FSX GUIDE
XTREME PROTOTYPES
AVRO CF-105 ARROW Mk I

BY CHUCK
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Special thanks to Paul "Goldwolf" Whittingham for creating the guide icons.

This guide is aimed to give you an insight on how the Avro Arrow was developed and flown. The Arrow is a special aircraft for me: it's an aircraft that has a story that is nothing short of mythical in Canada.

The **Avro Canada CF-105 Arrow** was a delta-winged interceptor aircraft designed and built by Avro Canada. The Arrow is considered to have been an advanced technical and aerodynamic achievement for the Canadian aviation industry. The CF-105 (Mark II) held the promise of near-Mach 2 speeds at altitudes of 50,000 feet (15,000 m) and was intended to serve as the Royal Canadian Air Force's (RCAF) primary interceptor in the 1960s and beyond. The Arrow was the culmination of a series of design studies begun in 1953 examining improved versions of the Avro Canada CF-100 Canuck.

Intensive discussions between Avro and the RCAF examined a wide range of alternative sizes and configurations for a supersonic interceptor, culminating in RCAF "Specification AIR 7-3" in April 1953. AIR 7-3 called specifically for crew of two, twin engines, with a range of 300 nautical miles (556 km) for a normal low-speed mission, and 200 nm (370 km) for a high-speed interception mission. It also specified operation from a 6,000 ft (1,830 m) runway; a Mach 1.5 cruising speed at an altitude of 70,000 ft (21,000 m); and manoeuvrability for 2 g turns with no loss of speed or altitude at Mach 1.5 and 50,000 ft. The specification required five minutes from starting the aircraft's engines to reaching 50,000 ft altitude and Mach 1.5. It was also to have turn-around time on the ground of less than 10 minutes.

After considerable study, the RCAF selected a dramatically more powerful design, and serious development began in March 1955. Flight testing began with RL-201 on 25 March 1958, and the design quickly demonstrated excellent handling and overall performance, reaching Mach 1.9 in level flight. Powered by the Pratt & Whitney J75, another three Mk. I's were completed, RL-202 through -204. The lighter and more powerful Orenda Iroquois engine was soon ready for testing, and the first Mk.II with the Iroquois, RL-206, was ready for taxi testing in preparation for flight and acceptance tests by RCAF pilots by early 1959.

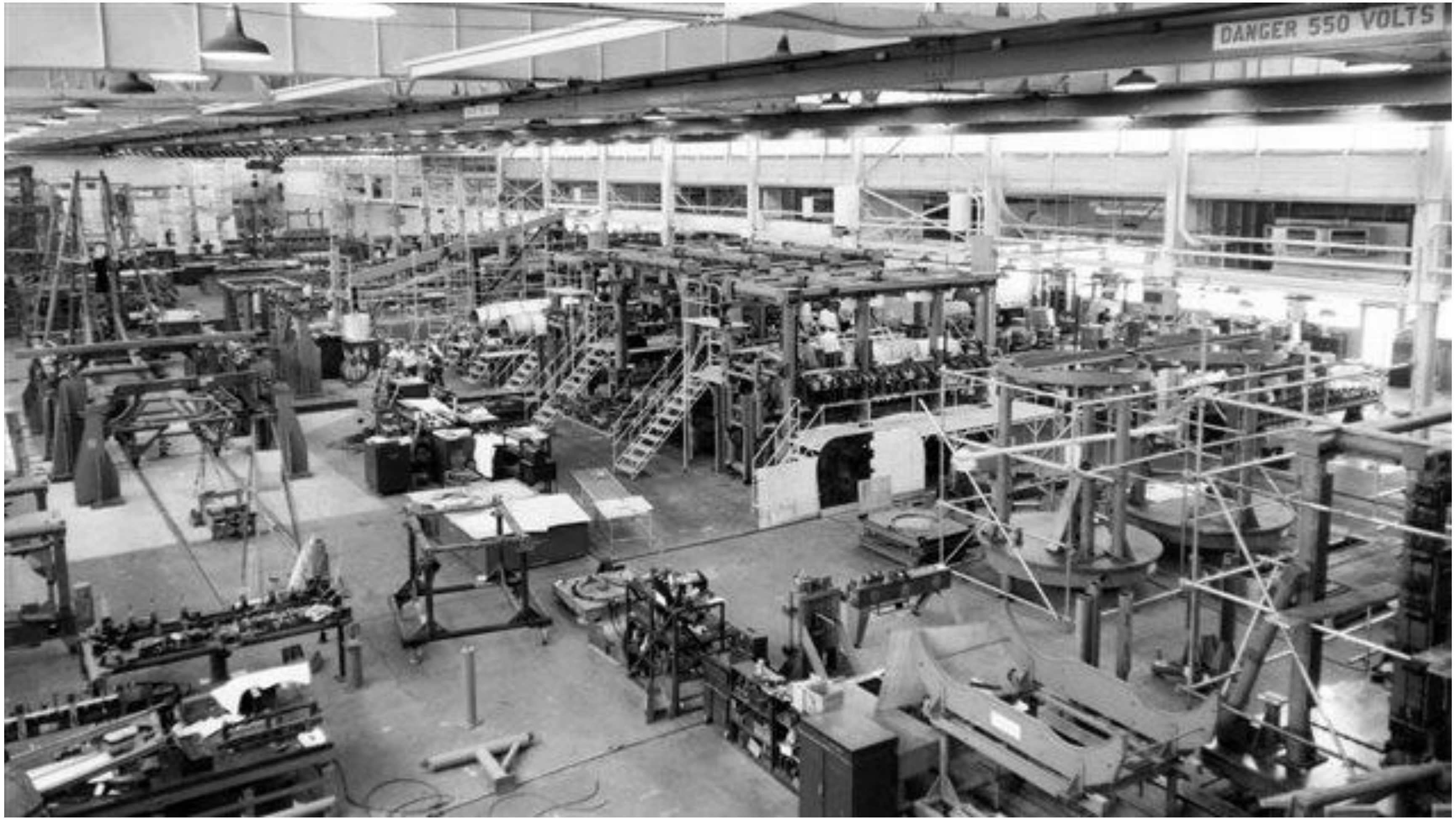
In June 1957, when the governing Liberals lost the federal election and a Progressive Conservative government under John Diefenbaker took power, the aircraft's prospects began to noticeably change. Diefenbaker had campaigned on a platform of reining in what the Conservatives claimed was "rampant Liberal spending". Nonetheless, by 1958, the parent company had become Canada's third largest business enterprise and had primary interests in rolling stock, steel and coal, electronics and aviation with 39 different companies under the A. V. Roe Canada banner.

On 20 February 1959, the development of the Arrow (and its Iroquois engines) was abruptly halted before a planned project review had taken place. Two months later, the assembly line, tooling, plans and existing airframes and engines were ordered to be destroyed.

The Arrow program was a special aircraft for Canadians. It was meant to be one of the most modern and innovative products ever built by canadian engineers. The truly controversial part was that the government not only cancelled it, but ordered Avro to destroy not only all planes, but all jigs, all special tools… everything was ordered destroyed. Avro never recovered, and the Canadian aviation industry never fully recovered either. No military aircraft was ever developed by Canada since 1959. It was a tragedy for the skilled workforce that worked so hard to bring this aircraft to life. Luckily, photos and films survived, along with other documentation, and even some parts that were smuggled out as souvenirs by some of the employees.

It was on February 20th 1959, a day that became known as "Black Friday", that a sudden and unexpected announcement from the nation's capital shocked the many thousands of workers at an aerospace plant near Toronto, Ontario. With the announcement of the Arrow's cancellation, some 14,000 A.V. Roe employees lost their jobs along with an additional 15000 employees in subcontracted equipment suppliers.

Empty workstations, jigs, tools and components of the Arrow left in place as stunned workers went home after the devastating news of Black Friday © Avro Aircraft



Following the cancellation of the Avro Arrow project, CF-105 Chief Aerodynamicist Jim Chamberlin lead a team of 25 engineers to join the National Aeronautics & Space Administration (NASA) and went on to become lead engineers, program managers, and heads of engineering in NASA's manned space programs—Projects Mercury, Gemini and Apollo. This expatriate team eventually grew to 32 ex-Avro engineers and technicians, and became emblematic of what many Canadians later viewed as a "brain drain" to the US.

To this day, conspiracy theories about American involvement to end the Canadian project abound. They concern allegations that American aerospace companies did not want competition for sales from a much superior interceptor from Canada, and that they were also eager to hire away the brilliant engineers who created the Arrow.

Source: Canada Aviation & Space Museum Aircraft – Avro Canada CF-105 Arrow (T.F.J. Leversedge) https://documents.techno-science.ca/documents/CASM-Aircrafthistories-AvroCanadaCF-105Arrownose.pdf

One can wonder… why was a promising aircraft like the Arrow cancelled if it was such a great plane? It's a heated debate, even today. The consensus between experts is that bad timing, bad luck, poor management decisions and a lack of political willingness from the Canadian government lead the program to its untimely end. Here are some of the main causes for the program's cancellation.

Political Intrigue

From as early as 1953, some senior Canadian military officials within the various Chiefs of Staff had begun to question the program. Such questioning persisted with the Diefenbaker administration, which had issues with the mounting costs of the aircraft development.

The CF-105 Arrow appeared to be far from being operational and there were questions of costly re-engineering work that continued to occur. Orenda's Iroquois engine proposed for the Mk II production aircraft was also lagging behind schedule. Worse off was the Astra fire control system — it seemed to be getting nowhere. Naturally, almost any technical problem could be overcome by pouring in money. However, Ottawa was weary of Avro Canada overruns. What had begun as a CA$1.5 million fighter had grown in steps to CA$4 million, with ranges between CA$8 million to CA$13 million being forecast for a smaller RCAF production run. In comparison, a later model CF-100 Mk.5 had cost just CA$700,000 and the cost of the F-106 Delta Dart was CA$5.59 million.

Crawford Gordon Jr., Avro Canada CEO

What didn't help was Diefenbaker's tense relationship with Avro Canada's President and General Manager Crawford Gordon Jr. Paul Squires, a historian with the Canadian Aeronautical Preservation Association, said: "*Diefenbaker didn't drink, didn't smoke, he was a complete teetotaler... And in walks Crawford Gordon with his hip flask, a cigarette in his hand, pounding on Diefenbaker's desk. They were complete polar opposites*." This clash in personality ended up making Diefenbaker's decision to kill the Arrow easier.

Lack of Foreign Interest

Canada had already tried to market the Arrow project, primarily to the US and Britain. But the aircraft industry in both these countries were considered in the national interest and the purchase of foreign designs was rare; moreover both the US and the UK had also cancelled a number of their own projects. Some analysts mentioned that the United States tried to get rid of the Arrow, but one has to keep in mind that at that time every major western power was trying to export their own military jets to other countries.

There was also the changing politics surrounding the creation of the North American Aerospace Defense Command, or NORAD. One of the specifics of this deal was the purchase by the U.S. Air Force of the new Avro Arrow fighter. "*When we were negotiating NORAD under the St. Laurent government, the U.S. would send a note, and the government would haggle over specifics and send one back*," Paul Squires explained. "*Well Mr. St. Laurent lost [the 1957 election], Mr. Diefenbaker came in, and the newest U.S. paper now says they no longer wish to purchase the Arrow*." "*Diefenbaker just looked at it, said 'looks good' and signed it. Even Americans were shocked, because they expected some pushback*."

John Diefenbaker, Canada Prime Minister

The Effect of Sputnik

The launch of Sputnik changed the military's view of soviet capabilities. The concept of interceptors (high-speed aircraft that were meant to intercept soviet nuclear bombers) became somewhat irrelevant overnight. Defence against ballistic missiles was becoming a priority. The existence of Sputnik raised the possibility of attacks from space, and, as the year progressed, word of a "missile gap" began spreading. An American brief of the meeting with George Pearkes (minister of national defence) records his concern that Canada could not afford defensive systems against both ballistic missiles and manned bombers. It is also said Canada could afford the Arrow or BOMARC/SAGE, but not both. This brings us to our next topic: the infamous BOMARC.

BOMARC & The CF-101 Voodoo

Canada's alternative to the Arrow was to purchase some American McDonnell F-101 Voodoo interceptors and Bomarc B missiles.

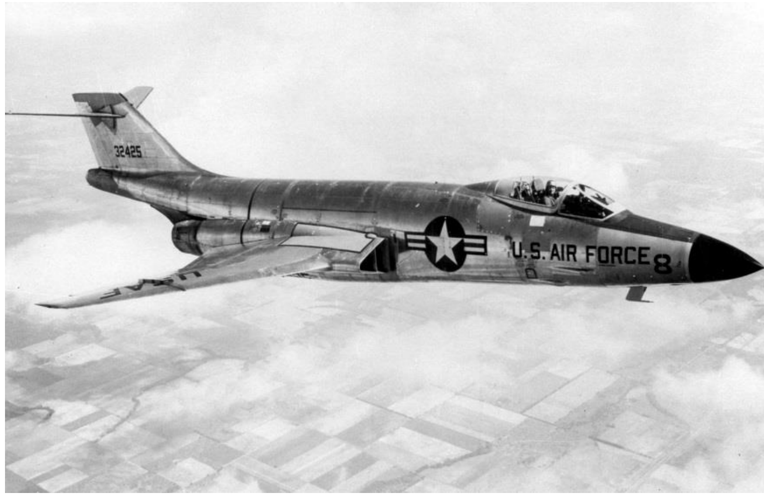
The USAF was in the process of completely automating their air defence system with the SAGE project (Semi-Automatic Ground Environment), a system of large computers and associated networking equipment that coordinated data from many radar sites and processed it to produce a single unified image of the airspace over a wide area. The USAF offered Canada the opportunity to share this sensitive information for the air defence of North America. One aspect of the SAGE system was the BOMARC nuclear-tipped anti-aircraft missile. This led to studies on basing BOMARCs in Canada in order to push the defensive line further north, even though the deployment was found to be extremely costly.

In 1961, the RCAF obtained 66 McDonnell CF-101 Voodoo aircraft, one of the American designs the RCAF originally rejected, to serve in the role originally intended for the Avro Arrow. In 1963, the Diefenbaker government was forced to call an election because of a cabinet revolt over the issue of nuclear weapons being acquired. In that election, the Liberals, led by Lester B. Pearson, defeated Diefenbaker's Conservatives. The success of the Liberals was due, at least in part, to their campaign promise that Canada would live up to its NORAD and North Atlantic Treaty Organization commitments. Pearson's government went on to accept Bomarc missile armed with nuclear weapons.

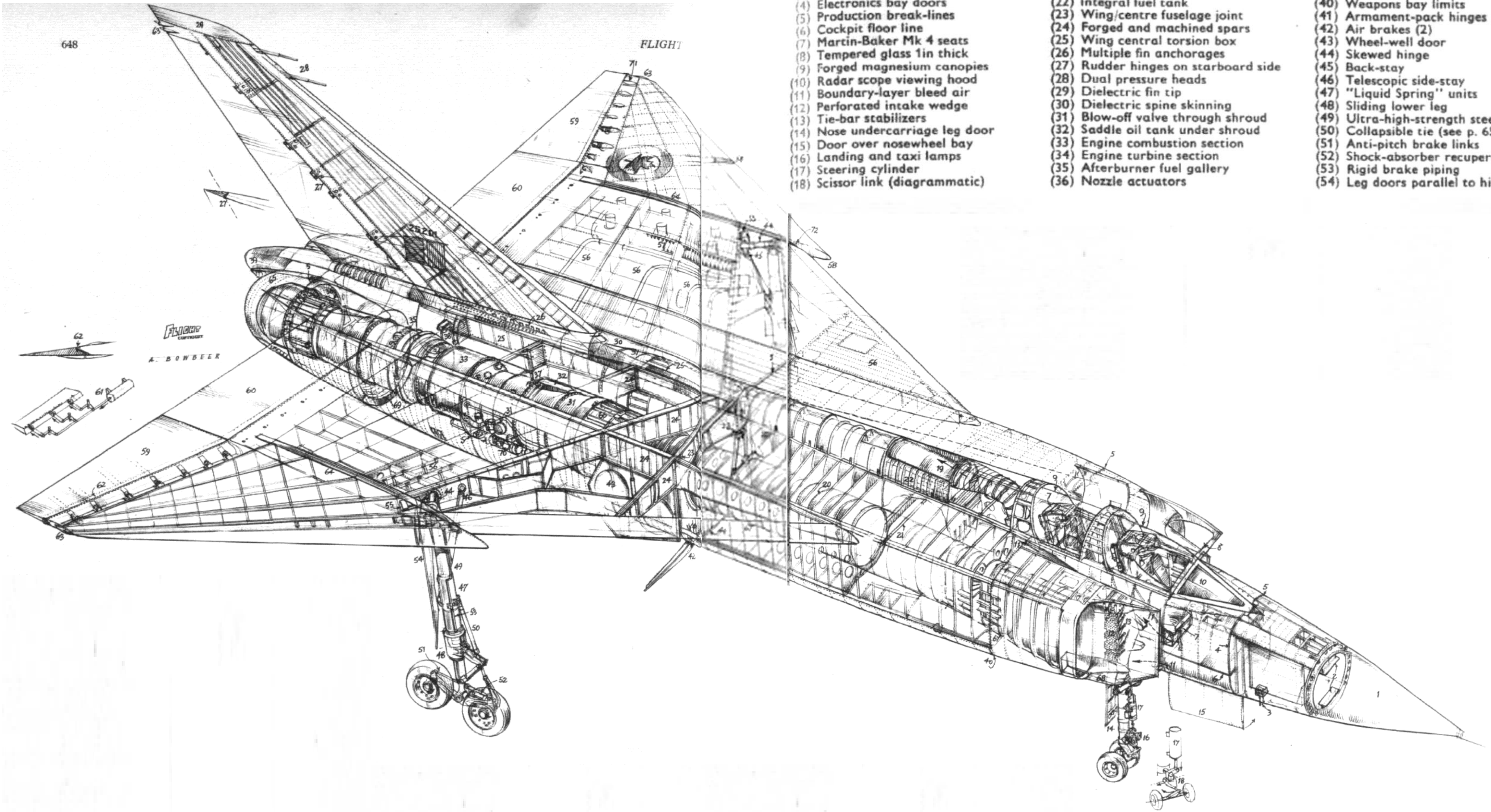
The nuclear weapons controversy had very serious implications for North American defence. Initially, the United States had planned to deploy a line of BOMARC air defence missile sites along the Canadian border, a location that was extremely problematic from a Canadian perspective. Missiles launched from these sites would have downed incoming Soviet bombers over southern Ontario and Quebec. Canada therefore convinced the United States to relocate the missile sites to northern Ontario and Quebec, positions from which incoming aircraft would be downed before they got to Canada's industrial heartland. Further complicating matters was the fact that these missiles would essentially be useless unless they were armed with nuclear warheads. Missiles intercepting bombers carrying nuclear weapons had to be capable of incinerating both the aircraft and its payload, tasks that required a nuclear capacity.

