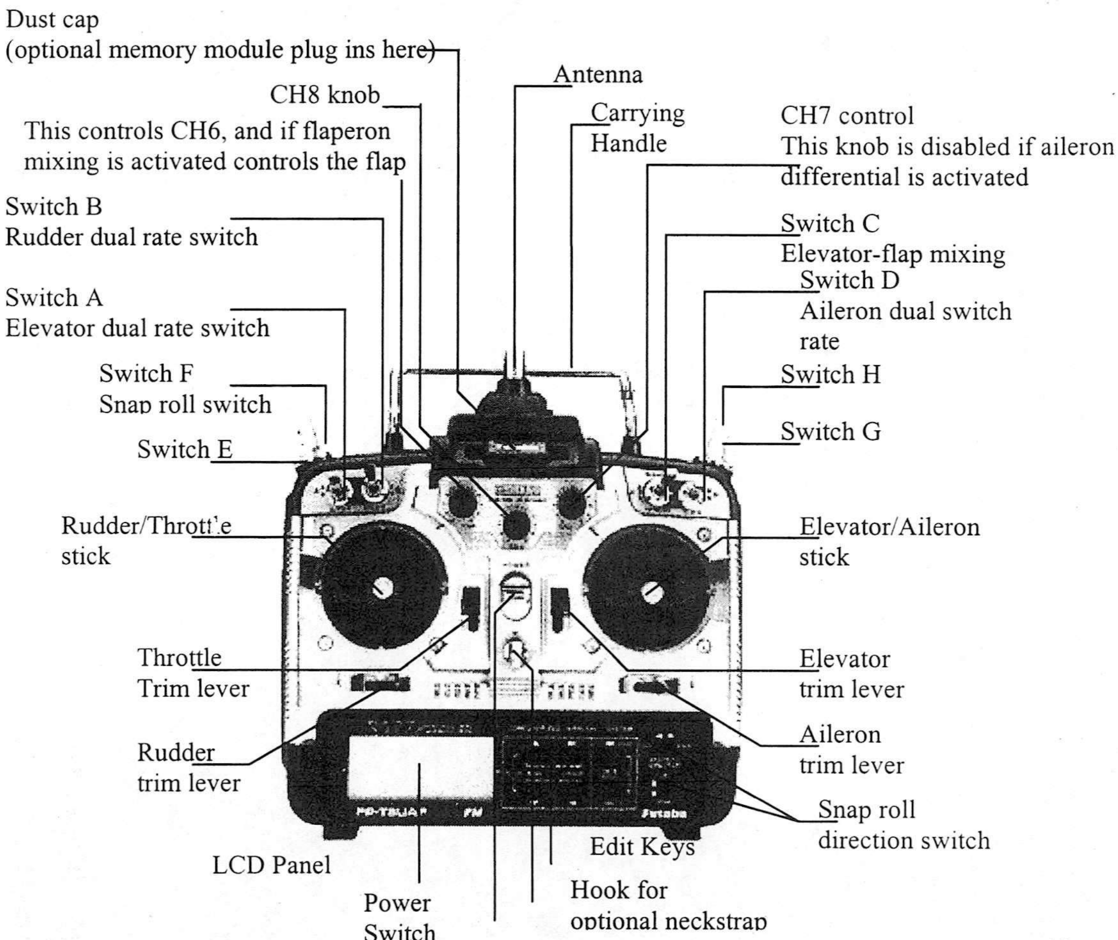
The ideal position is 30% MAC



The ideal CG position of 30% MAC is also the position of the rear bolts which attach the wing to the fuselage. A special rig has been set up which can suspend the UAV from the bolts and establish that the CG is indeed at this ideal position.

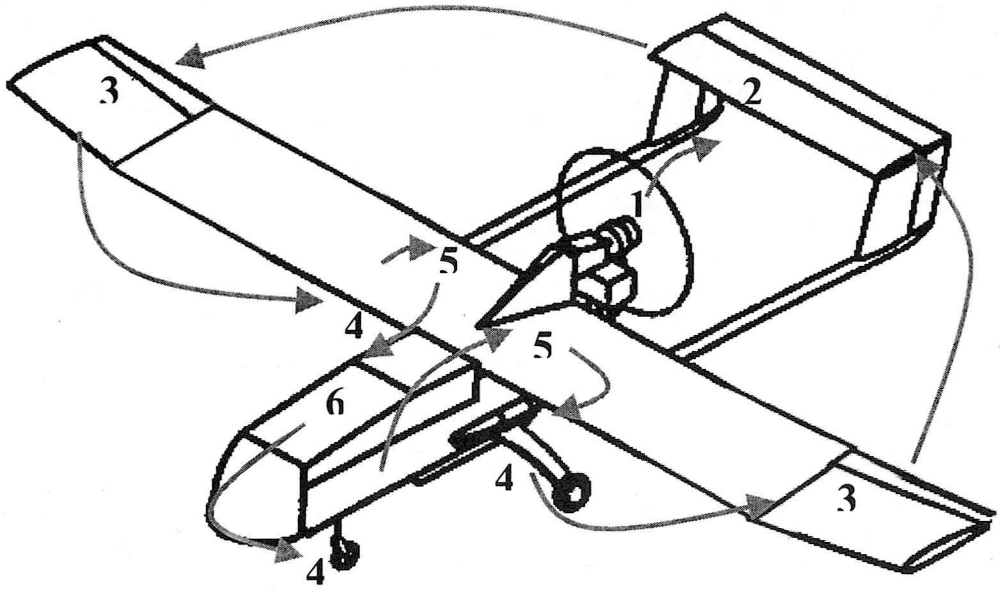
Normal Operating Procedures

CONTROLLER LAYOUT AND CONTROLS



The chosen 8-channel Futaba FP-T8Ua computer radio is fully programmable. The basic flight control surfaces have been assigned channels, although there are further aspects to be determined.

WEEKLY INSPECTIONS



1. Engine

    - Check the propeller blades for cracks and dents and proper installation
    - Remove cowling
    - Check oil
    - Visually inspect the engine
    - Install cowling

2. Tail Unit

    - Proper installation
    - Securely locked
    - Servo connections
    - Freedom of movement of rudders and stabiliser

3. Wings

    - Condition
    - Attachment of tail booms
    - Aileron (and flaperon, if applicable) freedom of movement
    - If wing glove attached, check attachment and connections

4. Undercarriage

  - Tyre pressures
  - Tyre conditions

5. Wing Connections

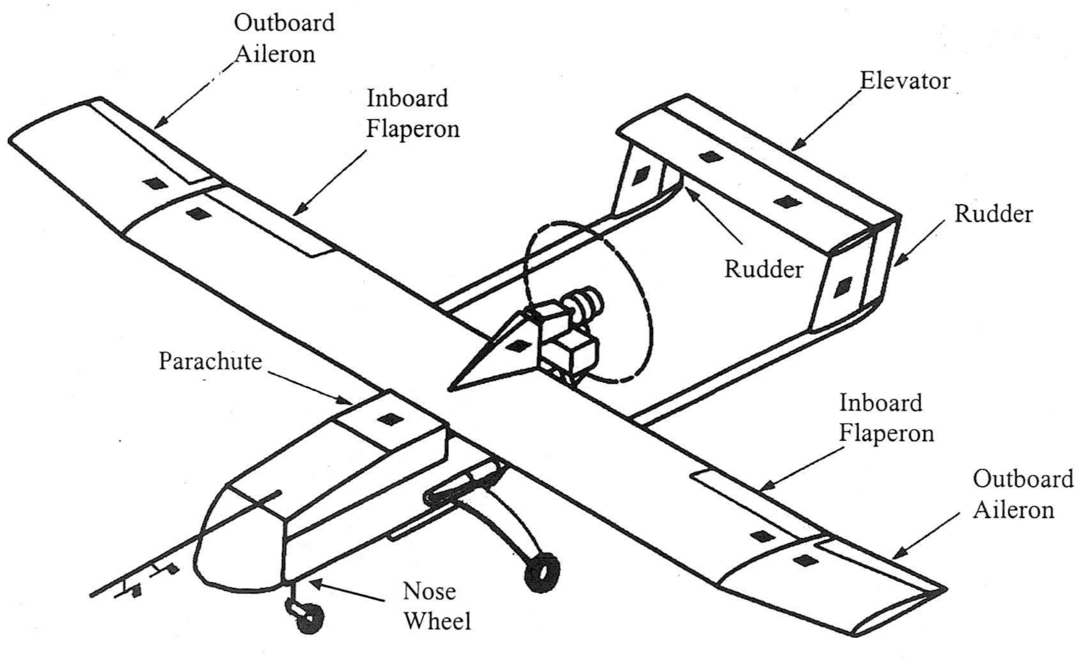
  - Check four bolts attaching wing to fuselage

6. Fuselage

  - Damage

PREFLIGHT INSPECTION

1. Daily inspections complete?
2. Oil and fuel quantity
3. Centre of gravity check
4. Each of the control surface servos, although the one controlling the parachute deployment should firstly be disconnected. In the diagram below, the black squares denote the location of the servos.



INSPECTIONS AFTER HARD LANDING

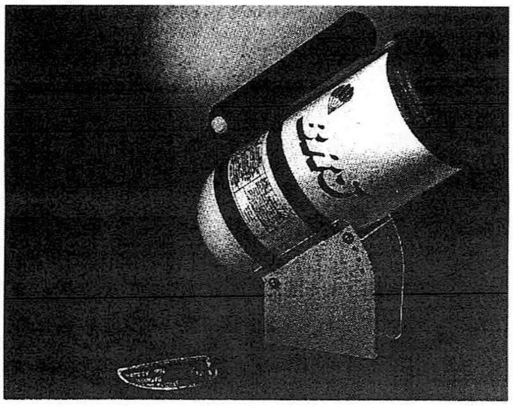
After a hard landing or, other undue stress during flight, the aircraft must be checked very thoroughly. If damage is found, the technicians at the Spencer Street Workshop must be consulted. Under no circumstances MAY the aircraft be flown until repairs have been completed.

After hard landings inspect the following:

- Wheels
- Undercarriage
- Fuselage
- Tailbooms

Emergency Procedures

In the event of any emergency the parachute should be activated, unless the aircraft is sufficiently close to the ground and travelling relatively slowly that it may be landed by the conventional method. No hesitation should be made in deploying the parachute as the aircraft can only be flown in isolated areas and the likelihood of landing somewhere hazardous is minimal. In the event of losing the radio signal, the aircraft will return to steady level flight, induced by the onboard autopilot, and then after a short time will launch the parachute itself. This will give the UAV time to recover the signal or if at least level out the aircraft for an effective parachute deployment.



	BRS-750
SYSTEM	
Maximum Capacity	340 kg
Maximum Deployment Speed	160 km/h
Overall System Weight	
Canister	10.3 kg
Dimensions (mm)	
Canister(length & diameter)	460 x 180
CANOPY	
Gores(panels)	28
Nominal Diameter	8.5 m
Square Area	55 sq m
Repack Cycle	
Canister	6 yrs
Riser(all use Type 20 webbing)	4100 kg
Suspension Lines(all use Dacron)	182 kg

Does Canopy use "Slider"?	Yes
BALLISTIC DEVICE	
Type – Rocket	Solid Fuel
Power(Newton/Second)	285 N/sec
Igniter(Mechanical Ignition)	Dual Primer
Thrust	30 kg
Burn Time	1.2 sec
Time to Line Stretch	0.94 sec
Inspection Cycle	9 yrs

The model and specification of parachute are shown above. This will be housed in the fuselage of the aircraft and thus will have no direct effect on the aerodynamics of the vehicle.

Performance Data

TAKEOFF DISTANCE(See Appendix A)

All figures based on ISA – International Standard Atmosphere

NB All distances are total and NOT incremental

From Grass

Ground Run	160 m (525 ft)
Acceleration from vlof to v2	187 m (613 ft)
Transition Arc	201 m (659 ft)
Climb to 10.5 m (35 ft)	246 m (807 ft)

From Concrete

Ground Run	124 m (407 ft)
Acceleration from vlof to v2	151 m (495 ft)
Transition Arc	165 m (541 ft)
Climb to 10.5 m (35 ft)	210 m (689 ft)

Atmospheric moisture reduces engine power and increases the take-off distance.
All figures are based on a maximum takeoff weight of 145 kg (lbs) in zero wind and from a dry, level, hard surface.
Moist and soft surfaces can considerably increase the takeoff distance.

LANDING DISTANCE(See Appendix B)

All figures based on ISA – International Standard Atmosphere

NB All distances are total and NOT incremental

Onto Grass

Descent from Altitude of 15 m (50 ft) to Origin of Transition Arc	283 m (928 ft)
Transition Arc	289 m (948 ft)
Deceleration from Airspeed V to V_{TD}	480 m (1574 ft)
Ground Run	735 m (2411 ft)

Onto Concrete

Descent from Altitude of 15 m (50 ft) to Origin of Transition Arc	283 m (928 ft)
Transition Arc	289 m (948 ft)
Deceleration from Airspeed V to V_{TD}	480 m (1574 ft)
Ground Run	978 m (3208 ft)

CRUISE SPEEDS

The designated cruise speed for the Condor is 160 km/h

RANGE

The Condor has a maximum range of 100 km, if flown at a flight altitude of 2000 m .

FLIGHT ALTITUDE

The minimum flight is currently 50 m, although this will become significantly lower upon ground effect modification completion. The maximum attainable altitude is 2000 m, although this is limited to 120m (400 ft) by the CAA.

STALL SPEEDS

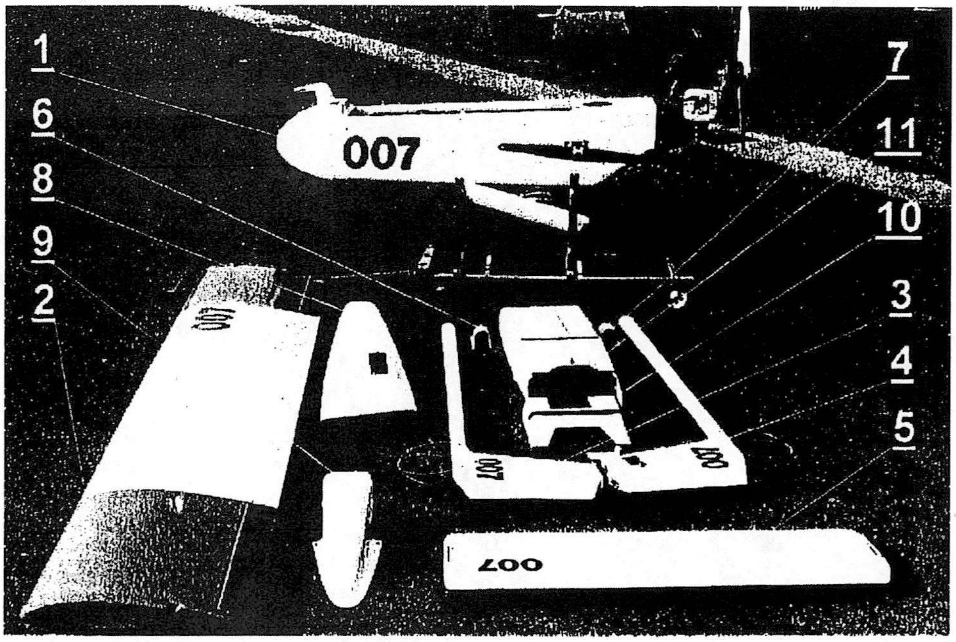
Stall speeds are dependent on the condition of the aircraft.

All figures are based on the maximum takeoff weight of 145 kg (320 lbs).