With the passage of time the operational capability of the 1950s-era BOMARC system no longer met modern requirements; the Department of National Defence deemed that the BOMARC missile defense was no longer a viable system, and ordered all squadrons to be stood down in 1972.

BOMARC Missile



CF-101 Voodoo



(1) Dielectric nose-cap
(2) Scanner mountings
(3) Ice-detection unit
(4) Electronics bay doors
(5) Production break-lines
(6) Cockpit floor line
(7) Martin-Baker Mk 4 seats
(8) Tempered glass 1in thick
(9) Forged magnesium canopies
(10) Radar scope viewing hood
(11) Boundary-layer bleed air
(12) Perforated intake wedge
(13) Tie-bar stabilizers
(14) Nose undercarriage leg door
(15) Door over nosewheel bay
(16) Landing and taxi lamps
(17) Steering cylinder
(18) Scissor link (diagrammatic)
(19) Air-conditioning discharge
(20) Frames assembled on ducting
(21) Weapons bay bracing tubes
(22) Integral fuel tank
(23) Wing/centre fuselage joint
(24) Forged and machined spars
(25) Wing central torsion box
(26) Multiple fin anchorages
(27) Rudder hinges on starboard side
(28) Dual pressure heads
(29) Dielectric fin tip
(30) Dielectric spine skinning
(31) Blow-off valve through shroud
(32) Saddle oil tank under shroud
(33) Engine combustion section
(34) Engine turbine section
(35) Afterburner fuel gallery
(36) Nozzle actuators
(37) Engine front mounting
(38) Engine rear mounting
(39) Braking parachute box
(40) Weapons bay limits
(41) Armament-pack hinges
(42) Air brakes (2)
(43) Wheel-well door
(44) Skewed hinge
(45) Back-stay
(46) Telescopic side-stay
(47) "Liquid Spring" units
(48) Sliding lower leg
(49) Ultra-high-strength steel
(50) Collapsible tie (see p. 652)
(51) Anti-pitch brake links
(52) Shock-absorber recuperator
(53) Rigid brake piping
(54) Leg doors parallel to hinge

BEST RESOURCES

- CF-105 Arrow Mk. I – Pilot's Operating Instructions Handbook, April 1958 (K.A.R. Reproduction)
- Destruction of a Dream – The Tragedy of Avro Canada and the CF-105 Arrow – Tome 1, 2, 3 & 4 (Marc-André Valiquette)
- Canada Aviation & Space Museum Aircraft – Avro Canada CF-105 Arrow (T.F.J. Leversedge)
  https://documents.techno-science.ca/documents/CASM-Aircrafthistories-AvroCanadaCF-105Arrownose.pdf
- The Arrow Scrapbook (Peter Zuuring)
  https://issuu.com/tikit/docs/scrapbook
- Arrow Countdown (Peter Zuuring)
  https://issuu.com/tikit/docs/countdowno9
- The Avro Arrow – University of Saskatchewan
  http://scaa.usask.ca/gallery/arrow/
- The Avro Canada CF-105 Arrow Definitive Documentary
  https://youtu.be/7sFRiacvNYo
- Iroquois Rollout – 45 Years Memorial Photo Album
  https://issuu.com/tikit/docs/iroquoisrollout
- Xtreme Prototypes CF-105 Pilot's Operating Instructions
  https://xtremeprototypes.com/en/pdf/XP_Arrow_manual_en_v1r0.pdf

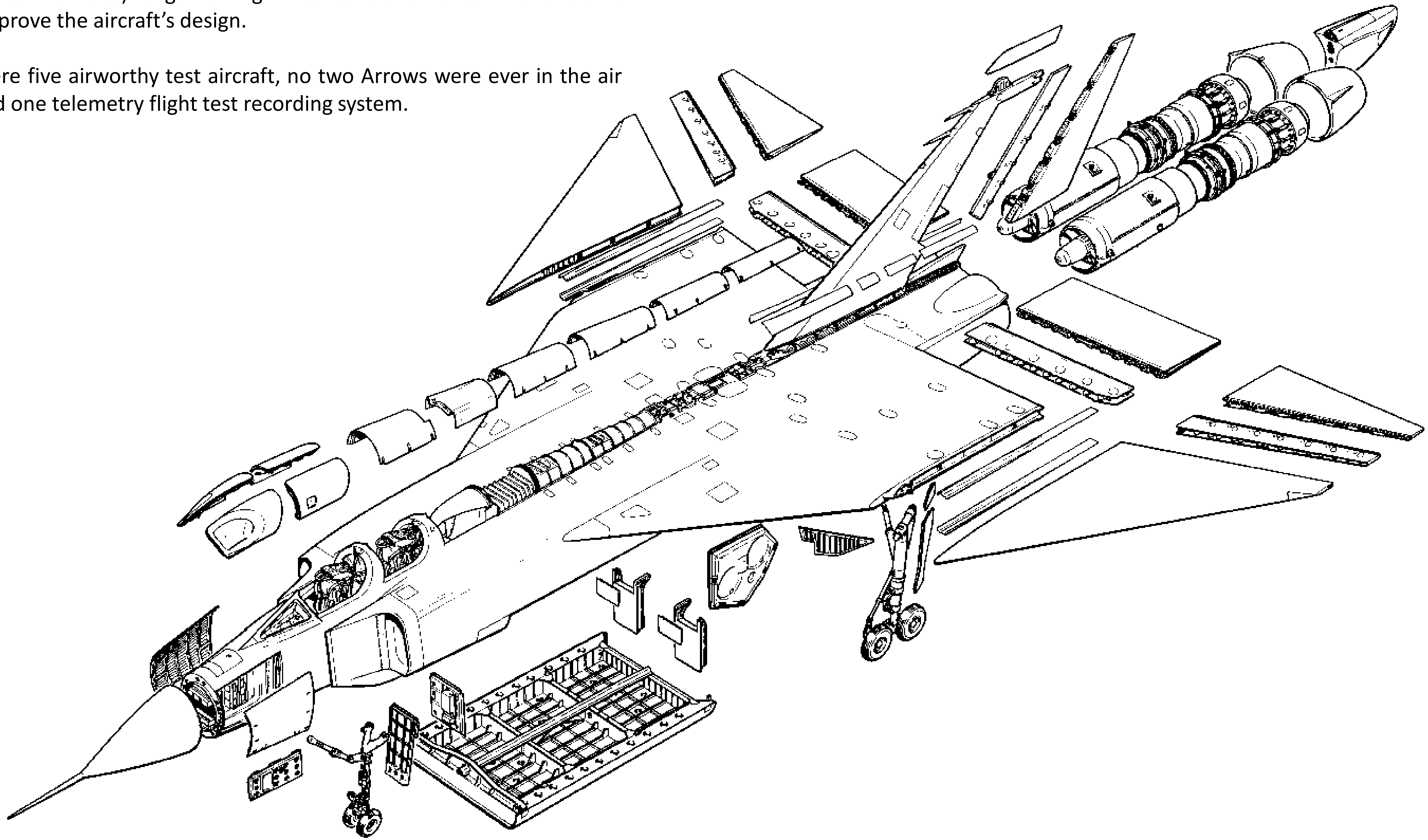
HIGHLY RECOMMENDED!

GREAT SOURCE FOR PHOTOS & TECHNICAL DRAWINGS

AVRO ARROW – THE PROTOTYPES

There are six prototypes of the Arrow that are known to have existed: five Mark I (RL-201 through RL-205) and one Mark 2 (RL-206) which was ready for its first taxi but never got to fly officially since the Arrow program was binned by the Canadian government. They were aimed to be used as FTVs (Flight Test Vehicles) to gather flight test data and to test the aircraft's flying characteristics and improve the aircraft's design.

Fun fact: although there were five airworthy test aircraft, no two Arrows were ever in the air at one time as Avro only had one telemetry flight test recording system.



RL-201 (Mk. I)

Factory rollout: October 4, 1957

First Flight: March 25, 1958

Number of flights: 25 (25.40 hours)

Engines: Pratt & Whitney J75-P-5 Turbojets

The rollout of the first CF-105 prototype, marked as RL-201, took place on October 4, 1957. The company had planned to capitalize on the event, inviting more than 13,000 guests to the occasion. Unfortunately for Avro, the media and public attention for the Arrow rollout was dwarfed by the launch of Sputnik the same day. RL-201 first flew on March 25, 1958 with Chief Development Test Pilot S/L Janusz Żurakowski at the controls.

The Arrow did not fly any combat mission per se; the early prototypes were aimed to study and test the design in a series of planned test flights. The test flights were limited to "proof-of-concept" and assessing flight characteristics. Pilots said that there did not seem to be any serious design faults. The CF-105 demonstrated excellent handling throughout the flight envelope, a large part due to the natural qualities of the delta-wing, but responsibility can also be attributed to the Arrow's Stability Augmentation System.

Of the six prototypes, RL-201 was the one with the most hours flown. With RL-204, it was the last Arrow to fly on February 19, 1959… before being grounded permanently. It was likely destroyed around May 8, 1959 after Diefenbaker's order to destroy all prototypes of February 20th, 1959.

You can see its first flight in this video:
https://www.youtube.com/watch?v=E8lTGTPQlDE

RL-201 Rollout (October 4, 1957)

RL-202 (Mk. I)

Factory rollout: April 14, 1958

Number of flights: 22 (23.40 hours)

Engines: Pratt & Whitney J75-P-5 Turbojets

Wladeck "Spud" Potocki recorded the fastest flight of an Arrow in RL-202 when he reached "Mach 1.98" … and this was not at the limits of its performance. However, an Avro report made public in 2015 clarifies that during the highest speed flight, the Arrow reached Mach 1.90 in steady level flight, and an indicated Mach number of 1.95 was recorded in a dive. Estimates up to Mach 1.98 likely originated from an attempt to compensate for lag error, which was expected in diving flight. Janusz Żurakowski, on the other hand, had the highest altitude record on September 14, 1959: 50000 ft!

On November 11, 1958, the flight control system of RL-202 commanded elevons full down at landing; the resulting reduction in weight on the gears reduced the effective tire friction, ultimately resulting in brake lockup and subsequent gear collapse. A photograph taken of the incident proved that inadvertent flight control activation had caused the accident.

Accident of RL-202 after a landing gear failure (November 11, 1958)

This particular prototype is shrouded in mystery. No one seems to know what happened to RL-202 which had just received major maintenance due to landing gear collapse experienced several months prior, and was just repaired and returned to flight worthiness immediately before program cancellation. There are tales of an Arrow being spirited away on a covered flatbed truck or secretly being flown to safety. There are numerous rumours about the fate of RL-202...

Sadly, the most sinister (and likely) answer may lie in Peter Zuuring's "Arrow Scrapbook" on page 125, where it is shown being partially dismantled.

RL-203 (Mk. I)

Factory rollout: May 30, 1958

Number of flights: 12 (13.30 hours)

Engines: Pratt & Whitney J75-P-5 Turbojets

While the real RL-203 was scrapped with every other jet and parts of its wings are exposed in the Canada Air & Space Museum, there is an interesting "beyond the grave" kind of story about it.

The Canadian Air and Space Museum, located at the former CFB Downsview, features a full-size (but not airworthy) replica Arrow built by volunteers with assistance from local aerospace firms. With a metal structure, the replica features many authentic-looking components including landing gear constructed by Messier-Dowty, the original Arrow primary landing gear sub-contractor. Painted in the colours of Arrow 25203, the Arrow replica was rolled out for a media event on 28 September 2006 and was on public display on 8–9 October 2006 to commemorate the original aircraft's rollout in 1957.

Wing Parts of RL-203 at the Canada Air & Space Museum

RL-203 Replica

Another replica Arrow built by Allan Jackson was used in *The Arrow*, a Canadian Broadcasting Corporation (CBC) production. He began building a full-scale replica of the Arrow in 1989, and was approached by the producers of the Arrow miniseries in 1996, then about 70% complete, who made an offer to complete the construction if the replica could be used for the production. That replica was cut up at the end of the film and the owner got it back in pieces, much to his distress. Apparently there had been a miscommunication and Jackson was compensated for the screwup, but it took him some time to get the replica back into shape again.

RL-204 (Mk. I)

Factory rollout: July 11, 1958

Number of flights: 6 (7.00 hours)

Engines: Pratt & Whitney J75-P-5 Turbojets

With RL-201, RL-204 was the last Arrow to fly on February 19, 1959.

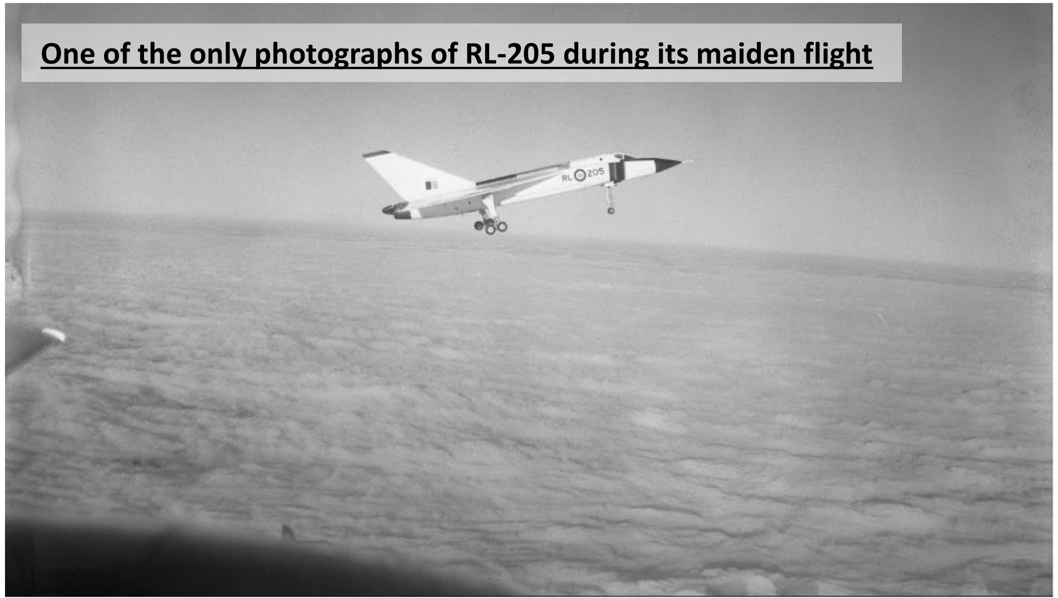
RL-204 had the dubious honour of being the only Arrow to land anywhere other than at Malton Airport, which was used by Avro Aircraft Ltd. as a base of operations, right next to the Orenda Engines Ltd facilities. On February 2, 1959, test pilot Peter Cope had 204 up when an airliner had a minor problem that left it immobilized on Malton's main runway. Avro shared that with Toronto's principal airport. The Arrow had to divert, and was sent to the RCAF base at Trenton, Ontario. Cope said afterward that he touched down at only a little over 160 mph just to make sure that he stopped in time on Trenton's runway. Cope's landing was fine, but he had to get himself down to ground level without the customary ladder by jumping off the aircraft's wing.

RL-204 circa 1958

Landing at Trenton

RL-205 (Mk. I)

One of the only photographs of RL-205 during its maiden flight



Factory rollout: December 10, 1958

Number of flights: 1 (0.40 hours)

Engines: Pratt & Whitney J75-P-5 Turbojets

Spud Potocki was the only pilot to fly RL 205 – it was ordered destroyed by government having ever only completed a forty-minute maiden flight on January 11, 1959. Avro never published its flight test performance.

The photograph below has been taken by a journalist who flew over the Avro facility without authorization in order to catch a last glimpse at the Arrow prototypes after their destruction was ordered by the Canadian government.

RL-205 being scrapped with the rest of the Arrows

RL-206 (Mk. II)

Factory rollout: Planned for March 31, 1959. Cancelled with Arrow Program.