Unaccelerated level flight	80 km/h (43 knots)

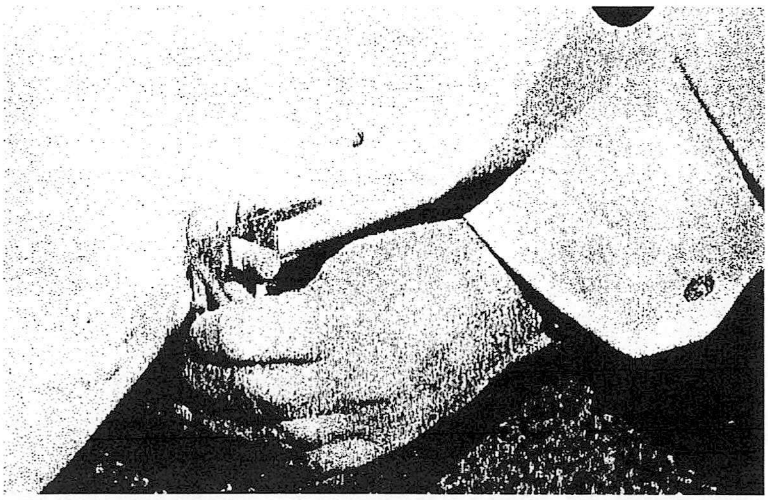
Rigging and Derigging

BASIC ASSEMBLY PARTS



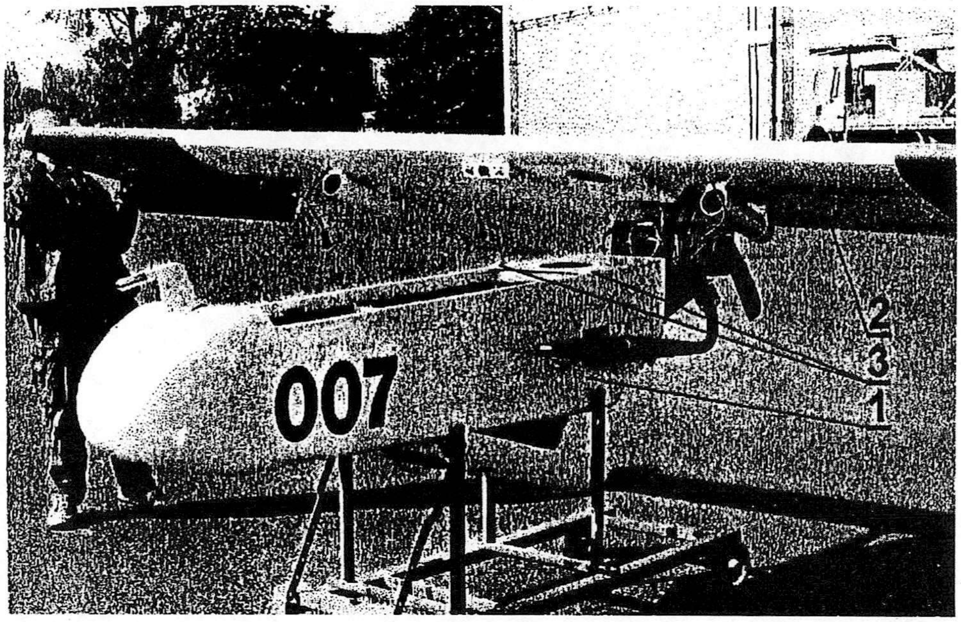
1. Fuselage complete with engine
2. Wing
3. Left Tailboom and Fin
4. Right Tailboom and Fin
5. Horizontal Tailplane (Stabiliser)
6. Aerodynamic Fairing for Tailboom
7. Aerodynamic Fairing for Tailboom
8. Aerodynamic Engine Fairing
9. Aerodynamic Carburettor Fairing
10. Small Fuselage Fairing
11. Main Fuselage Fairing

PLACING THE FUSELAGE ON THE TRANSPORT CART



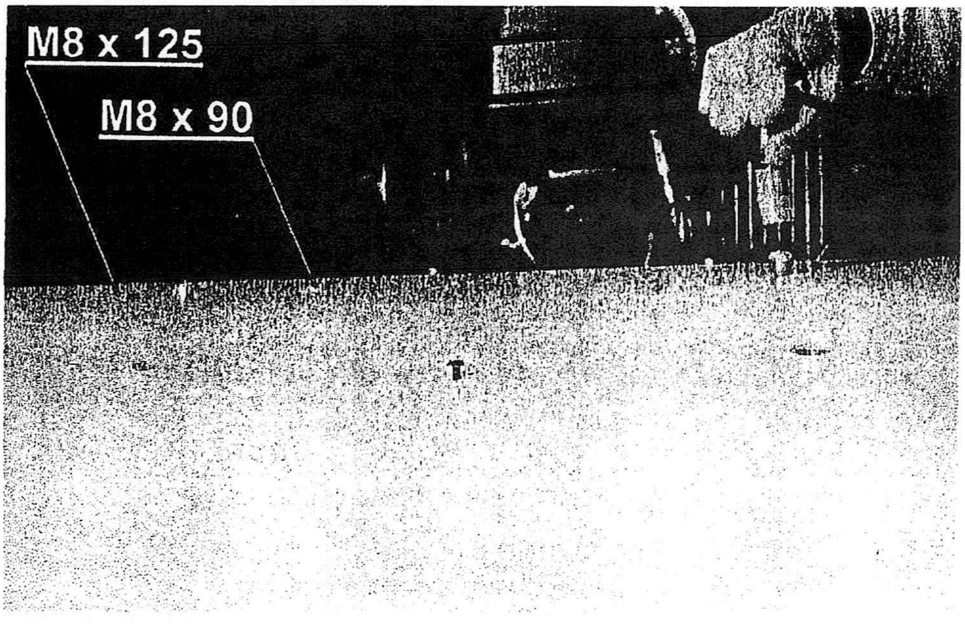
The personnel place the fuselage in the sockets of the transport cart. This is the assembly base for all the rigging of the UAV. This task requires four people minimum, with two people taking the fuselage at the front and two taking the fuselage at the engine. Once on the cart, the pivots must be secured with metal bolts as shown in the picture above.

WING ATTACHMENT TO THE FUSELAGE



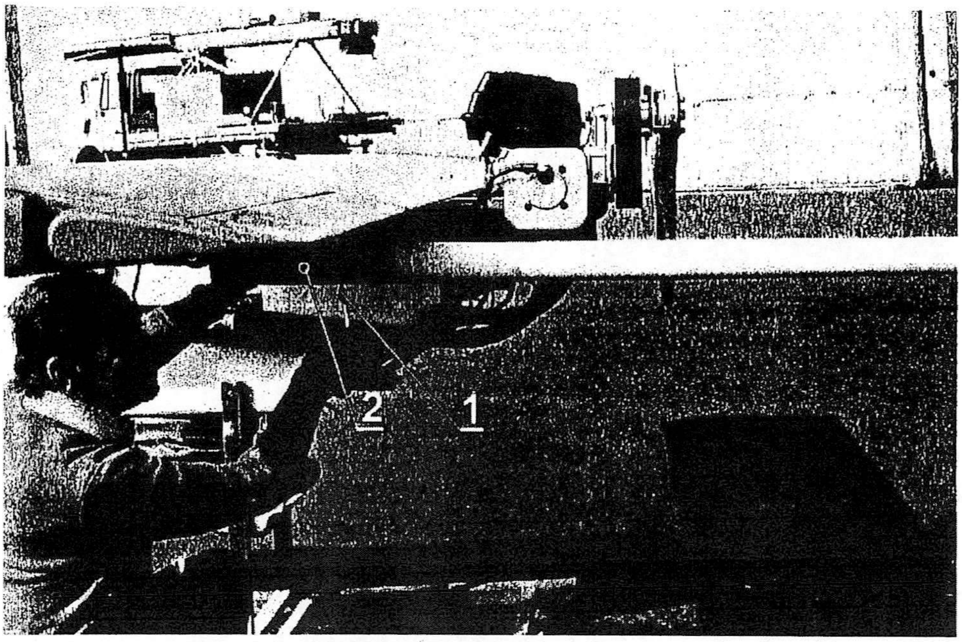
Two people are required to carry out this operation. Extreme care should be taken and the ailerons not touched. Washers have to be placed in the sockets (pos. 3). The sockets are on top of the fuselage (pos. 1). This position is defined exactly.

MECHANICAL FIXING OF THE WING



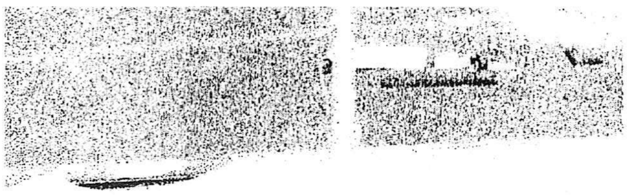
The personnel attach the wing assembly with two M8x125 bolts on the front part and two M8x90 bolts on the back part. The bolts need to be tightened with a tubular wrench (size 14). The torque must not exceed 14.7 Nm. Excessive force should not used.

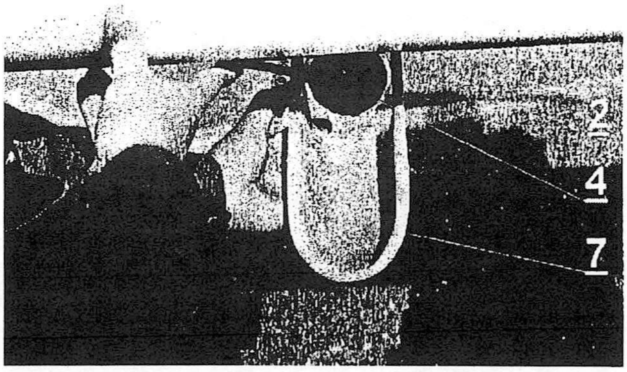
TAILBOOM ASSEMBLY



The tailbooms are assembled to the tubular sockets under the wing. The manufacturer attaches these sockets, however, after five flights the bolt attachments need to be checked by the appropriate personnel. The tailboom is secured with a pin (pos.1). The pin is inserted in the hole (pos. 2) and secured with a wire clip.

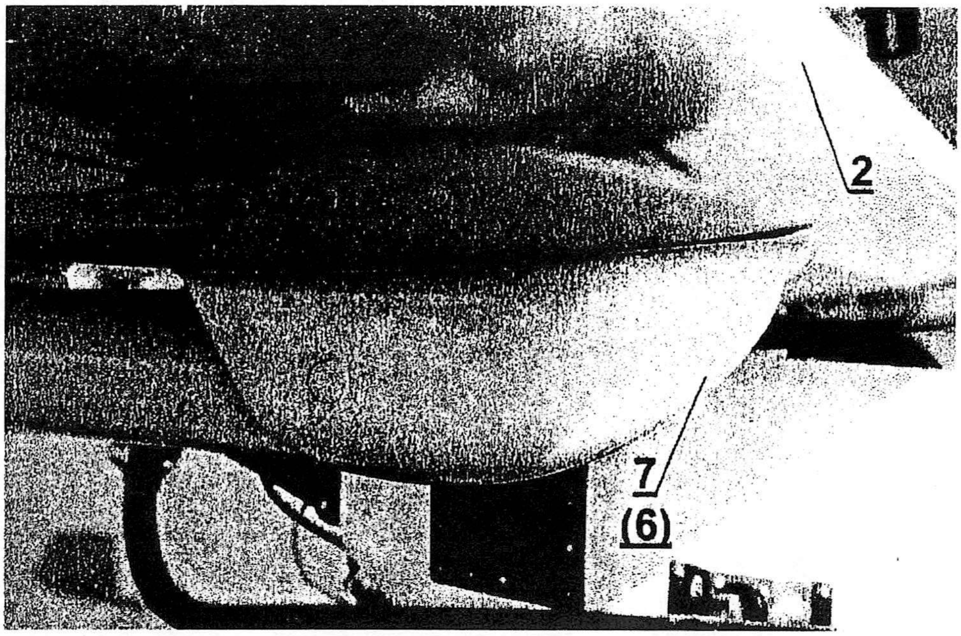
AERODYNAMIC FAIRING FOR THE TAILBOOM ASSEMBLY





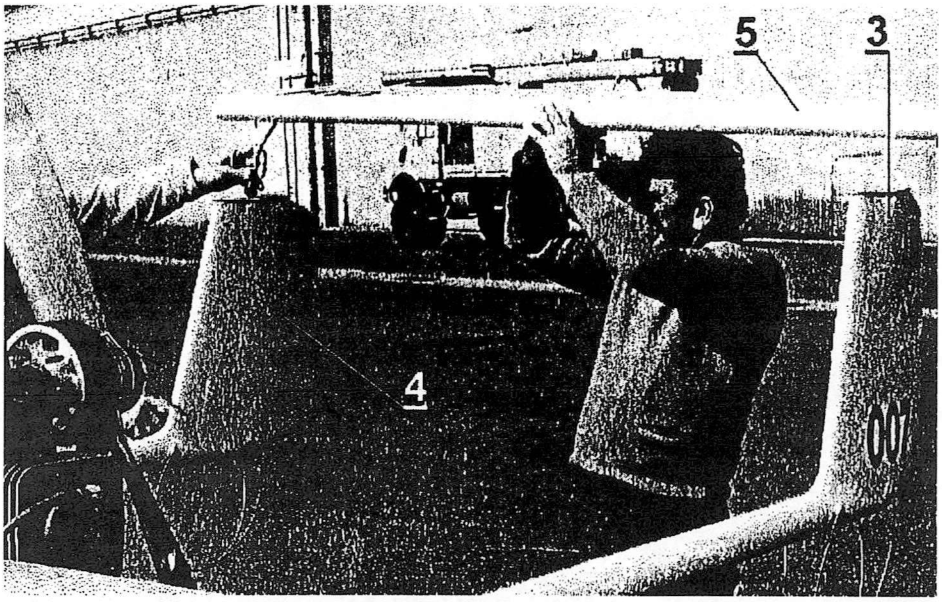
The front part of the tailboom has an aerodynamic fairing. The fairing is fixed using several pins. No special tools are required for this task.

AERODYNAMIC FARING FOR THE TAILBOOM - POST ASSEMBLY



The fairing has to be flush with the underside of the wing. The fairing should be checked prior to assembling and also after.
NOTE: Care should be taken, as a loose fairing can damage the UAV.

HORIZONTAL TAILPLANE ASSEMBLY

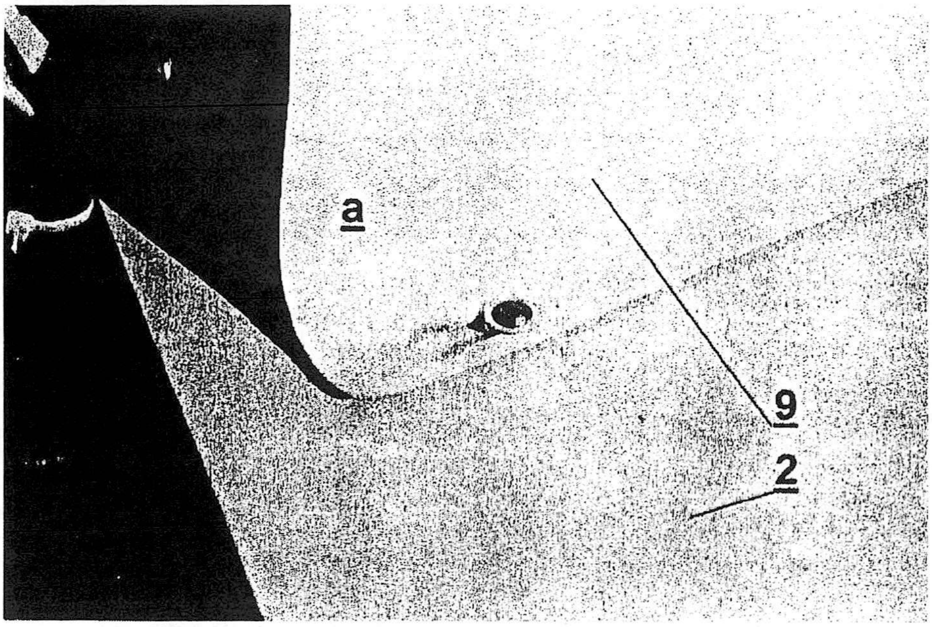


The attachement of the horizontal tailplane is best carried out with two people, as shown in the picture. The tail is attached via four bolts.

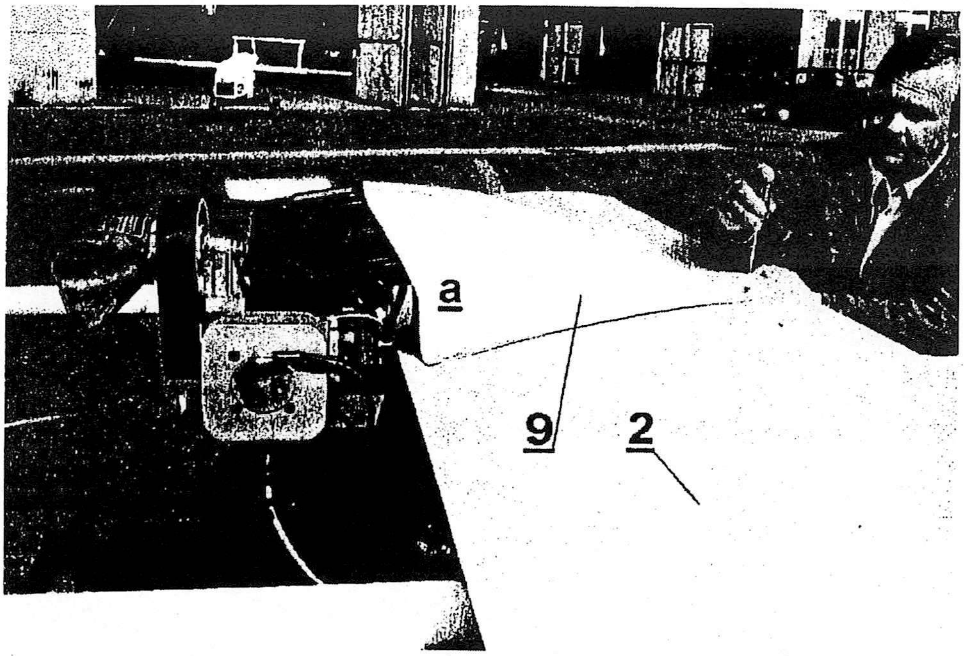
HORIZONTAL AND VERTICAL TAILPLANE ASSEMBLY

The horizontal tailplane is fixed to the vertical tailplane with four M5 bolts. The only piece of equipment required is a screwdriver. The torque must not exceed 3 Nm. NOTE: Excessive force should not be used.