Number of flights: 0 (never flown)

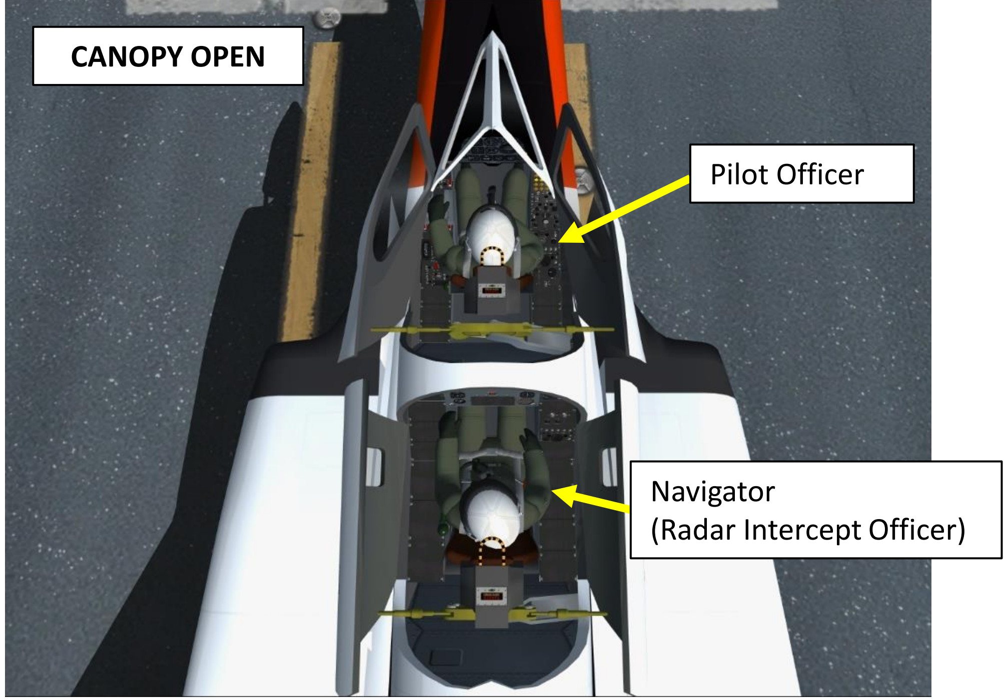
Engines: Orenda PS-13S Iroquois Turbojets

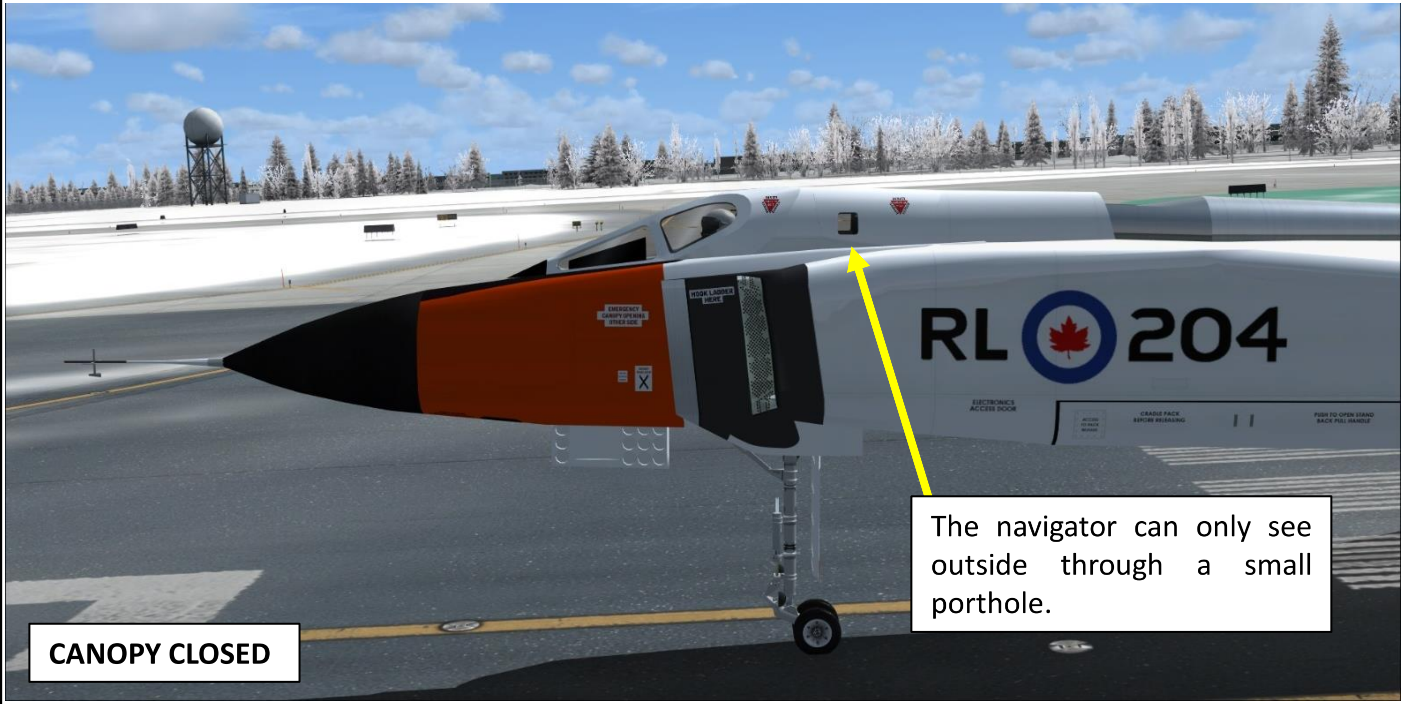
At the time of cancellation of the entire program, the first Arrow Mk. II, RL-206, was ready for taxi trials; Avro expected it to break the world speed record, but it never flew. Top speed would have been limited by atmospheric frictional heating, but according to project engineer James Floyd, "[the] aluminum alloy structure which we favoured was good for speeds greater than a Mach number of 2." The Mk II was intended to use the Iroquois engines, which were designed to produce 30,000 lbf (130 kN) each. While the J75 met requirements, Avro wanted a better engine designed by Canadians for Canadians.

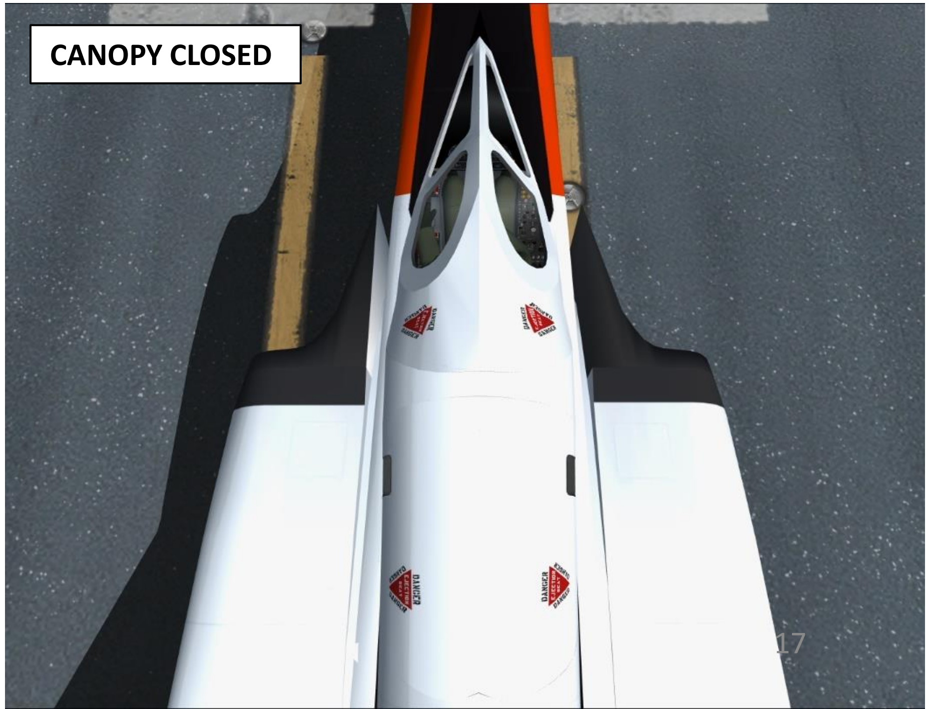
The RL-206 cockpit displayed at the Canada Aviation & Space Museum

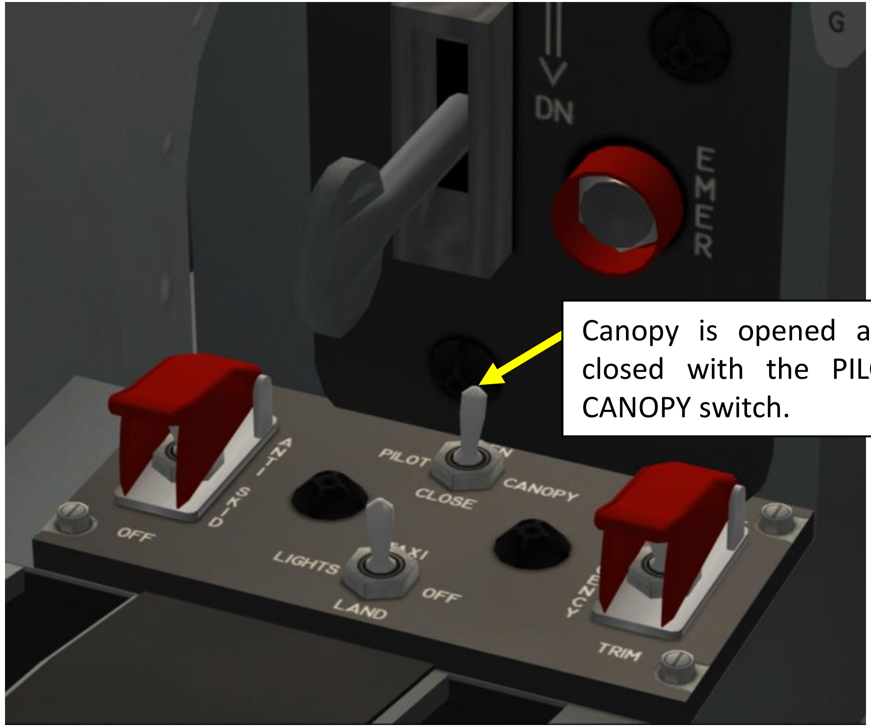
The nosecone section of Avro Arrow RL-206 is currently on display at the Canada Aviation and Space Museum in Ottawa; it was smuggled out of the Avro Aircraft plant in Malton by members of the RCAF Flying Personnel Medical Establishment, a detachment of RCAF Station Downsview on Avenue Road in Toronto, where it resided for many years in secrecy.


CANOPY OPEN
RL 204


CANOPY OPEN
Pilot Officer
Navigator
(Radar Intercept Officer)


CANOPY CLOSED
RL 204
The navigator can only see outside through a small porthole.

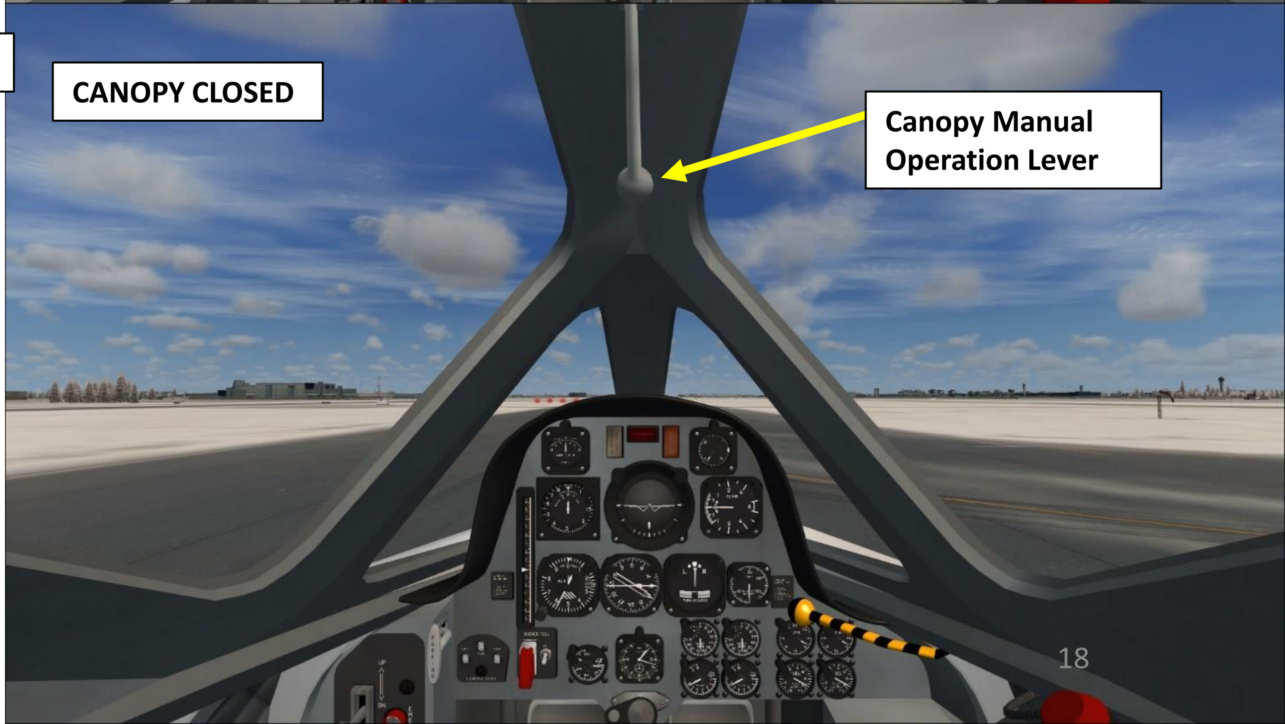

CANOPY CLOSED



Canopy is opened and closed with the PILOT CANOPY switch.

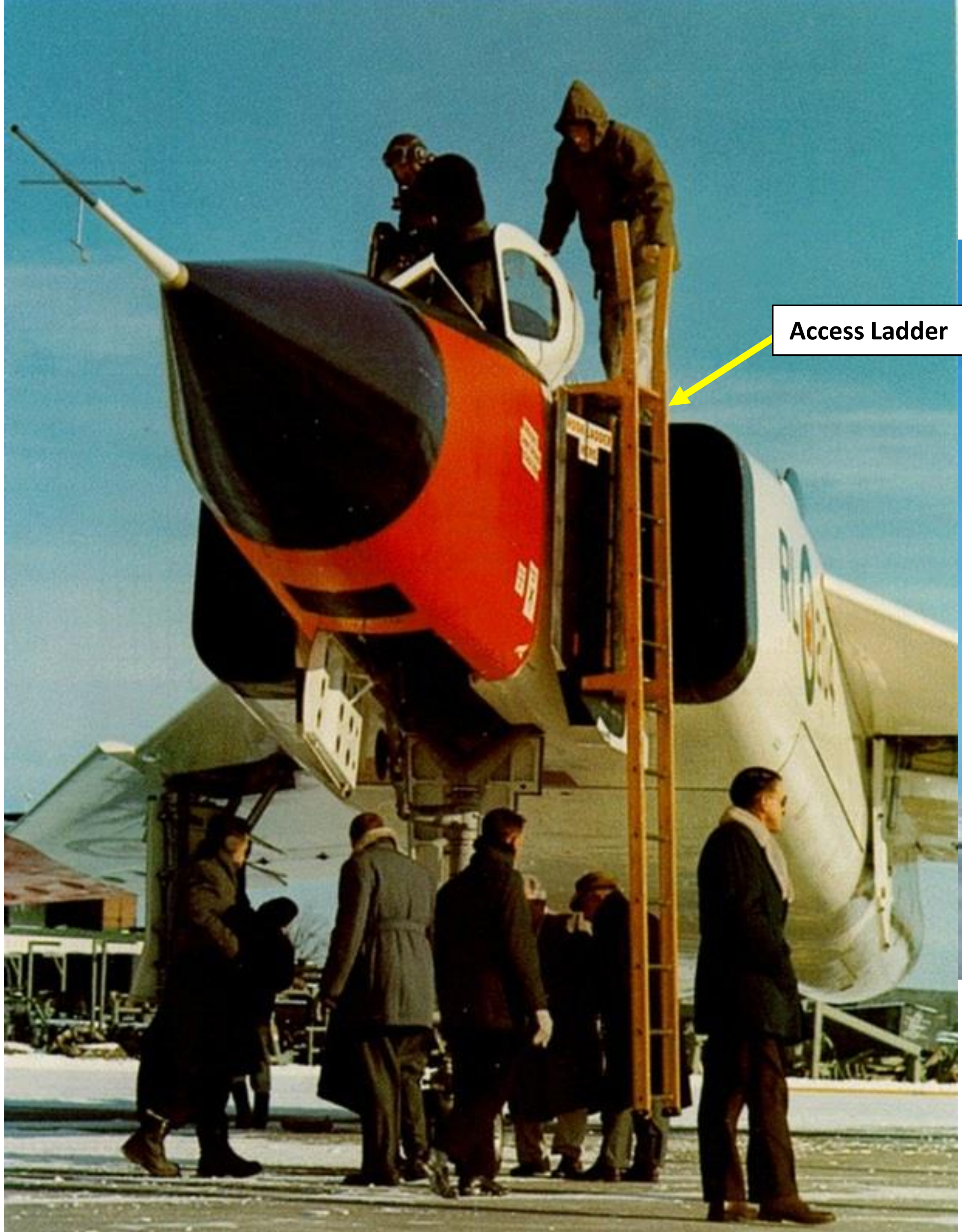
Clam-shell Canopy

CANOPY OPEN



CANOPY CLOSED

Canopy Manual Operation Lever



Source: The Arrow Countdown by Peter Zuuring

Irvin is located in Fort Erie, Ontario. They made chutes for the Arrow. They can do it again!