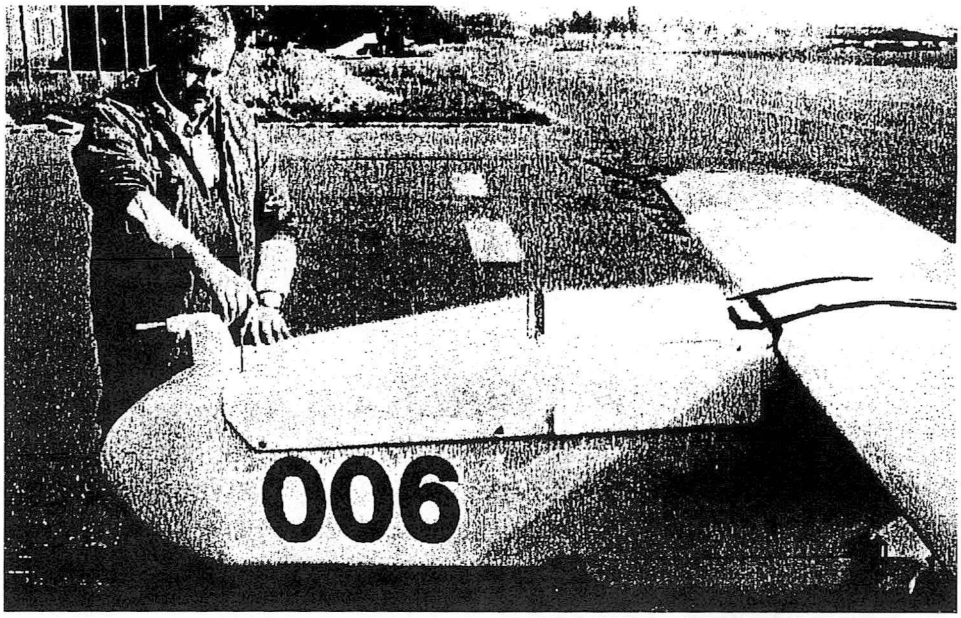
AERODYNAMIC FAIRING FOR CARBURETTOR



The cover (pos. 9) is fixed on the wing (pos. 2). The rear part of the fairing has a locking mechanism whilst the front part is fixed with an M4 bolt.



FUSELAGE FAIRING ASSEMBLY



This is the last operation. Before assembly, all internal electronic connections should be checked. The fuselage fairing is then fixed in place with ten bolts.

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Appendix A

Flight Envelope Calculations

Basic Input Data and Nomenclature

Wing Area	S	$4.151\ m^2$
Aspect Ratio	A	8.471
Mean Aerodynamic Chord	c	0.7 m
Wing Lift Curve Slope	a	4.297 1/rad
Air Density	ρ	$1.225\ kg/m^3$
Maximum Take-Off Weight	m_{mtow}	145 kg
Operational Empty Weight	m_{oew}	105 kg

All speeds are in EAS.

n_1 - Positive manoeuvre load factor at V_A.

n_2 - Positive manoeuvre load factor at V_D.

n_3 - Negative manoeuvre load factor at V_D.

n_4 - Negative manoeuvre load factor at V_G.

n_F - Aeroplane positive limit load with flaps fully extended at V_F.

Each load factor value is LIMIT.

V_A - Positive manoeuvre design speed.

V_H - Maximum speed of level flight at full power.

V_D - Maximum manoeuvre design speed.

V_G - Negative manoeuvre design speed.

Limit Load Factor

According to JAR - VLA 337 and 345 the minimum values are:

$n_1 = 3.8$ $\quad n_3 = -1.5$ $\quad n_F = 2.0$

$n_2 = 3.8$ $\quad n_4 = -1.5$

Design Speeds

Manoeuvre Design Speed

$$V_A = V_{S1} * \sqrt{n_1}$$

Where V_{S1} is the maximum stall speed at the maximum take-off weight (m_{mtow}) and idle engine power - according to JAR - VLA 335 (c).

$m_{mtow} = 145kg$ $\qquad$ $c_{lmax} = 1.16$

Thus:

$$V_{S1} = \sqrt{\frac{2.m_{mtow} \cdot g}{c_{l\max} \cdot \rho.S}} \qquad V_{S1} = 22.06\ m/s$$

$$V_{S1} = 79.42\ km/h$$

Therefore:

$$V_A = V_{S1} * \sqrt{n_1} = 22.06 * \sqrt{3.8} = 43.0\ m/s = 154.8\ km/h$$

Select: $V_A = 155$ km/h

Flap Design Speed

The requirements for this section are in accordance with JAR - VLA 345.

i) $V_{F1} = 1.4 * V_{S1} = 1.4 * 22.06 = 30.88\ m/s = 111.18\ km/h$
ii) $V_{F2} = 1.8 * V_{S0}$

$$V_{S0} = \sqrt{\frac{2.m_{mtow} \cdot g}{c_{l\max} \cdot \rho.S}} = 21.07\ m/s$$

$$V_{F2} = 1.8 * V_{S0} = 1.8 * 21.07 = 37.93\ m/s = 136.53\ km/h$$

Select: $V_F = 140$ km/h

Design Dive Speed

JAR - VLA (a) and (b) states that $V_D \geq 1.25 * V_C$, where V_C is the design cruising speed and also that $V_D \geq 1.4 * V_{C\min}$ where $V_{C\min} = 2.4\sqrt{mg/S}$.

$$V_{C\,min} = 2.4\sqrt{\frac{145*9.81}{4.151}} = 44.43 \text{ m/s} = 159.94 \text{ km/h}$$

$$V_D = 1.4*44.43 = 62.2 \text{ m/s} = 223.93 \text{ km/h}$$

$$V_D = 1.25*47.22 = 59.0 \text{ m/s} = 212.5 \text{ km/h}$$

Select: $V_D = 225$ km/h

Maximum Lift Curve

$$V_{max} = \sqrt{\frac{2.m_{mtow}.n.g}{c_{l\,max}.\rho.S}}$$

n	1.0	1.5	2.0	2.5	3.0	3.5	3.5
V (m/s)	22.1	27.1	31.3	34.9	38.3	41.3	43.1
V (km/h)	79.4	97.4	112.5	125.8	137.8	148.8	155.0

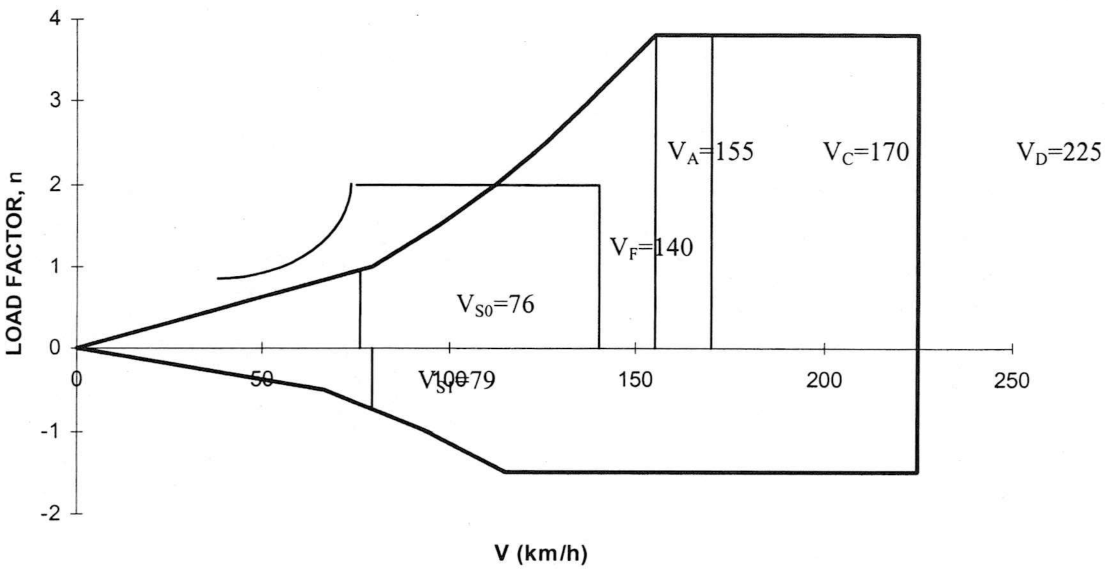
Negative Lift Curve

$$V_{max} = \sqrt{\frac{2.m_{mtow}.n.g}{-c_{l\,max}.\rho.S}}$$

n	-0.5	-1.0	-1.5
V (m/s)	18.5	25.1	32.0
V (km/h)	66.4	94.0	115.1

MANOEUVRE ENVELOPE

m=145kg



Gust Envelope

The Gust Load Factor according to JAR - VLA 341 is given by the equation:

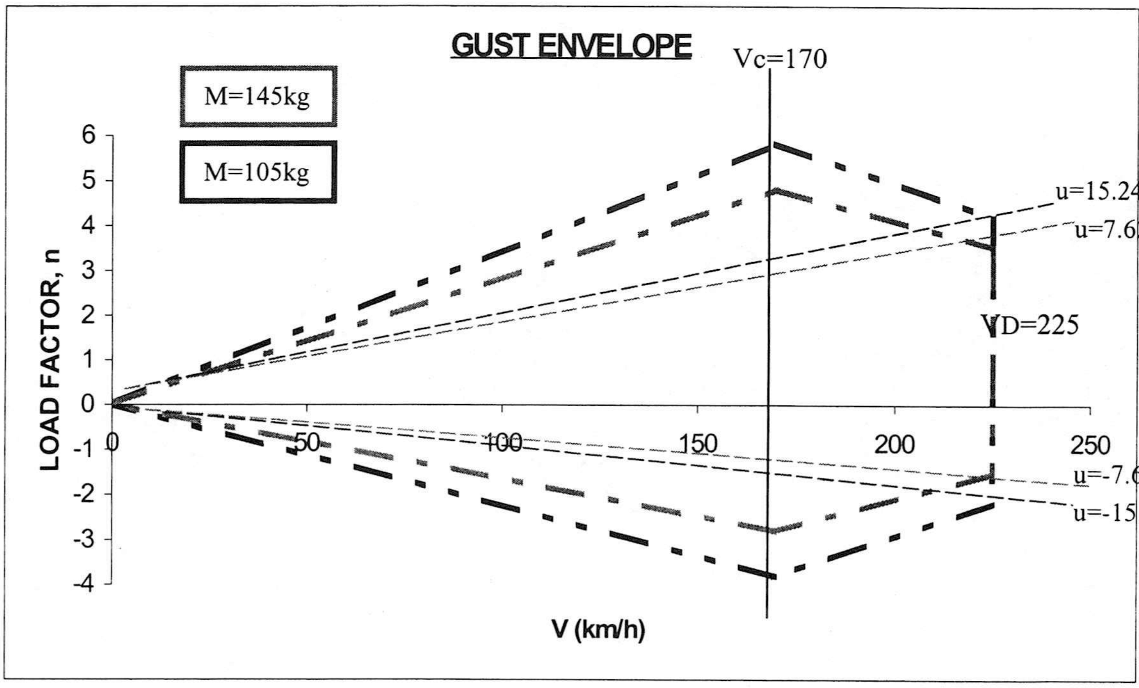
$$n = 1 \pm \frac{0.5 * r * a * k * V * U}{\left(m \frac{g}{S} \right)}$$

Where k is the Gust Alleviation Factor and μ the aeroplane mass ration.

$$k = \frac{0.88 * m}{5.3 + m} \qquad \mu = \frac{2 \frac{m}{S}}{\rho . S . a}$$

m = 145 kg	μ = 18.96	k = 0.688	a = 4.297 1/rad
m = 105 kg	μ = 13.73	k = 0.635	a = 4.297 1/rad

Altitude MSA Air Density (m), (kg/m^3)	Flight Mass (kg)	Speed EAS (km/h)/(m/s)	Vertical Gust Speed (m/s)	Load Factor Increment	Gust Load Factor
0.00	145	V_C 170 / 47.2	+15.24	3.81	4.81
			-15.24	-3.81	-2.81
1.225		V_D 225 / 62.5	+7.62	2.52	3.52
			-7.62	-2.52	-1.52
	105	V_C 170 / 47.2	+15.24	4.82	5.82
			-15.24	-4.82	-3.82
		V_D 225 / 62.5	+7.62	3.19	4.19
			-7.62	-3.19	-2.19



Maximum Limit Load Factors

Speed	Load Factor	Mass
V_A = 155 km/h	n_1 = 3.8	m = 145 kg
V_D = 225 km/h	n_2 = 3.8	m = 145 kg
V_E = 225 km/h	n_3 = -1.5	m = 145 kg
V_C = 170 km/h	n = 4.81	m = 145 kg
V_C = 170 km/h	n = -2.81	m = 145 kg
V_C = 170 km/h	n = 5.82	m = 105 kg
V_C = 170 km/h	n = -3.82	m = 105 kg
V_F = 140 km/h	n = 2.0	m = 105 kg
V_F = 140 km/h	n = 0.0	m = 105 kg

The maonouevre and gust envelopes for the Condor RPV have now been set according to the JAR requirements.

Appendix B

Take-Off and Landing Calculations

Used Equations:

Take-Off

For acceleration calculation on ground and in air

Gear drag	$F = \mu(mg - L)$
Acceleration on ground	$acc = \frac{dV}{dt} = \frac{(T_A - D - F)}{m}$
Acceleration in air	$acc = \frac{dV}{dt} = \frac{(T_A - D)}{m}$
Increment of speed	$\Delta V = acc.\Delta t$
Real time speed	$V_t \cong V_{t-\Delta t} + \Delta V = V_{t-\Delta t} + acc_{t-\Delta t}.\Delta t$
Distance increment	$\Delta l = V_a.\Delta t = \frac{(V_t + V_{t-\Delta t})}{2}.\Delta t$
Real time distance	$l_t = l_{t-\Delta t} + \Delta l$

For transition arc

Lift load factor	$n_L = \frac{L}{mg} = \left(\frac{V_2}{V_{S1}}\right)^2 = 1.2^2$
Radius of transition arc	$r = \frac{V_2^2}{g(n_L - \cos\theta)}$
Angle of climb	$\theta = \arcsin\left(\frac{T_A - T_R}{mg}\right)$
Length of transition arc	$l_3 = r.\sin\theta$
Increment of altitude	$h_3 = r(1 - \cos\theta)$
Time of transition arc	$t_3 = \frac{l_3}{V_2}$

For final climb to altitude of 10.5 m (35 ft.)

Length of climb	$l_4 = \frac{H - h}{\tan\theta}$
Time of climb	$t_4 = \frac{l_4}{V_2 \cos\theta}$

Landing

For transition arc

Lift load factor $n_L = \frac{L}{mg} = \left(\frac{V_A}{V_{S0}}\right)^2 = 1.3^2$

Radius of transition arc $r = \frac{V_A^2}{g(n_L - \cos\theta)}$

Length of transition arc $l_2 = r.\sin\theta$

Decrement of altitude $h_1 = r(1 - \cos\theta)$

Airspeed at end of arc $V_F = \sqrt{V_A^2 - 2gh_1}$

Time of transition arc $t_2 = \frac{2l_2}{(V_A + V_F)}$

For descent from altitude 15 m (50 ft.)