TECHNICAL BULLETIN

Arrow technical BULLETIN

VOLUME ONE
NUMBER ONE
SPECIAL BOOK ISSUE

RL205 One and only landing, AVRO

Arrow Parabrake

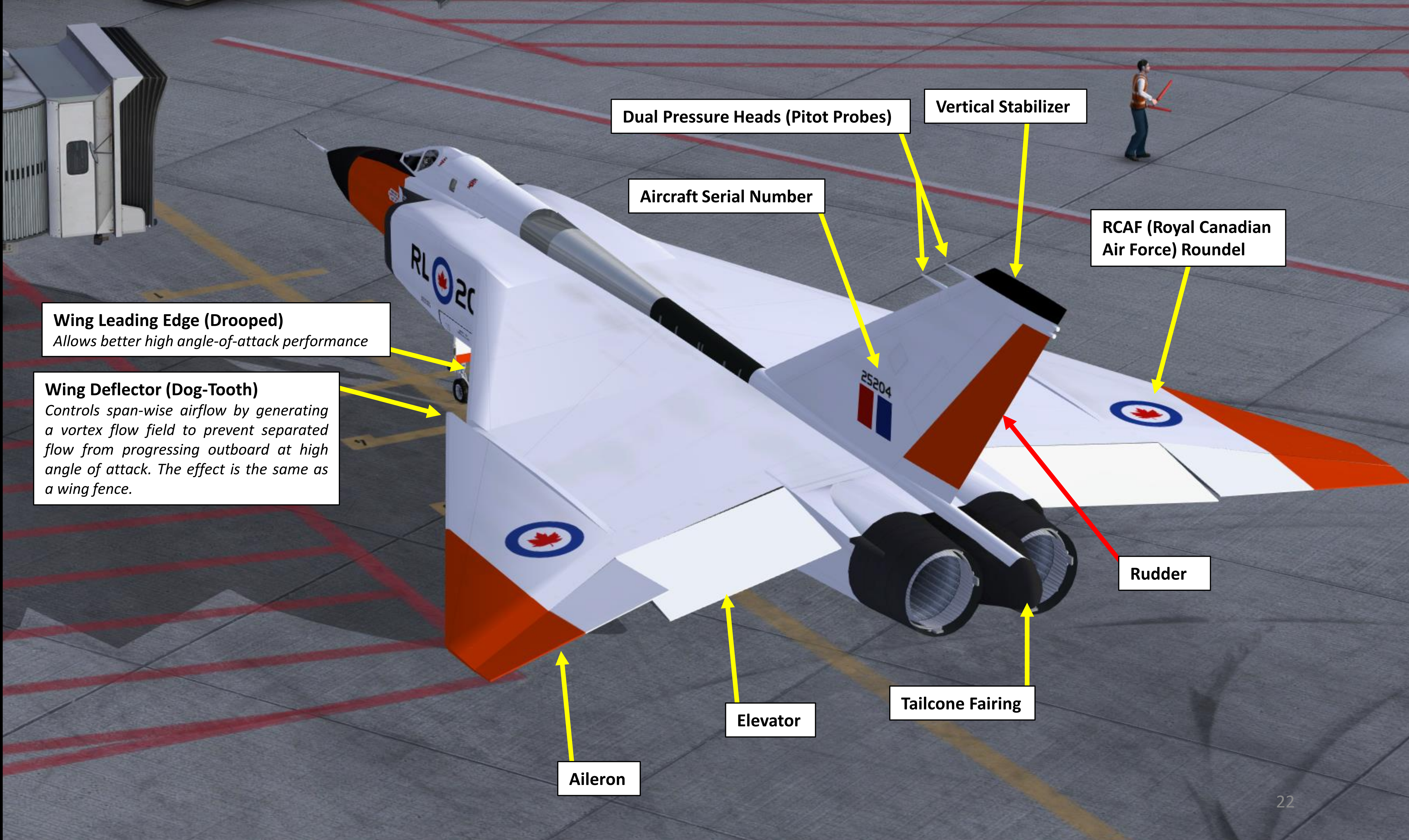
AVRO Photo

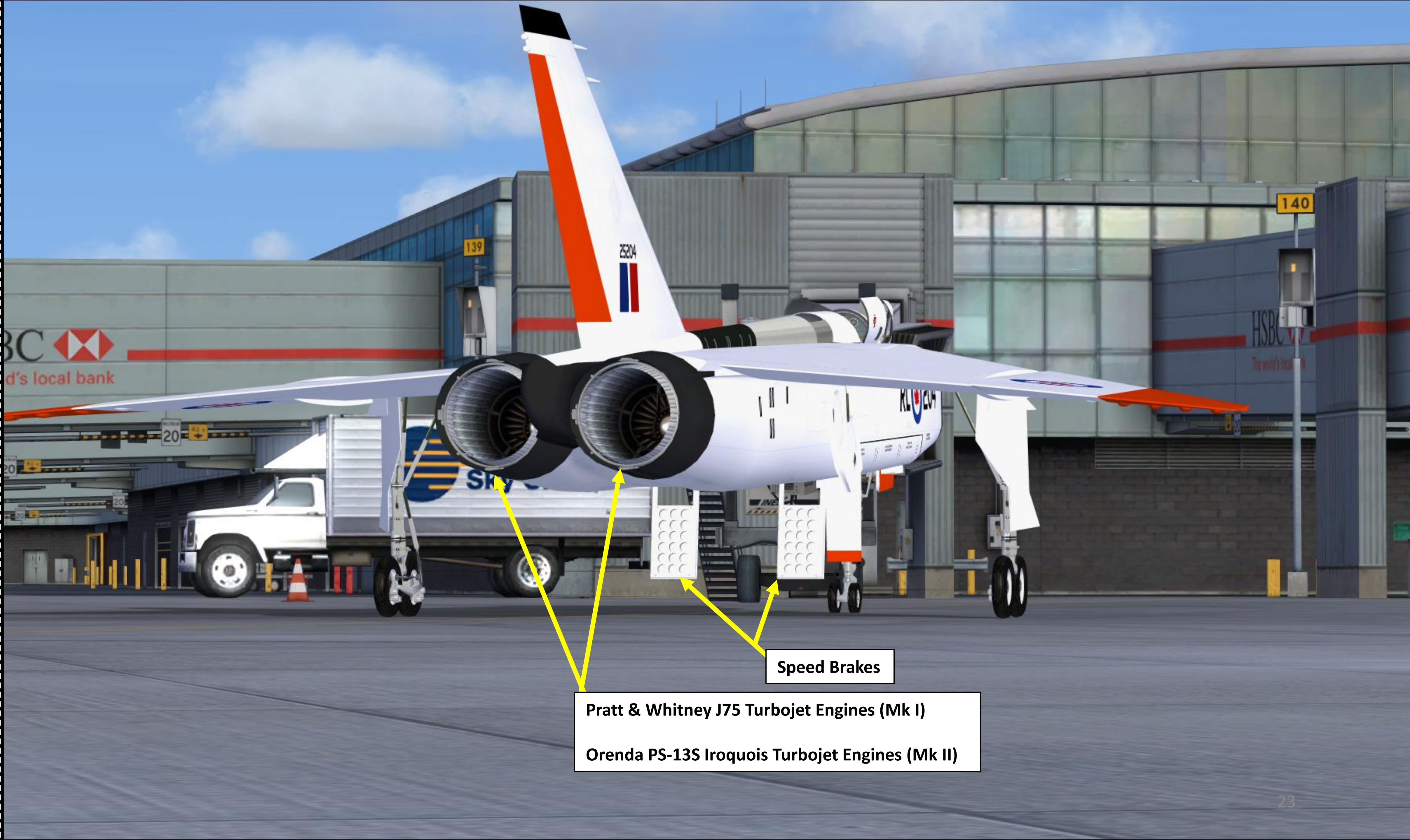
Source: The Arrow Countdown by Peter Zuuring

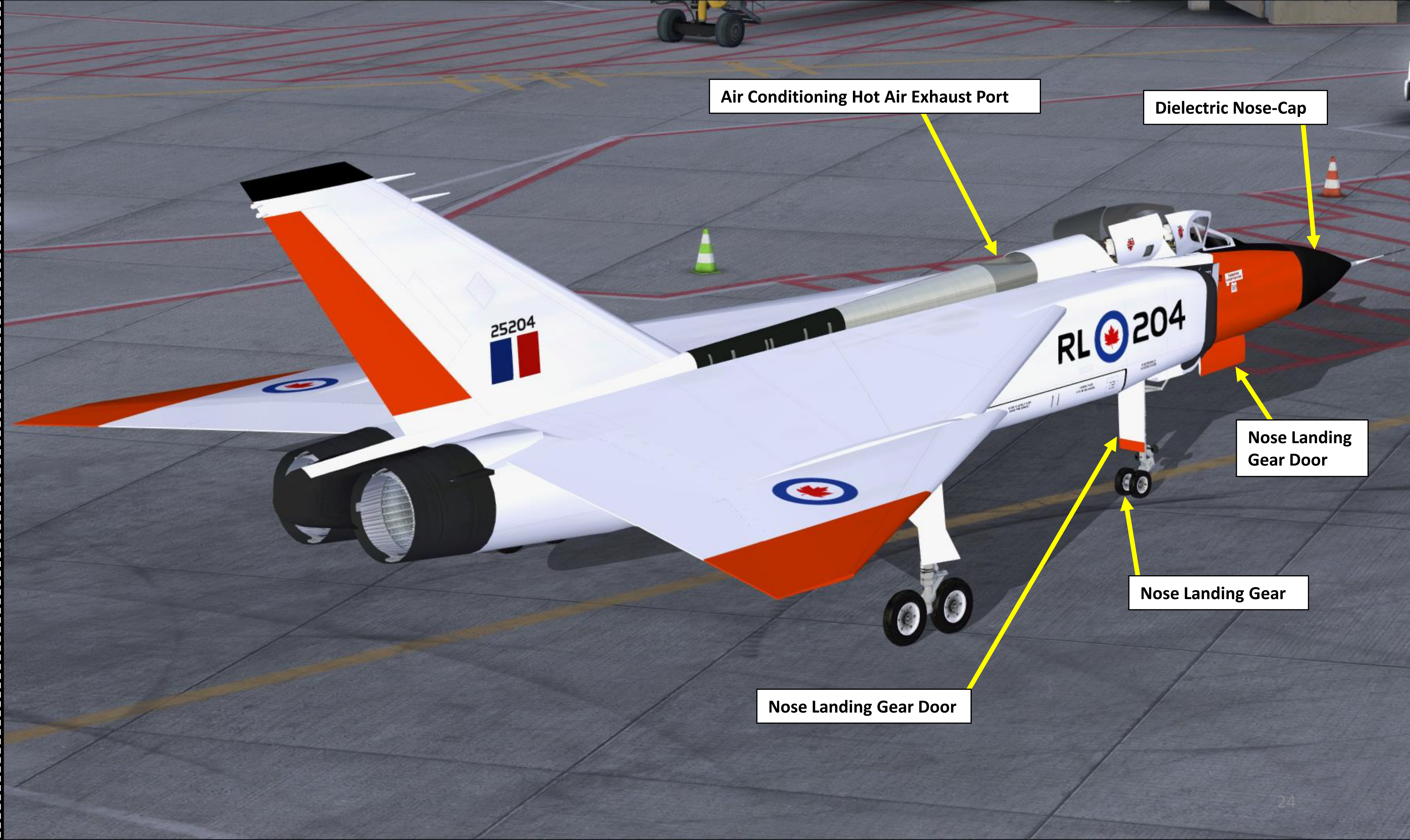
Vane-Type Flight Test Probe

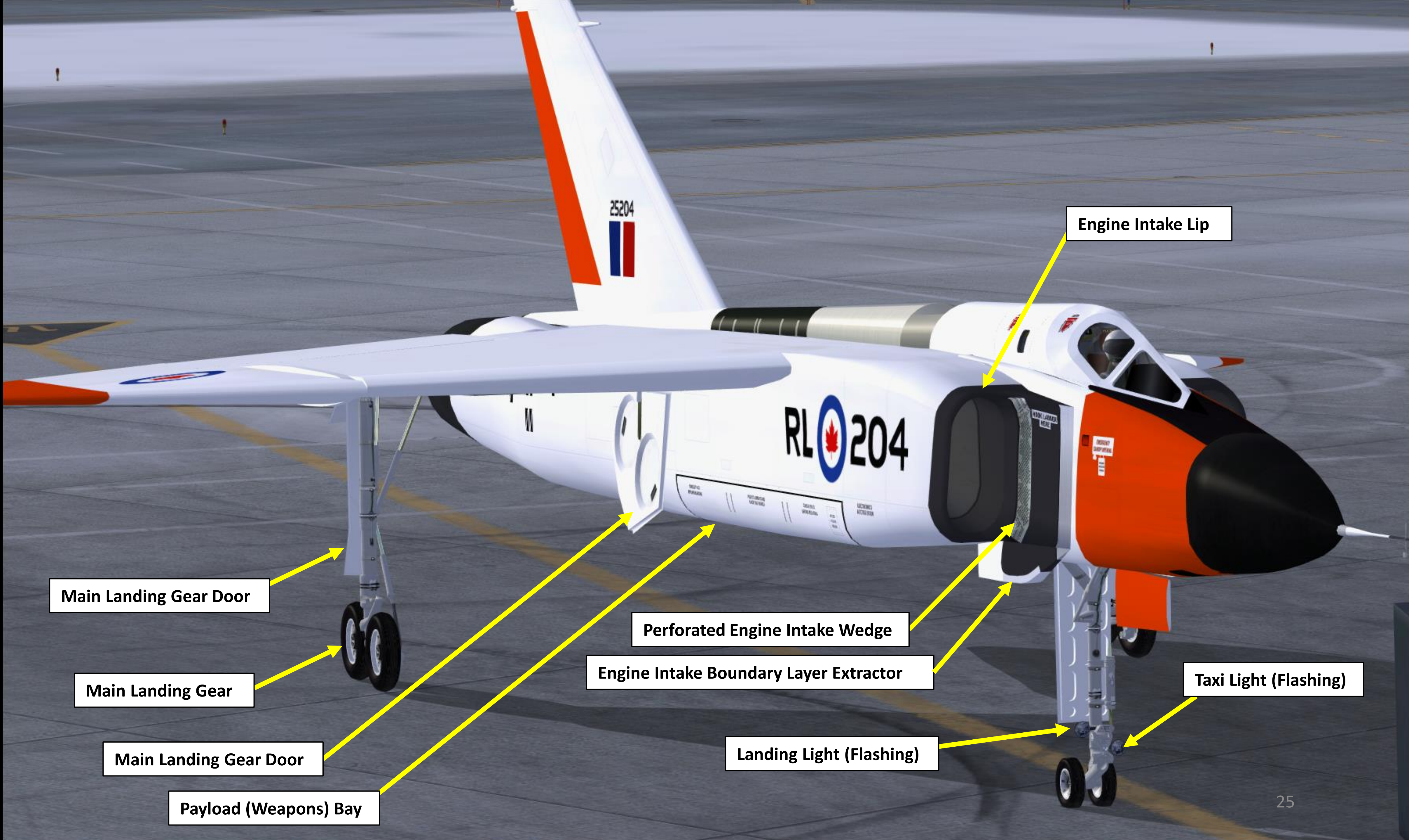
These types of probes are extensively used for measurement of the angles of incidence and yaw during flight. Their calibration is practically independent of Mach and Reynolds numbers. One of the advantages of these probes is that their location in front of the aircraft's nose makes them almost immune to the airflow disruptions caused by the aircraft itself.

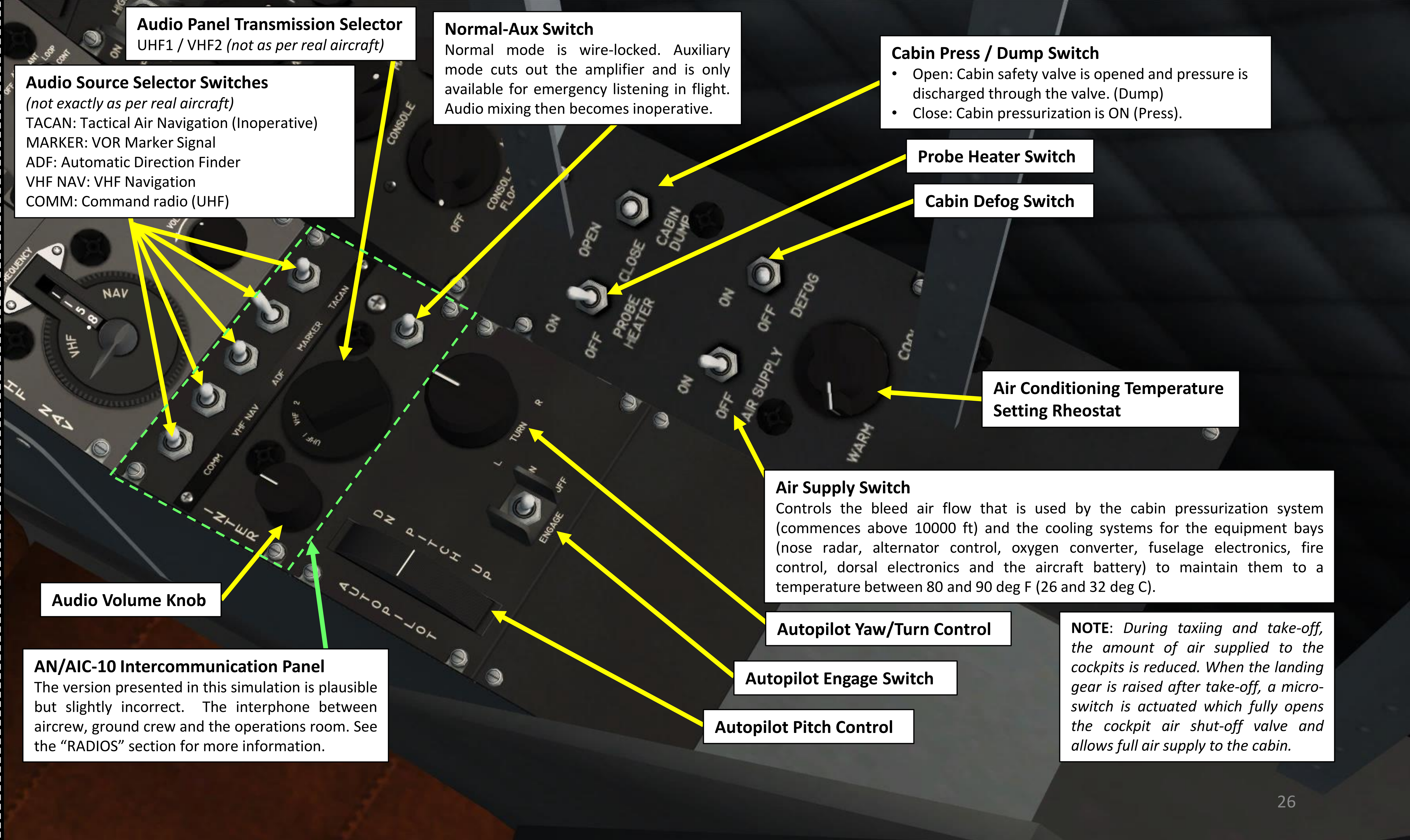
Probes of that kind are often used on FTVs (Flight Test Vehicles) to gather flight test data. The Arrows presented in this document are all aircraft that were built for testing purposes, which is why the aircraft is missing various components like the radar and armament systems.


Dual Pressure Heads (Pitot Probes)
Vertical Stabilizer
Aircraft Serial Number
RCAF (Royal Canadian Air Force) Roundel
Wing Leading Edge (Drooped)
Allows better high angle-of-attack performance
Wing Deflector (Dog-Tooth)
Controls span-wise airflow by generating a vortex flow field to prevent separated flow from progressing outboard at high angle of attack. The effect is the same as a wing fence.
RL 2C
25204
Rudder
Aileron
Elevator
Tailcone Fairing


Speed Brakes
Pratt & Whitney J75 Turbojet Engines (Mk I)
Orenda PS-13S Iroquois Turbojet Engines (Mk II)


Air Conditioning Hot Air Exhaust Port
Dielectric Nose-Cap
Nose Landing Gear Door
Nose Landing Gear
Nose Landing Gear Door
25204
RL 204


Engine Intake Lip
Main Landing Gear Door
Main Landing Gear
Main Landing Gear Door
Payload (Weapons) Bay
Perforated Engine Intake Wedge
Engine Intake Boundary Layer Extractor
Taxi Light (Flashing)
Landing Light (Flashing)
25204
RL 204



Audio Panel Transmission Selector
UHF1 / VHF2 *(not as per real aircraft)*

Audio Source Selector Switches
(not exactly as per real aircraft)
TACAN: Tactical Air Navigation (Inoperative)
MARKER: VOR Marker Signal
ADF: Automatic Direction Finder
VHF NAV: VHF Navigation
COMM: Command radio (UHF)

Normal-Aux Switch
Normal mode is wire-locked. Auxiliary mode cuts out the amplifier and is only available for emergency listening in flight. Audio mixing then becomes inoperative.