Length of descent $l_1 = \frac{H - h_1}{\tan\theta}$

Time of descent $t_1 = \frac{l_1}{V_A \cos\theta}$

For deceleration in air and on ground

Acceleration in the air $acc = \frac{(-D)}{m}$

Acceleration on ground $acc = \frac{(-D - F)}{m}$

Gear drag $F = \mu.F_f + \mu.F_m$

Force on front gear $F_f = \frac{(mg - L)X_G - (m.acc + D)Y_G}{X_F}$

Force on main gears $F_m = mg - L - F_f$

Increment of speed $\Delta V = acc.\Delta t$

Real time speed $V_t \cong V_{t-\Delta t} + \Delta V = V_{t-\Delta t} + acc_{t-\Delta t}.\Delta t$

Distance increment $\Delta l = V_a.\Delta t = \frac{(V_t + V_{t-\Delta t})}{2}.\Delta t$

Real time distance $l_t = l_{t-\Delta t} + \Delta l$

Takeoff From Grass

g =	9.80665 m/s2			
density =	1.225 kg/m3			
Wing area, S =	4.15 m2			
Takeoff weight =	145 kg			
Clmax =	1.15			
Friction coeff. =	0.1			
alpha on ground =	1 degree		=> CL =	0.22
	For a 15 degree flap		=> CD =	0.045

Vlof = 1.1Vs1 = 24.31 m/s
V2 = 1.2Vs1 = 26.52 m/s

Ground Run

t (sec)	TAS (m/s)	L (N)	D (N)	TA (N)	F (N)	Acc. (m/s2)	l (m)
0	0	0	0	550	142.20	2.81	0
1	2.81	4.42	0.90	512	141.75	2.55	1.41
2	5.36	16.06	3.29	469	140.59	2.24	5.49
3	7.60	32.32	6.61	460	138.96	2.17	11.97
4	9.77	53.38	10.92	450	136.86	2.08	20.66
5	11.85	78.59	16.07	439	134.34	1.99	31.47
6	13.84	107.19	21.93	430	131.48	1.91	44.32
7	15.75	138.76	28.38	424	128.32	1.84	59.12
8	17.60	173.14	35.42	419	124.88	1.78	75.79
9	19.38	210.03	42.96	413	121.19	1.72	94.28
10	21.10	248.88	50.91	408	117.31	1.65	114.52
11	22.75	289.42	59.20	403	113.25	1.59	136.44
12	24.34	331.29	67.76	398	109.07	1.53	159.99

11.98	24.31			398			159.55

Acceleration from Vlof to V2

t (sec)	TAS (m/s)	CL	CD	L (N)	D (N)	TA (N)	Acc. (m/s2)	l (m)
11.98	24.31	0.95	0.063	1422	94.64	398	2.09	159.55
13	26.40	0.80	0.055	1422	97.45	389	2.01	184.91
14	28.41	0.69	0.053	1422	107.73	384	1.91	212.31

13.05	26.52	0.79	0.055			389		186.55

Transition Arc

Required Thrust	107.73 N
Lift Load Factor	1.44
Angle of Climb	11.4 deg
Radius of Transition Arc	74.49 m
Increment of Altitude	1.47 m
Increment of Takeoff Distance	14.74 m
Increment of Time	0.56 sec

13.61	26.52		201.29

Climb to the Altitude of 10.5 m (35 ft)

Angle of Climb	11.4 deg
Increment of Takeoff Distance	44.74 m
Increment of Time	1.72 sec

15.33	26.52	Takeoff completed at an altitude of 10.5 m (35 ft)	246.03

Takeoff From Concrete

g = 9.80665 m/s2
density = 1.225 kg/m3
Wing area, S = 4.15 m2
Takeoff weight = 145 kg
Clmax = 1.15
Friction coeff. = 0..04
alpha on ground = 1 degree => CL = 0.22
For a 15 degree flap => CD = 0.045

Vlof = 1.1Vs1 = 24.31 m/s
V2 = 1.2Vs1 = 26.52 m/s

Ground Run

t (sec)	TAS (m/s)	L (N)	D (N)	TA (N)	F (N)	Acc. (m/s2)	l (m)
0	0	0	0	550	56.88	3.40	0
1	3.40	6.47	1.32	510	56.62	3.12	1.70
2	6.52	23.76	4.86	464	55.93	2.78	6.66
3	9.30	48.36	9.89	454	54.94	2.68	14.57
4	11.98	80.30	16.43	439	53.67	2.54	25.21
5	14.53	118.02	24.14	428	52.16	2.43	38.47
6	16.95	160.72	32.87	420	50.45	2.32	54.21
7	19.27	207.76	42.50	414	48.57	2.23	72.32
8	21.50	258.54	52.88	408	46.54	2.13	92.71
9	23.63	312.25	63.87	400	44.39	2.01	115.27
10	25.64	367.69	75.21	393	42.17	1.90	139.91

9.34	24.31		398		123.61

Acceleration from Vlof to V2

t (sec)	TAS (m/s)	CL	CD	L (N)	D (N)	TA (N)	Acc. (m/s2)	l (m)
9.34	24.31	0.95	0.063	1422	94.64	398	2.09	123.61
10	26.40	0.80	0.055	1422	97.45	389	2.01	148.97
11	28.41	0.69	0.053	1422	107.73	384	1.91	176.37

10.06	26.52	0.79	0.055		389		150.61

Transition Arc

Required Thrust	107.73 N
Lift Load Factor	1.44
Angle of Climb	11.4 deg
Radius of Transition Arc	74.49 m
Increment of Altitude	1.47 m
Increment of Takeoff Distance	14.74 m
Increment of Time	0.56 sec

10.62	26.52		165.35

Climb to the Altitude of 10.5 m (35 ft)

Angle of Climb	11.4 deg
Increment of Takeoff Distance	44.74 m
Increment of Time	1.72 sec

12.34	26.52	Takeoff completed at an altitude of 10.5 m (35 ft)	210.09

Landing on Grass

Aircraft Landing Weight		145 kg			
Aircraft Landing Configuration	δfl =	30 deg			
ISA Sea Level Conditions					
Angle of Atttack on Ground	α =	+ 1 deg	where	Cl =	0.22
Stall Airspeed Vso		22.1 m/s		CD =	0.045
Dry, Concrete Runway & Dry Grass					
Angle of Descent	θ =	3 deg			
Friction coefficient	Grass =	0.10			
Horizontal Arm of CG	XG =	1.27 m			
Vertical Arm of CG	YG =	0.64 m			
Horizontal Armof Front Gear	XF =	0.30 m			

VA = 1.3Vso = 28.73 m/s
VTD = 1.05Vso = 23.21 m/s

Transition Arc

Lift Load Factor	1.69
Angle of Descent	3 deg
Radius of Transition Arc	121.74 m
Decrement of Altitude	0.17 m
Increment of Landing Distance	6.37 m
Increment of Time	0.22 sec
Airspeed at the Beginning of Transition Arc	28.73 m/s
Airspeed at the End of Transition Arc	28.67 m/s

Descent from Altitude of 15 m (50 ft) to the altitude of the Transition Arc's Origin

Angle of Descent	3 deg
Desent Airspeed	28.73 m/s
Increment of landing Distance	283.03 m
Increment of Time	9.87 sec

Final Values at End of Transition Arc

time = 10.09 sec   Airspeed, VF = 28.67 m/s
Distance = 289.40 m

Deceleration from Airspeed V to VTD

t (sec)	TAS (m/s)	CL	CD	L (N)	D (N)	acc. (m/s2)	l (m)
10.09	28.73	0.68	0.058	1422.0	121.69	-0.84	289.40
11	27.89	0.72	0.059	1422.0	116.66	-0.80	317.72
12	27.09	0.76	0.060	1422.0	111.89	-0.77	345.20
13	26.31	0.81	0.061	1422.0	107.37	-0.74	371.90
14	25.57	0.86	0.063	1422.0	104.74	-0.72	397.85
15	24.85	0.91	0.065	1422.0	102.04	-0.70	423.06
16	24.15	0.96	0.0675	1422.0	100.05	-0.69	447.56
17	23.46	1.02	0.069	1422.0	96.51	-0.67	471.36
18	22.79	1.08	0.07	1422.0	92.43	-0.64	494.49

17.37	23.21					-0.66	480.00

Ground Run

t (sec)	TAS (m/s)	L (N)	D (N)	Ff (N)	Fm (N)	F (N)	acc (m/s2)	l (m)
17.37	23.21	301.25	61.62	112.11	1008.60	112.07	-1.20	480.00
18	22.46	281.98	57.68	141.27	998.71	114.00	-1.18	502.83
19	21.27	253.03	51.76	145.18	1023.75	116.89	-1.16	524.70
20	20.11	226.11	46.25	148.43	1047.42	119.59	-1.14	545.39
21	18.96	201.12	41.14	151.44	1069.40	122.08	-1.13	564.92
22	17.84	177.96	36.40	154.24	1089.77	124.40	-1.11	583.32
23	16.73	156.52	32.02	156.82	1108.62	126.54	-1.09	600.61
24	15.64	136.73	27.97	159.21	1126.03	128.52	-1.08	616.79
25	14.56	118.50	24.24	161.40	1142.06	130.35	-1.07	631.89
26	13.49	101.78	20.82	163.41	1156.77	132.02	-1.05	645.91
27	12.44	86.50	17.69	165.24	1170.22	133.55	-1.04	658.88
28	11.39	72.60	14.85	166.91	1182.46	134.94	-1.03	670.79
29	10.36	60.03	12.28	168.41	1193.52	136.19	-1.02	681.67
30	9.34	48.75	9.97	169.76	1203.45	137.32	-1.02	691.52
31	8.32	38.72	7.92	170.95	1212.29	138.32	-1.01	700.35
32	7.31	29.90	6.12	172.00	1220.06	139.21	-1.00	708.16
33	6.31	22.27	4.55	172.90	1226.80	139.97	-1.00	714.98
34	5.31	15.79	3.23	173.65	1232.52	140.62	-0.99	720.79
35	4.32	10.44	2.14	174.27	1237.25	141.15	-0.99	725.61
36	3.33	6.21	1.27	174.76	1240.99	141.58	-0.99	729.43
37	2.35	3.08	0.63	175.10	1243.78	141.89	-0.98	732.27
38	1.37	1.04	0.21	175.32	1245.60	142.09	-0.98	734.13
39	0.38	0.08	0.02	175.40	1246.48	142.19	-0.98	735.01
40	-0.60	0.20	0.04	175.35	1246.42	142.18	-0.98	734.90

39.39	0	Landing Complete	735.12

Landing on Concrete

Aircraft Landing Weight		145 kg			
Aircraft Landing Configuration	δfl =	30 deg			
ISA Sea Level Conditions					
Angle of Atttack on Ground	α =	+ 1 deg	where	Cl =	0.22
Stall Airspeed Vso		22.1 m/s		CD =	0.045
Dry, Concrete Runway & Dry Grass					
Angle of Descent	θ =	3 deg			
Friction coefficient	Concrete =	0.04			
Horizontal Arm of CG	XG =	1.27 m			
Vertical Arm of CG	YG =	0.64 m			
Horizontal Armof Front Gear	XF =	0.30 m			

VA = 1.3Vso = 28.73 m/s
VTD = 1.05Vso = 23.21 m/s

Transition Arc

Lift Load Factor	1.69
Angle of Descent	3 deg
Radius of Transition Arc	121.74 m
Decrement of Altitude	0.17 m
Increment of Landing Distance	6.37 m
Increment of Time	0.22 sec
Airspeed at the Beginning of Transition Arc	28.73 m/s
Airspeed at the End of Transition Arc	28.67 m/s

Descent from Altitude of 15 m (50 ft) to the altitude of the Transition Arc's Origin

Angle of Descent	3 deg
Desent Airspeed	28.73 m/s
Increment of landing Distance	283.03 m
Increment of Time	9.87 sec

Final Values at End of Transition Arc

time = 10.09 sec Airspeed, VF = 28.67 m/s
Distance = 289.40 m

Deceleration from Airspeed V to VTD

t (sec)	TAS (m/s)	CL	CD	L (N)	D (N)	acc. (m/s2)	l (m)
10.09	28.73	0.68	0.058	1422.0	121.69	-0.84	289.40
11	27.89	0.72	0.059	1422.0	116.66	-0.80	317.72
12	27.09	0.76	0.060	1422.0	111.89	-0.77	345.20
13	26.31	0.81	0.061	1422.0	107.37	-0.74	371.90
14	25.57	0.86	0.063	1422.0	104.74	-0.72	397.85
15	24.85	0.91	0.065	1422.0	102.04	-0.70	423.06
16	24.15	0.96	0.0675	1422.0	100.05	-0.69	447.56
17	23.46	1.02	0.069	1422.0	96.51	-0.67	471.36
18	22.79	1.08	0.07	1422.0	92.43	-0.64	494.49

17.37	23.21					-0.66	480.00

Ground Run

t (sec)	TAS (m/s)	L (N)	D (N)	Ff (N)	Fm (N)	F (N)	acc (m/s2)	l (m)
17.37	23.21	301.25	61.62	112.11	1008.60	44.83	-0.73	480.00
18	22.75	289.36	59.19	117.59	1015.01	45.30	-0.72	502.98
19	22.03	271.32	55.50	119.79	1030.85	46.03	-0.70	525.37
20	21.33	254.35	52.03	121.49	1046.13	46.70	-0.68	547.04
21	20.65	238.36	48.76	123.08	1060.52	47.34	-0.66	568.03
22	19.98	223.31	45.68	124.59	1074.07	47.95	-0.65	588.34
23	19.34	209.11	42.77	126.01	1086.85	48.51	-0.63	608.00
24	18.71	195.71	40.03	127.34	1098.91	49.05	-0.61	627.03
25	18.09	183.07	37.45	128.61	1110.29	49.56	-0.60	645.43
26	17.49	171.13	35.00	129.80	1121.03	50.03	-0.59	663.22
27	16.91	159.85	32.70	130.93	1131.19	50.48	-0.57	680.42
28	16.33	149.19	30.52	132.00	1140.78	50.91	-0.56	697.04
29	15.77	139.10	28.45	133.01	1149.85	51.31	-0.55	713.09
30	15.22	129.57	26.50	133.96	1158.44	51.70	-0.54	728.59
31	14.68	120.55	24.66	134.86	1166.55	52.06	-0.53	743.54
32	14.15	112.02	22.91	135.72	1174.23	52.40	-0.52	757.96
33	13.63	103.95	21.26	136.52	1181.49	52.72	-0.51	771.85
34	13.12	96.31	19.70	137.29	1188.36	53.03	-0.50	785.23
35	12.62	89.09	18.22	138.01	1194.86	53.31	-0.49	798.10
36	12.13	82.26	16.83	138.70	1201.01	53.59	-0.49	810.48
37	11.64	75.81	15.51	139.34	1206.81	53.85	-0.48	822.37
38	11.16	69.71	14.26	139.95	1212.31	54.09	-0.47	833.77
39	10.69	63.95	13.08	140.53	1217.49	54.32	-0.46	844.70
40	10.23	58.51	11.97	141.07	1222.39	54.54	-0.46	855.16
41	9.77	53.38	10.92	141.58	1227.00	54.74	-0.45	865.16
42	9.32	48.54	9.93	142.07	1231.35	54.94	-0.45	874.70
43	8.87	43.99	9.00	142.52	1235.45	55.12	-0.44	883.80
44	8.43	39.72	8.12	142.95	1239.30	55.29	-0.44	892.45
45	7.99	35.70	7.30	143.35	1242.91	55.45	-0.43	900.65
46	7.56	31.94	6.53	143.72	1246.30	55.60	-0.43	908.43
47	7.13	28.42	5.81	144.07	1249.47	55.74	-0.42	915.77
48	6.70	25.14	5.14	144.40	1252.43	55.87	-0.42	922.69
49	6.28	22.08	4.52	144.70	1255.18	56.00	-0.42	929.18
50	5.87	19.24	3.94	144.98	1257.74	56.11	-0.41	935.26
51	5.45	16.62	3.40	145.24	1260.10	56.21	-0.41	940.92
52	5.04	14.21	2.91	145.48	1262.27	56.31	-0.41	946.16

53	4.63	12.00	2.45	145.70	1264.27	56.40	-0.41	951.00
54	4.23	9.99	2.04	145.89	1266.08	56.48	-0.40	955.43
55	3.82	8.17	1.67	146.07	1267.72	56.55	-0.40	959.45
56	3.42	6.55	1.34	146.23	1269.19	56.62	-0.40	963.08
57	3.02	5.11	1.04	146.36	1270.49	56.67	-0.40	966.30
58	2.62	3.85	0.79	146.48	1271.63	56.72	-0.40	969.12
59	2.23	2.77	0.57	146.59	1272.60	56.77	-0.40	971.55
60	1.83	1.88	0.38	146.67	1273.42	56.80	-0.39	973.58
61	1.44	1.16	0.24	146.73	1274.08	56.83	-0.39	975.21
62	1.04	0.61	0.12	146.78	1274.58	56.85	-0.39	976.45
63	0.65	0.24	0.05	146.81	1274.92	56.87	-0.39	977.30
64	0.26	0.04	0.01	146.82	1275.11	56.88	-0.39	977.75
65	-0.13	0.01	0.00	146.81	1275.14	56.88	-0.39	977.82

64.67	0	Landing Complete	977.8