Cabin Press / Dump Switch
- Open: Cabin safety valve is opened and pressure is discharged through the valve. (Dump)
- Close: Cabin pressurization is ON (Press).

Probe Heater Switch

Cabin Defog Switch

Air Conditioning Temperature Setting Rheostat

Air Supply Switch
Controls the bleed air flow that is used by the cabin pressurization system (commences above 10000 ft) and the cooling systems for the equipment bays (nose radar, alternator control, oxygen converter, fuselage electronics, fire control, dorsal electronics and the aircraft battery) to maintain them to a temperature between 80 and 90 deg F (26 and 32 deg C).

Audio Volume Knob

AN/AIC-10 Intercommunication Panel
The version presented in this simulation is plausible but slightly incorrect. The interphone between aircrew, ground crew and the operations room. See the "RADIOS" section for more information.

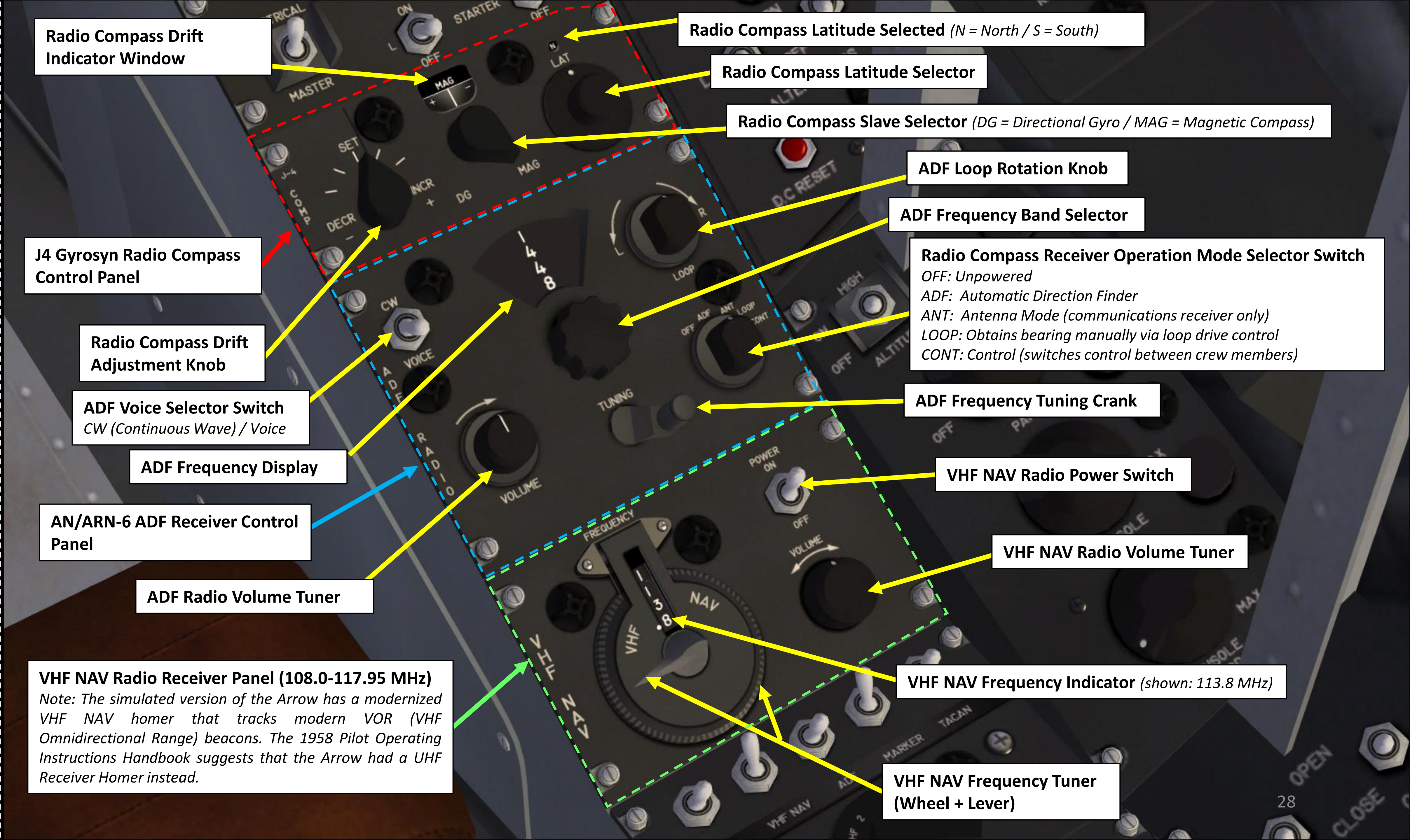
Autopilot Yaw/Turn Control

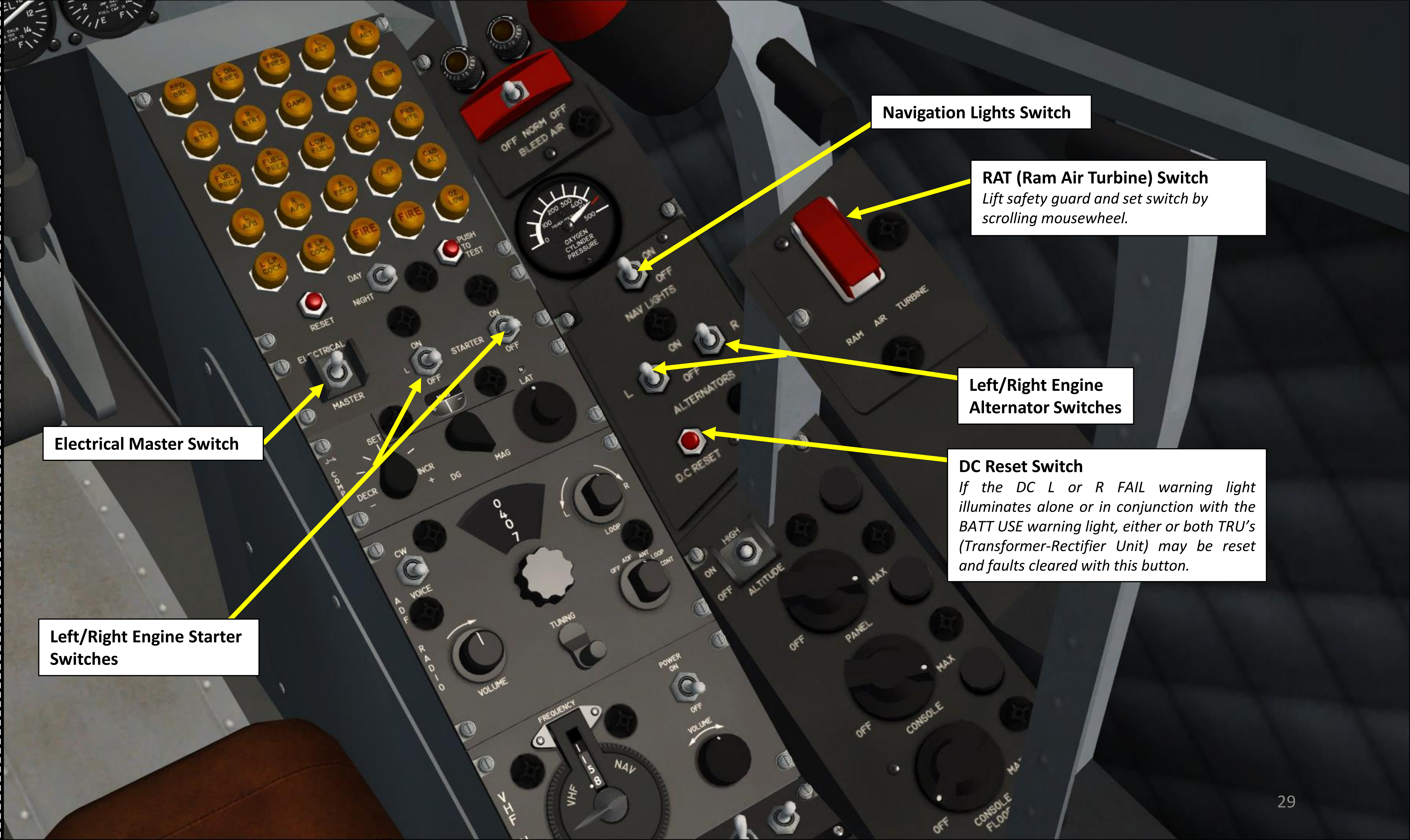
Autopilot Engage Switch

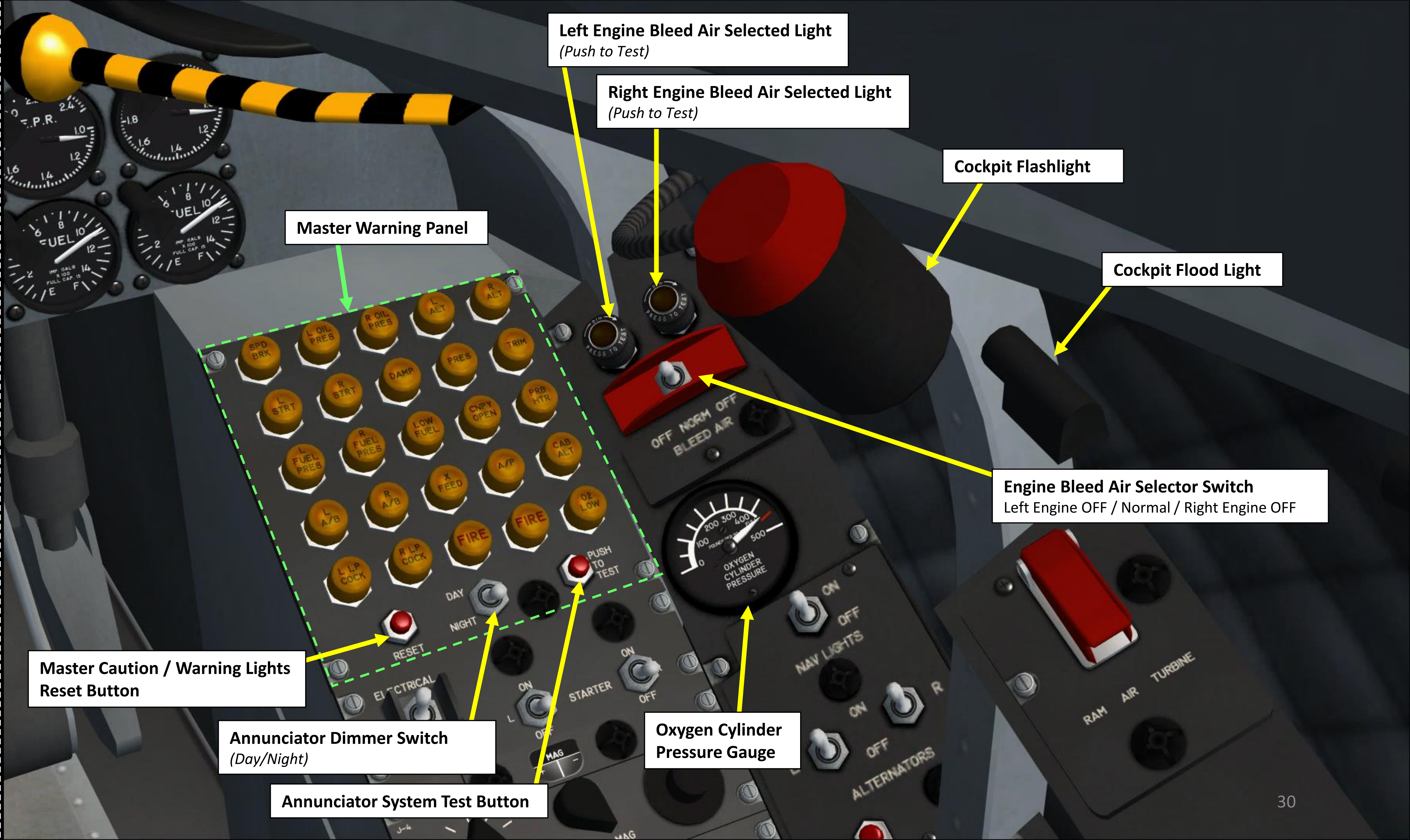
Autopilot Pitch Control

NOTE: *During taxiing and take-off, the amount of air supplied to the cockpits is reduced. When the landing gear is raised after take-off, a micro-switch is actuated which fully opens the cockpit air shut-off valve and allows full air supply to the cabin.*


High/Low Altitude Cabin Lighting Selector Switch
Main Panel Lighting Rheostat
Console Lighting Rheostat
Console Flood Lights Rheostat


Radio Compass Drift Indicator Window
Radio Compass Latitude Selected (N = North / S = South)
Radio Compass Latitude Selector
Radio Compass Slave Selector (DG = Directional Gyro / MAG = Magnetic Compass)
ADF Loop Rotation Knob
ADF Frequency Band Selector
J4 Gyrosyn Radio Compass Control Panel
Radio Compass Receiver Operation Mode Selector Switch
OFF: Unpowered
ADF: Automatic Direction Finder
ANT: Antenna Mode (communications receiver only)
LOOP: Obtains bearing manually via loop drive control
CONT: Control (switches control between crew members)
Radio Compass Drift Adjustment Knob
ADF Voice Selector Switch
CW (Continuous Wave) / Voice
ADF Frequency Tuning Crank
ADF Frequency Display
VHF NAV Radio Power Switch
AN/ARN-6 ADF Receiver Control Panel
VHF NAV Radio Volume Tuner
ADF Radio Volume Tuner
VHF NAV Radio Receiver Panel (108.0-117.95 MHz)
Note: The simulated version of the Arrow has a modernized VHF NAV homer that tracks modern VOR (VHF Omnidirectional Range) beacons. The 1958 Pilot Operating Instructions Handbook suggests that the Arrow had a UHF Receiver Homer instead.
VHF NAV Frequency Indicator (shown: 113.8 MHz)
VHF NAV Frequency Tuner (Wheel + Lever)


Navigation Lights Switch
RAT (Ram Air Turbine) Switch
Lift safety guard and set switch by scrolling mousewheel.
Left/Right Engine Alternator Switches
DC Reset Switch
If the DC L or R FAIL warning light illuminates alone or in conjunction with the BATT USE warning light, either or both TRU's (Transformer-Rectifier Unit) may be reset and faults cleared with this button.
Electrical Master Switch
Left/Right Engine Starter Switches


Left Engine Bleed Air Selected Light
(Push to Test)
Right Engine Bleed Air Selected Light
(Push to Test)
Cockpit Flashlight
Cockpit Flood Light
Master Warning Panel
Engine Bleed Air Selector Switch
Left Engine OFF / Normal / Right Engine OFF
Master Caution / Warning Lights Reset Button
Annunciator Dimmer Switch
(Day/Night)
Annunciator System Test Button
Oxygen Cylinder Pressure Gauge

Master Warning Panel

When the Master Warning or Master Caution lights are illuminated, this means you should monitor the Master Warning Panel to identify the warning or caution. You can then reset the lights using the RESET button.

SPD BRK Speed brakes deployed	**L OIL PRES** Left engine oil pressure low	**R OIL PRES** Right engine oil pressure low	**L ALT** Left Alternator OFF	**R ALT** Right Alternator OFF
L STRT Left engine starter engaged	**R STRT** Right engine starter engaged	**DAMP** Damping system is OFF	**PRES** Cabin Pressurization is OFF	**TRIM** Pitch Trim Out of Takeoff Range
L FUEL PRES Left Fuel Pressure is Low	**R FUEL PRES** Right Fuel Pressure is Low	**LOW FUEL** Fuel Quantity is Low in Left or Right Collector Tank	**CNPY OPEN** Canopy is unsafe or Open	**PRB HTR** Probe Heater is OFF
L A/B Left Afterburner is ON	**R A/B** Right Afterburner is ON	**X FEED** Crossfeed Valve Open	**A/P** Autopilot is ON	**CAB ALT** Cabin Altitude greater than 20000 ft
L LP COCK Left Firewall Fuel Shutoff Valve (low-pressure cock) is Closed	**R LP COCK** Right Firewall Fuel Shutoff Valve (low-pressure cock) is Closed	**FIRE** Left Engine Fire is Detected	**FIRE** Right Engine Fire is Detected	**O2 LOW** Oxygen Quantity is lower than 20 %

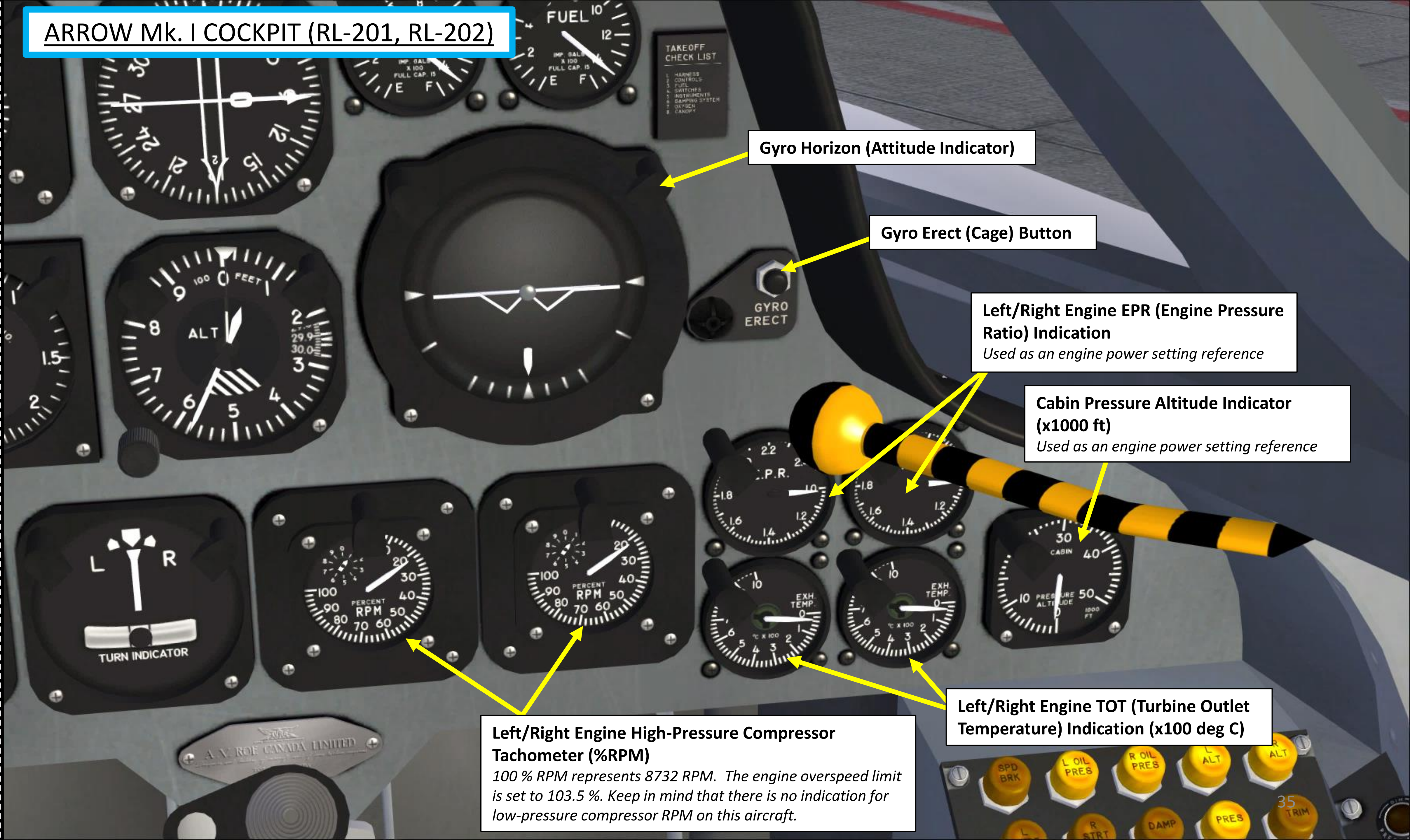
Note: descriptions are for when lights are illuminated.


Canopy Manual Operation Lever
Canopy Emergency Release Lever

ARROW Mk. I COCKPIT (RL-201, RL-202)

ARROW Mk. I COCKPIT (RL-201, RL-202)

ARROW Mk. I COCKPIT (RL-201, RL-202)



Gyro Horizon (Attitude Indicator)

Gyro Erect (Cage) Button

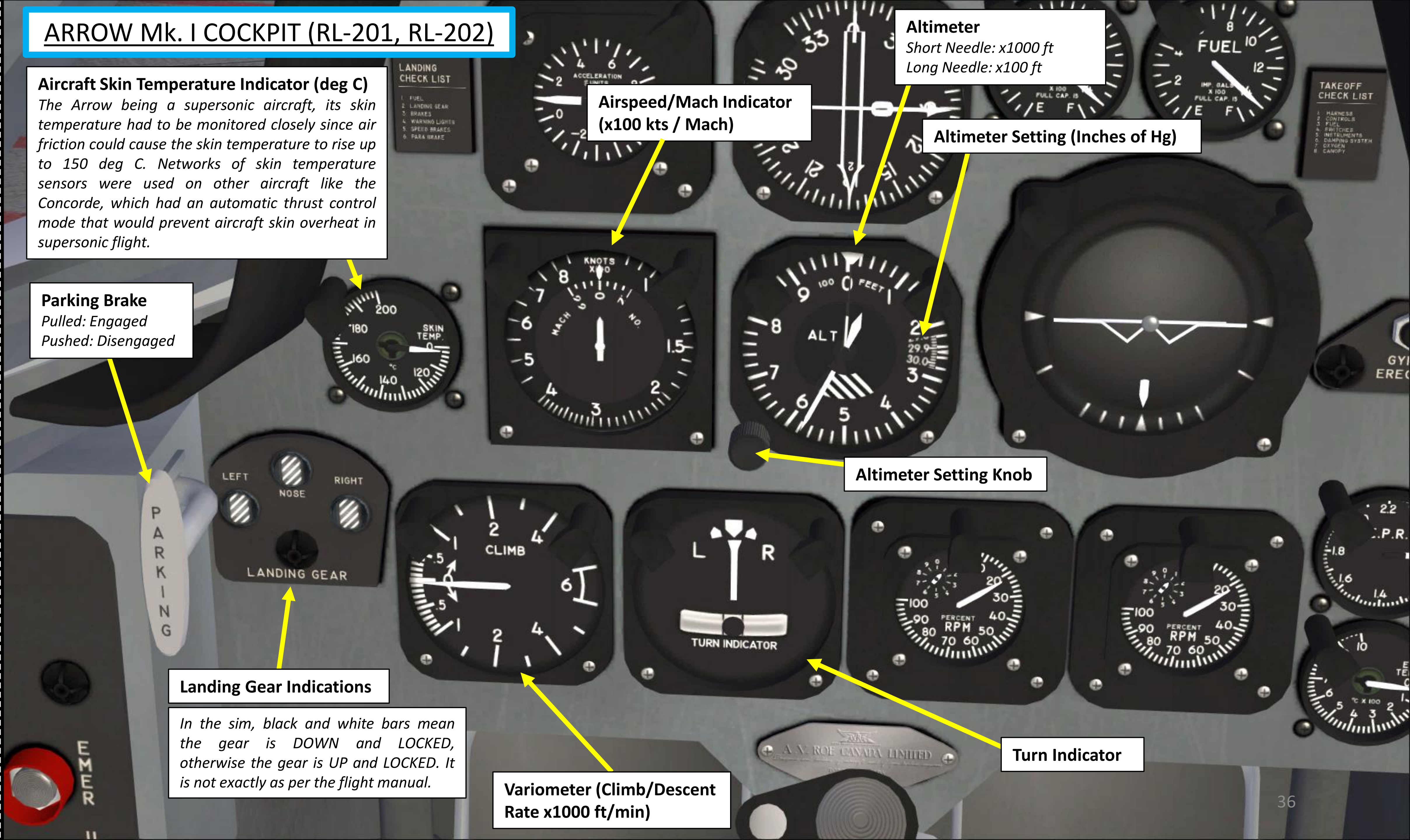
Left/Right Engine EPR (Engine Pressure Ratio) Indication
Used as an engine power setting reference

Cabin Pressure Altitude Indicator (x1000 ft)
Used as an engine power setting reference

Left/Right Engine TOT (Turbine Outlet Temperature) Indication (x100 deg C)

Left/Right Engine High-Pressure Compressor Tachometer (%RPM)
100 % RPM represents 8732 RPM. The engine overspeed limit is set to 103.5 %. Keep in mind that there is no indication for low-pressure compressor RPM on this aircraft.

ARROW Mk. I COCKPIT (RL-201, RL-202)



Aircraft Skin Temperature Indicator (deg C)

The Arrow being a supersonic aircraft, its skin temperature had to be monitored closely since air friction could cause the skin temperature to rise up to 150 deg C. Networks of skin temperature sensors were used on other aircraft like the Concorde, which had an automatic thrust control mode that would prevent aircraft skin overheat in supersonic flight.

Parking Brake

Pulled: Engaged

Pushed: Disengaged

Airspeed/Mach Indicator (x100 kts / Mach)

Altimeter

Short Needle: x1000 ft

Long Needle: x100 ft

Altimeter Setting (Inches of Hg)

Altimeter Setting Knob

Landing Gear Indications

In the sim, black and white bars mean the gear is DOWN and LOCKED, otherwise the gear is UP and LOCKED. It is not exactly as per the flight manual.

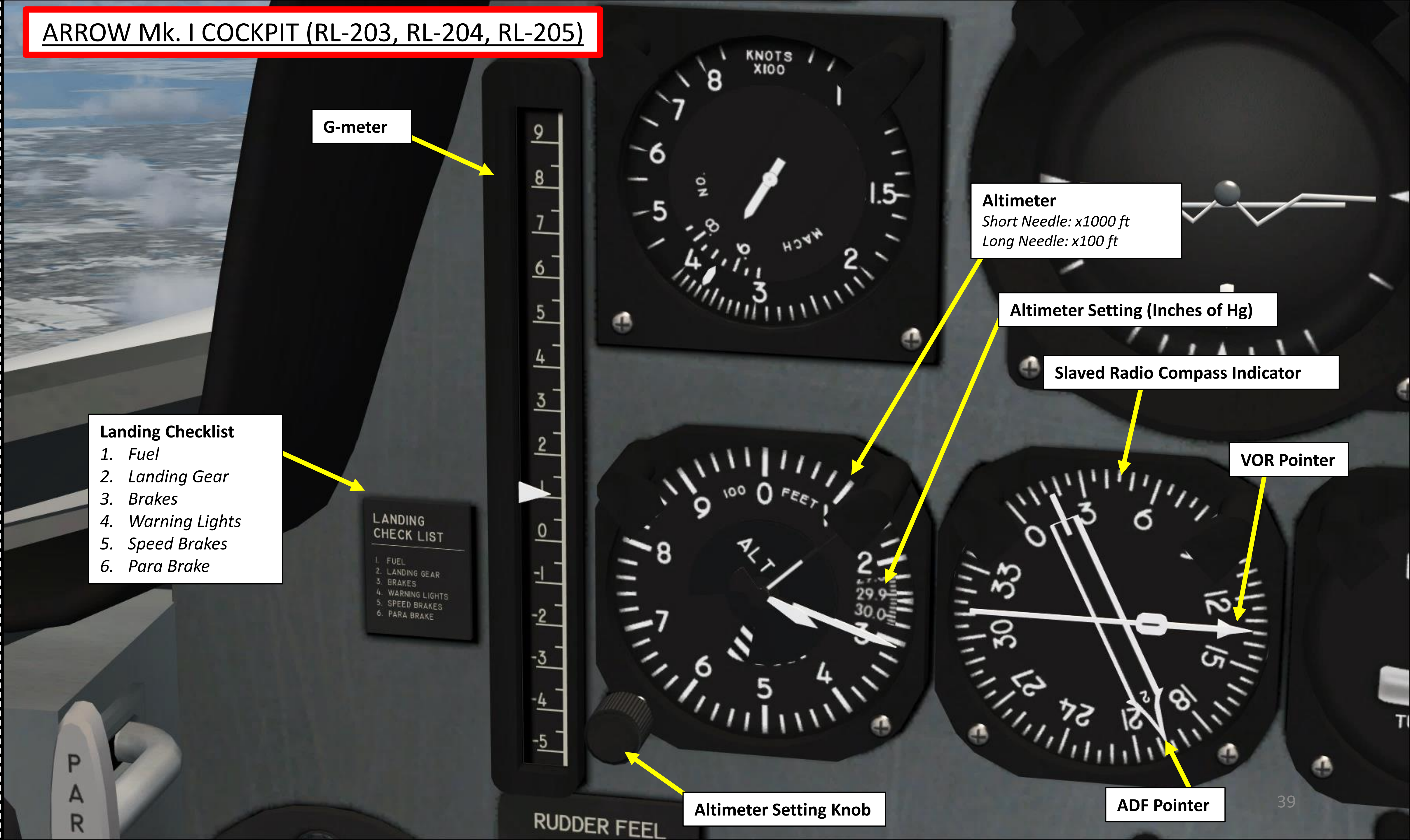
Variometer (Climb/Descent Rate x1000 ft/min)

Turn Indicator

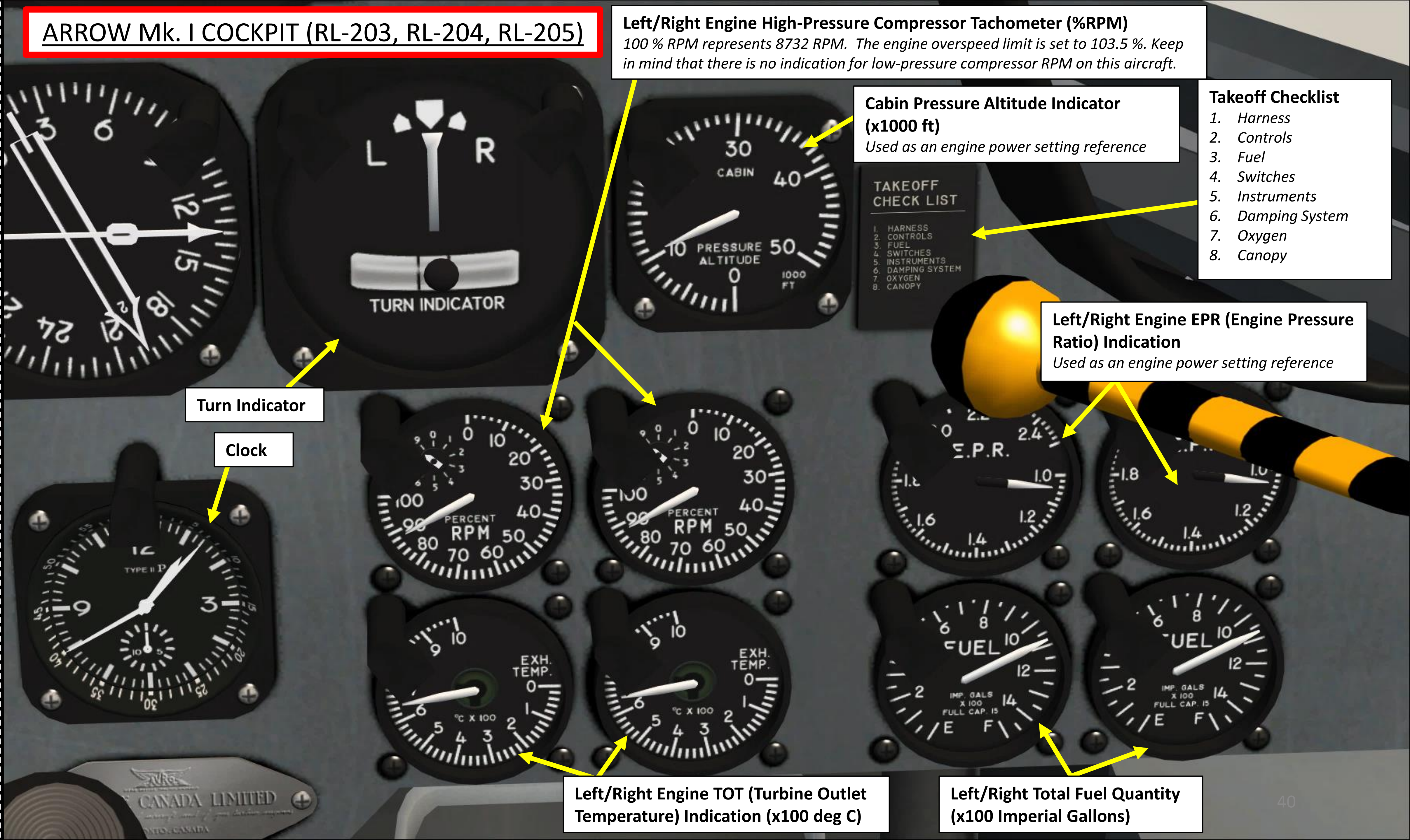
ARROW Mk. I COCKPIT (RL-203, RL-204, RL-205)

ARROW Mk. I COCKPIT (RL-203, RL-204, RL-205)

ARROW Mk. I COCKPIT (RL-203, RL-204, RL-205)



ARROW Mk. I COCKPIT (RL-203, RL-204, RL-205)



Left/Right Engine High-Pressure Compressor Tachometer (%RPM)
100 % RPM represents 8732 RPM. The engine overspeed limit is set to 103.5 %. Keep in mind that there is no indication for low-pressure compressor RPM on this aircraft.

Cabin Pressure Altitude Indicator (x1000 ft)
Used as an engine power setting reference

Takeoff Checklist
1. *Harness*
2. *Controls*
3. *Fuel*
4. *Switches*
5. *Instruments*
6. *Damping System*
7. *Oxygen*
8. *Canopy*

Left/Right Engine EPR (Engine Pressure Ratio) Indication
Used as an engine power setting reference

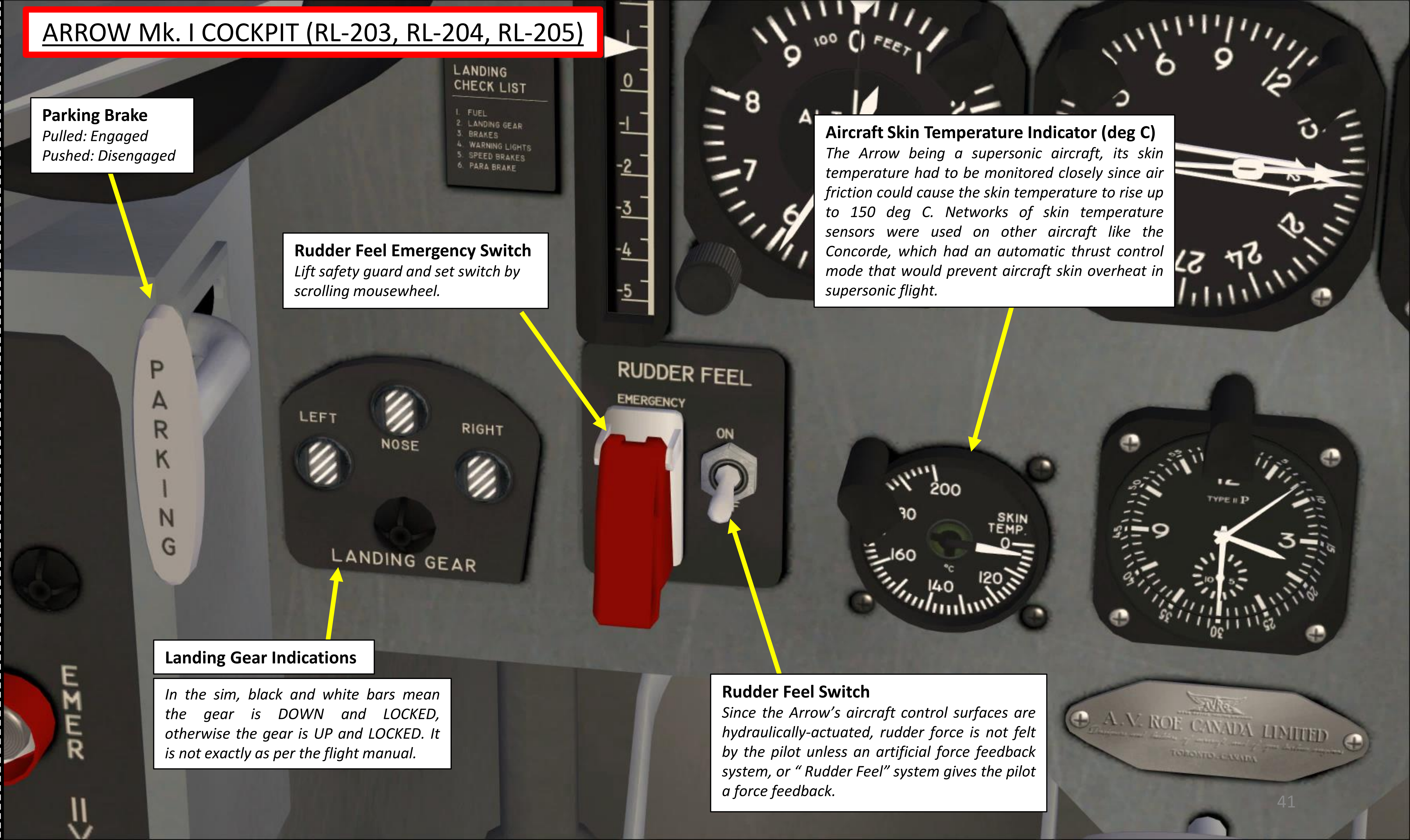
Turn Indicator

Clock

Left/Right Engine TOT (Turbine Outlet Temperature) Indication (x100 deg C)

Left/Right Total Fuel Quantity (x100 Imperial Gallons)

ARROW Mk. I COCKPIT (RL-203, RL-204, RL-205)



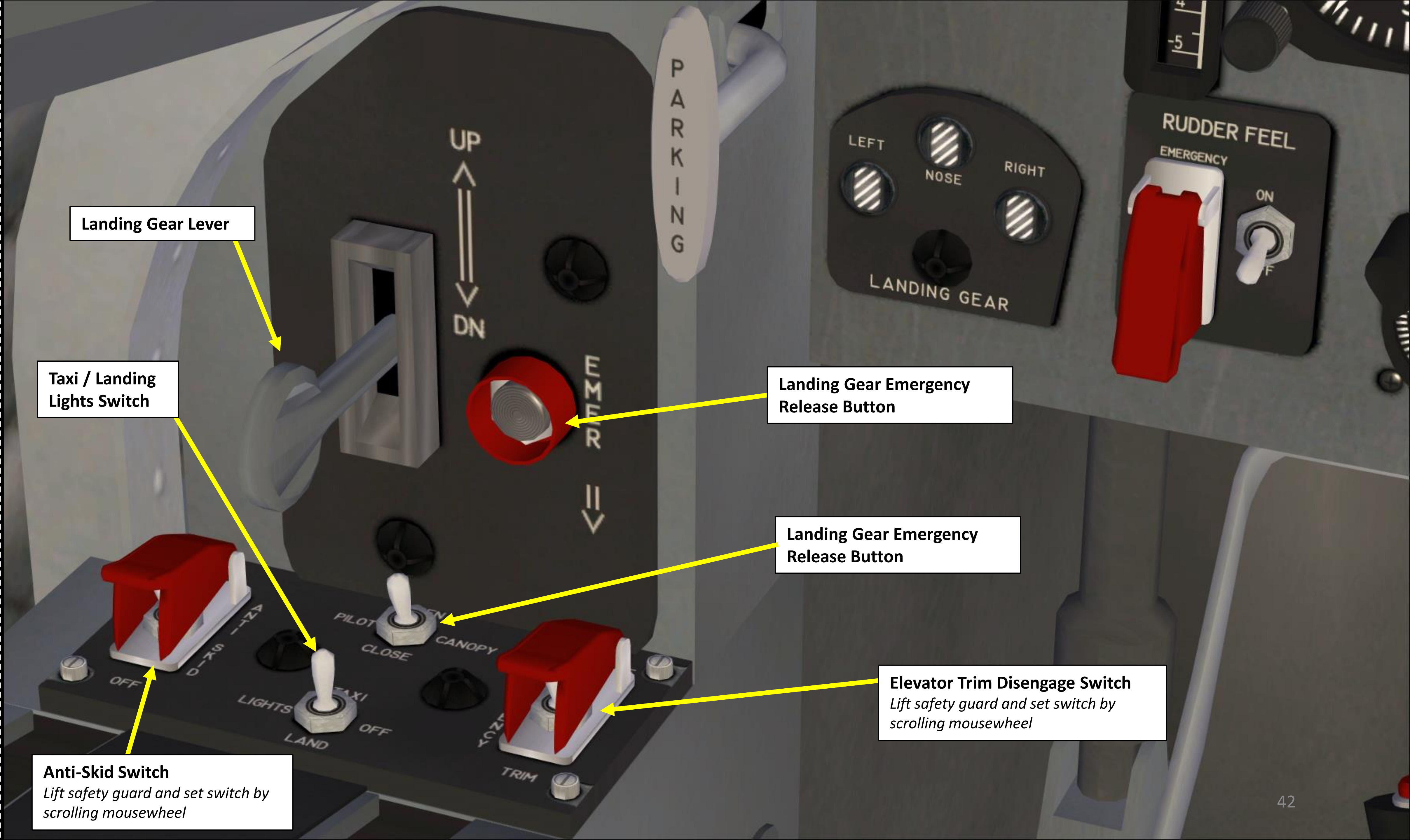
Parking Brake
Pulled: Engaged
Pushed: Disengaged

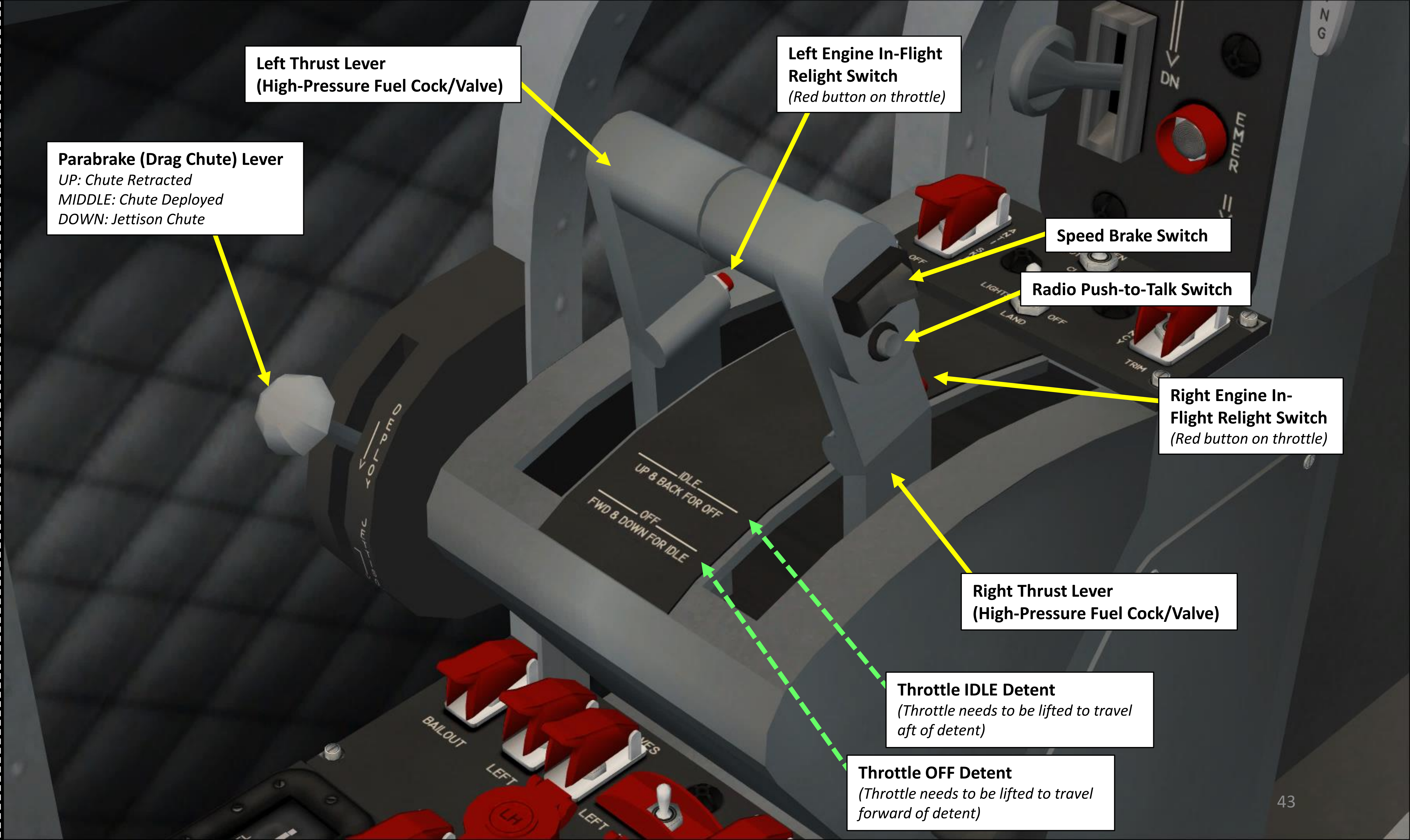
Rudder Feel Emergency Switch
Lift safety guard and set switch by scrolling mousewheel.

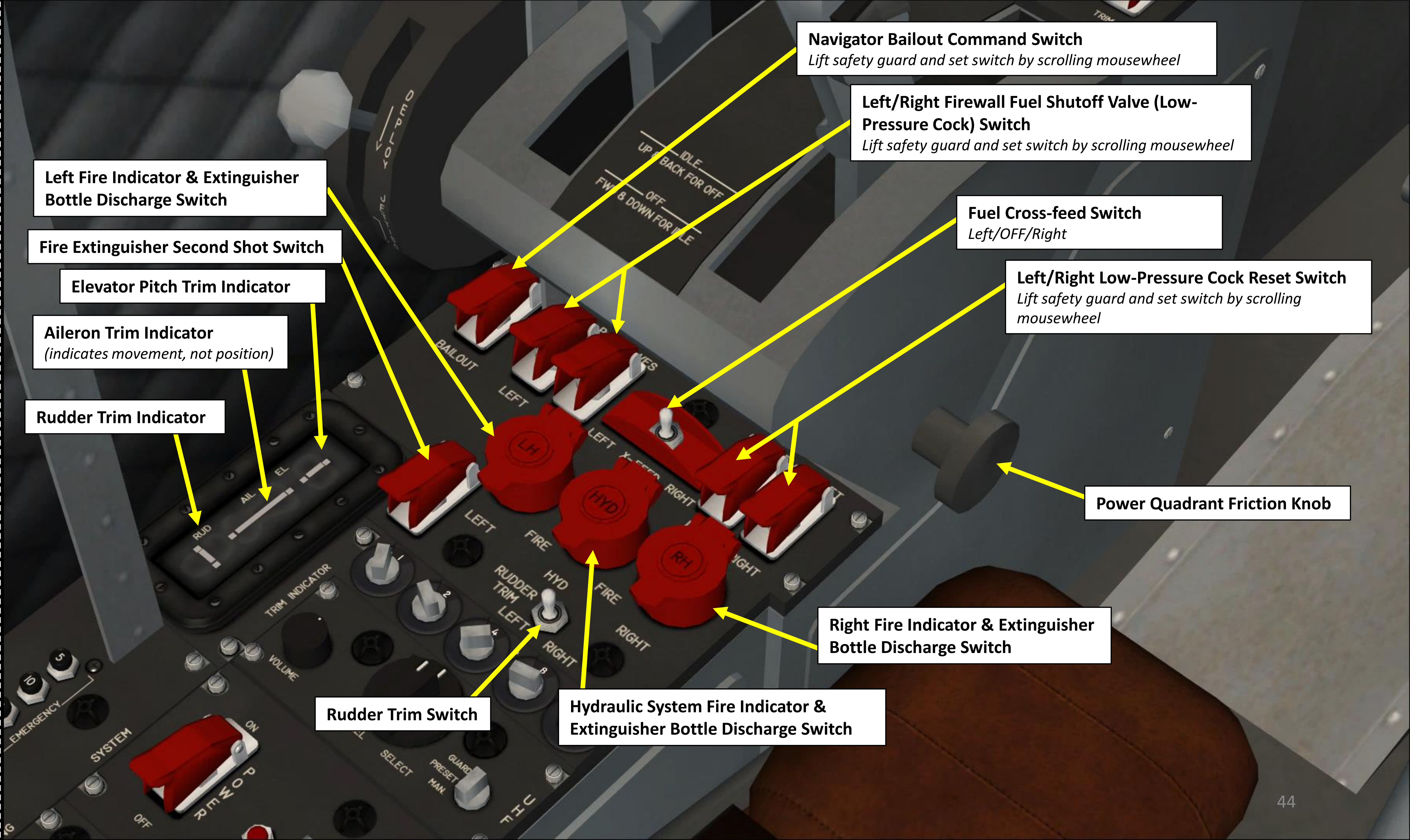
Aircraft Skin Temperature Indicator (deg C)
The Arrow being a supersonic aircraft, its skin temperature had to be monitored closely since air friction could cause the skin temperature to rise up to 150 deg C. Networks of skin temperature sensors were used on other aircraft like the Concorde, which had an automatic thrust control mode that would prevent aircraft skin overheat in supersonic flight.

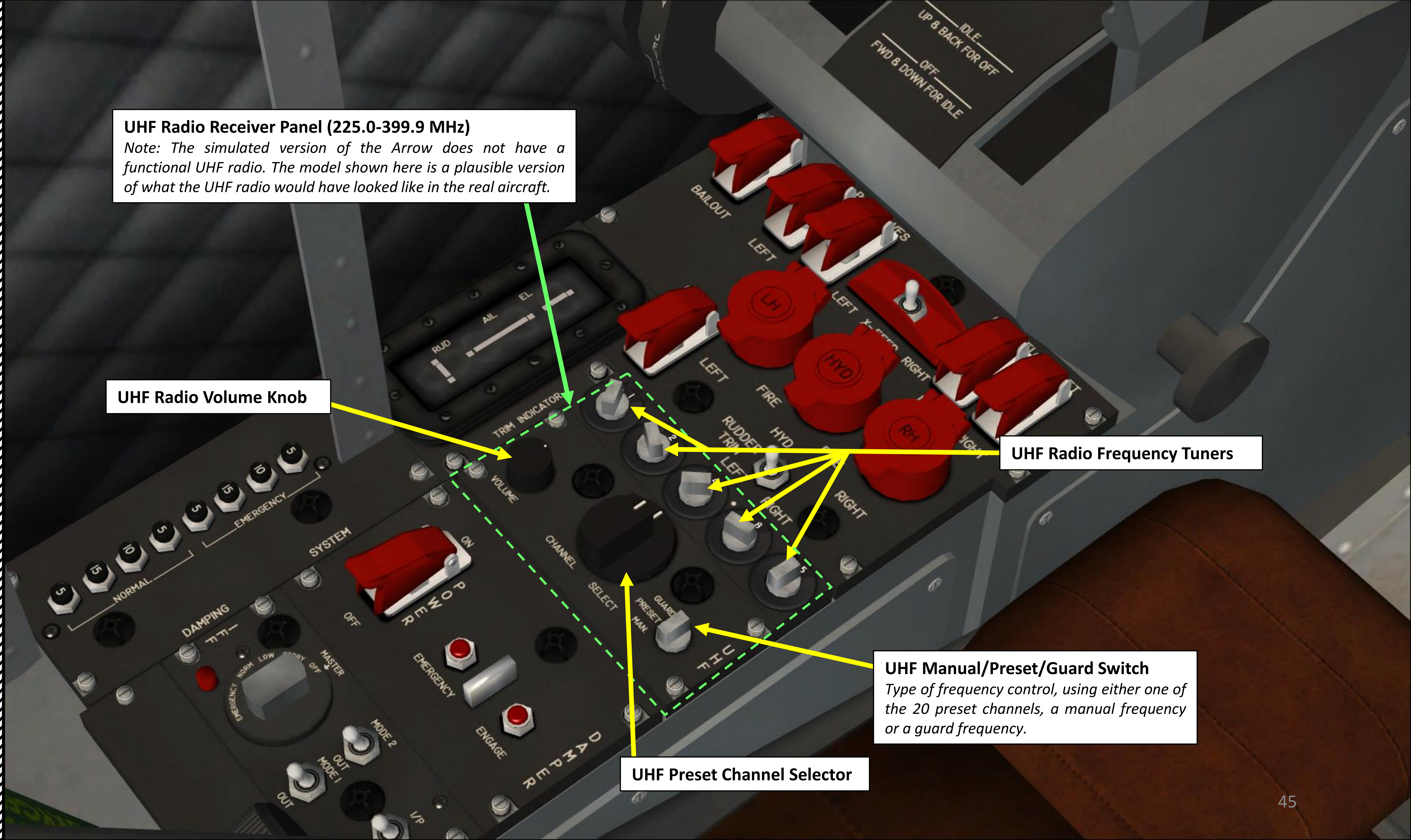
Landing Gear Indications
In the sim, black and white bars mean the gear is DOWN and LOCKED, otherwise the gear is UP and LOCKED. It is not exactly as per the flight manual.

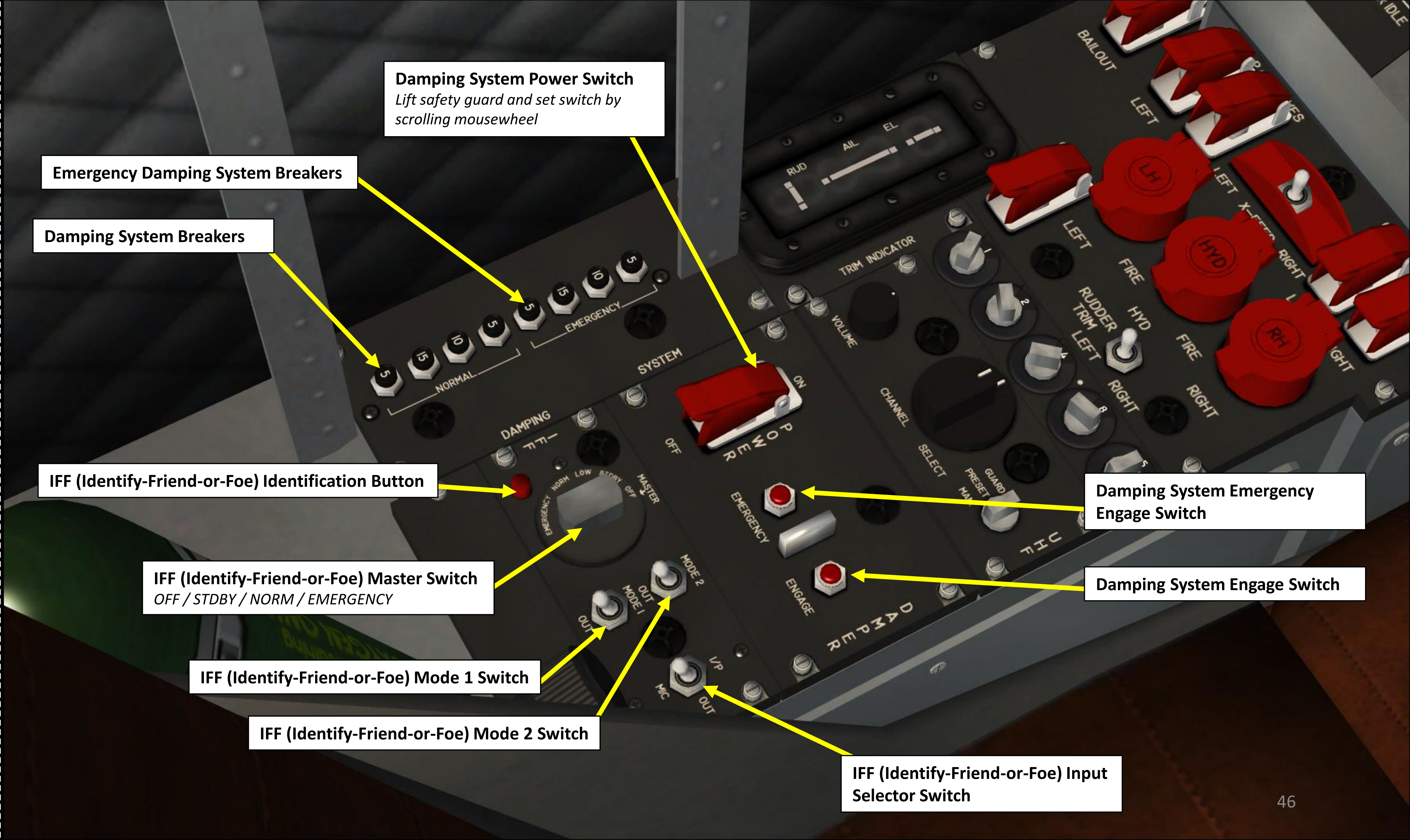
Rudder Feel Switch
Since the Arrow's aircraft control surfaces are hydraulically-actuated, rudder force is not felt by the pilot unless an artificial force feedback system, or " Rudder Feel" system gives the pilot a force feedback.

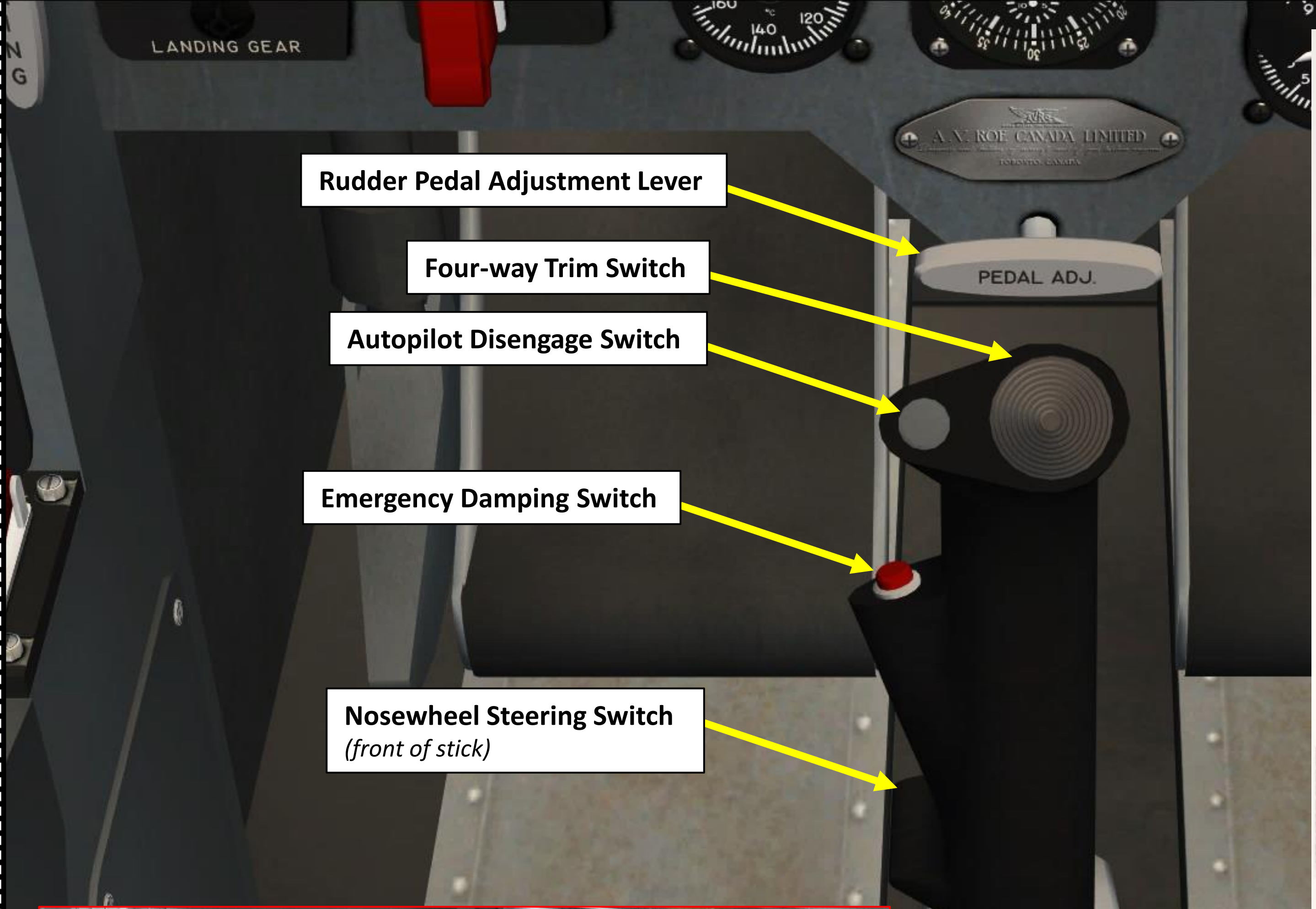

Landing Gear Lever
Taxi / Landing Lights Switch
Landing Gear Emergency Release Button
Landing Gear Emergency Release Button
Elevator Trim Disengage Switch
Lift safety guard and set switch by scrolling mousewheel
Anti-Skid Switch
Lift safety guard and set switch by scrolling mousewheel
PARKING
UP
DN
EMER
LEFT
NOSE
RIGHT
LANDING GEAR
RUDDER FEEL
EMERGENCY
ON
PILOT
CLOSE
CANOPY
LIGHTS
LAND
OFF
OFF
TRIM

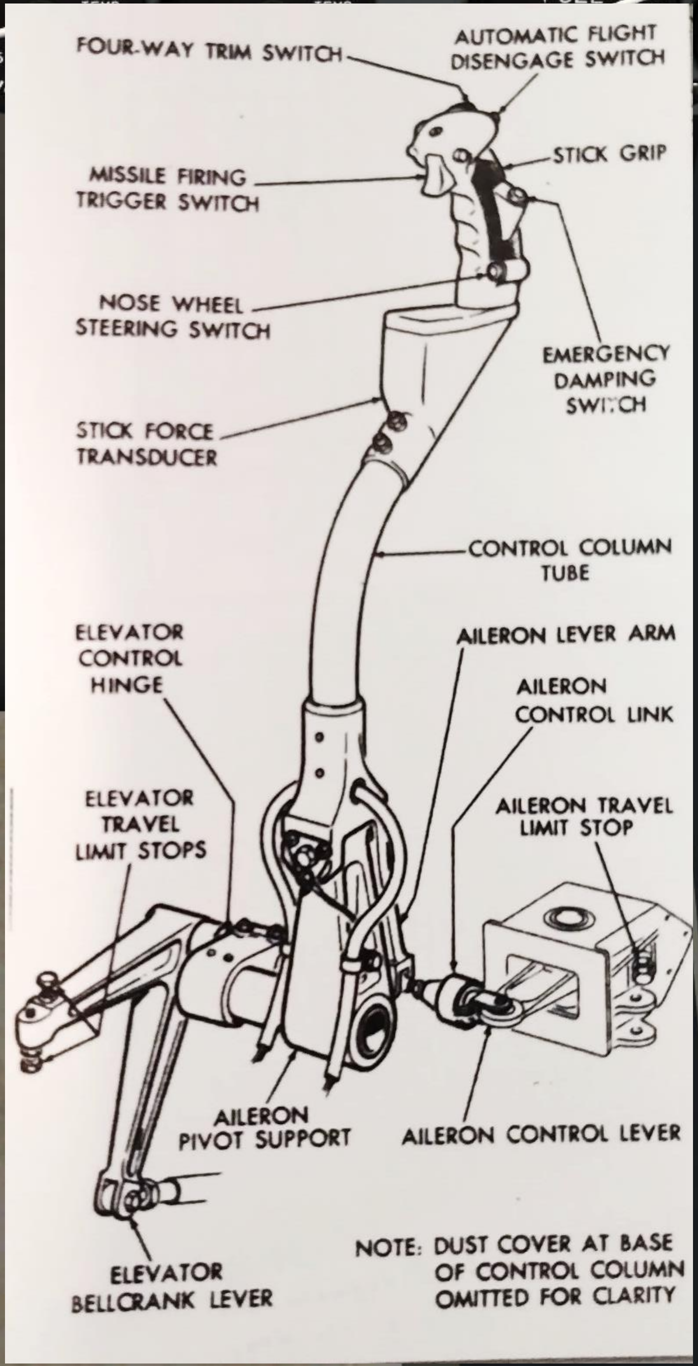

Left Thrust Lever (High-Pressure Fuel Cock/Valve)
Left Engine In-Flight Relight Switch *(Red button on throttle)*
Parabrake (Drag Chute) Lever
UP: Chute Retracted
MIDDLE: Chute Deployed
DOWN: Jettison Chute
Speed Brake Switch
Radio Push-to-Talk Switch
Right Engine In-Flight Relight Switch *(Red button on throttle)*
Right Thrust Lever (High-Pressure Fuel Cock/Valve)
Throttle IDLE Detent *(Throttle needs to be lifted to travel aft of detent)*
Throttle OFF Detent *(Throttle needs to be lifted to travel forward of detent)*
DEPLOY
IDLE
UP & BACK FOR OFF
OFF
FWD & DOWN FOR IDLE
DN
EMER
OFF
LIGHTS
LAND
OFF
TRIM
BAILOUT
LEFT
LEFT
LH


Navigator Bailout Command Switch
Lift safety guard and set switch by scrolling mousewheel
Left/Right Firewall Fuel Shutoff Valve (Low-Pressure Cock) Switch
Lift safety guard and set switch by scrolling mousewheel
Fuel Cross-feed Switch
Left/OFF/Right
Left/Right Low-Pressure Cock Reset Switch
Lift safety guard and set switch by scrolling mousewheel
Left Fire Indicator & Extinguisher Bottle Discharge Switch
Fire Extinguisher Second Shot Switch
Elevator Pitch Trim Indicator
Aileron Trim Indicator
(indicates movement, not position)
Rudder Trim Indicator
Power Quadrant Friction Knob
Right Fire Indicator & Extinguisher Bottle Discharge Switch
Rudder Trim Switch
Hydraulic System Fire Indicator & Extinguisher Bottle Discharge Switch

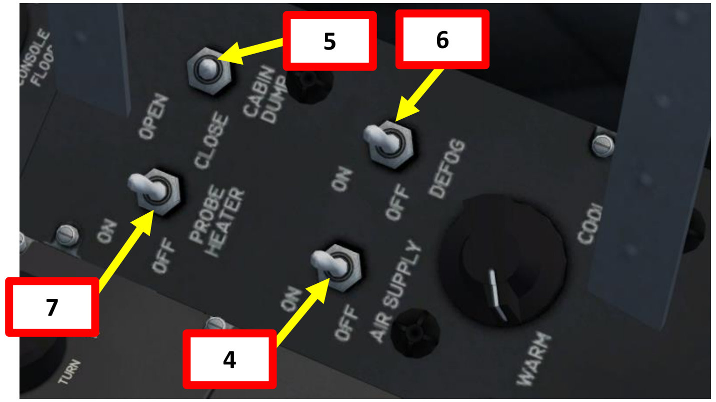

UHF Radio Receiver Panel (225.0-399.9 MHz)
Note: The simulated version of the Arrow does not have a functional UHF radio. The model shown here is a plausible version of what the UHF radio would have looked like in the real aircraft.
UHF Radio Volume Knob
UHF Radio Frequency Tuners
UHF Manual/Preset/Guard Switch
Type of frequency control, using either one of the 20 preset channels, a manual frequency or a guard frequency.
UHF Preset Channel Selector


Damping System Power Switch
Lift safety guard and set switch by scrolling mousewheel
Emergency Damping System Breakers
Damping System Breakers
IFF (Identify-Friend-or-Foe) Identification Button
IFF (Identify-Friend-or-Foe) Master Switch
OFF / STDBY / NORM / EMERGENCY
IFF (Identify-Friend-or-Foe) Mode 1 Switch
IFF (Identify-Friend-or-Foe) Mode 2 Switch
Damping System Emergency Engage Switch
Damping System Engage Switch
IFF (Identify-Friend-or-Foe) Input Selector Switch
NORMAL
EMERGENCY
DAMPING
SYSTEM
POWER
ON
OFF
TRIM INDICATOR
RUD
AIL
EL
VOLUME
CHANNEL
SELECT
UHF
EMERGENCY
ENGAGE
DAMPER
MASTER
MODE 2
MODE 1
BAILOUT
LEFT
FIRE
HYD
RIGHT
LH
RH
RUDDER TRIM


LANDING GEAR
PEDAL ADJ.
Rudder Pedal Adjustment Lever
Four-way Trim Switch
Autopilot Disengage Switch
Emergency Damping Switch
Nosewheel Steering Switch
(front of stick)
SPD BRK
L STRT
L FUEL PRES
L A/B
L LP COCK
RESET
ELECTRICAL
MASTER
SET
DECR

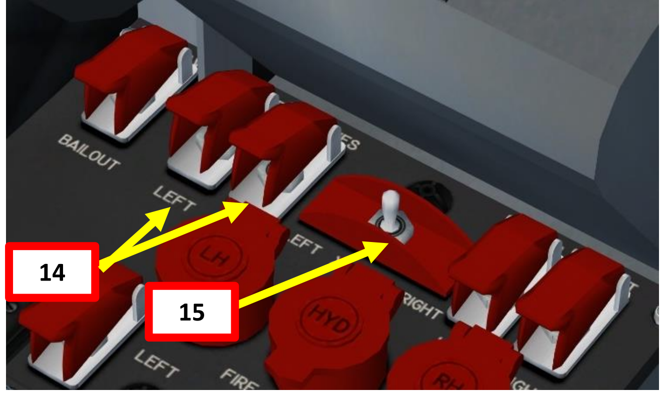

FOUR-WAY TRIM SWITCH
AUTOMATIC FLIGHT DISENGAGE SWITCH
STICK GRIP
MISSILE FIRING TRIGGER SWITCH
NOSE WHEEL STEERING SWITCH
EMERGENCY DAMPING SWITCH
STICK FORCE TRANSDUCER
CONTROL COLUMN TUBE
ELEVATOR CONTROL HINGE
AILERON LEVER ARM
AILERON CONTROL LINK
ELEVATOR TRAVEL LIMIT STOPS
AILERON TRAVEL LIMIT STOP
AILERON PIVOT SUPPORT
AILERON CONTROL LEVER
ELEVATOR BELLCRANK LEVER
NOTE: DUST COVER AT BASE OF CONTROL COLUMN OMITTED FOR CLARITY

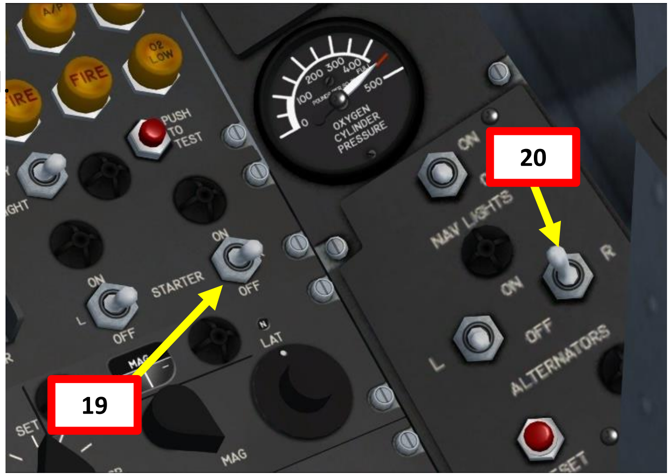
1. Signal the ground crew to plug the ground starter cart and the external AC power supply into the aircraft receptacles (not simulated)
2. Set Master Electrics Switch – ON
3. Set J4 Compass MAG-DG Switch – MAG
4. Set Air Supply switch – NORM
5. Set Cabin PRESS/DUMP switch – CLOSE (PRESS)
6. Set Defog switch – As required (ON)
7. Set Probe Heater switch – ON
8. Set Damper Power Switch – ON (Scroll mousewheel)
9. Set Canopy Switch – CLOSE

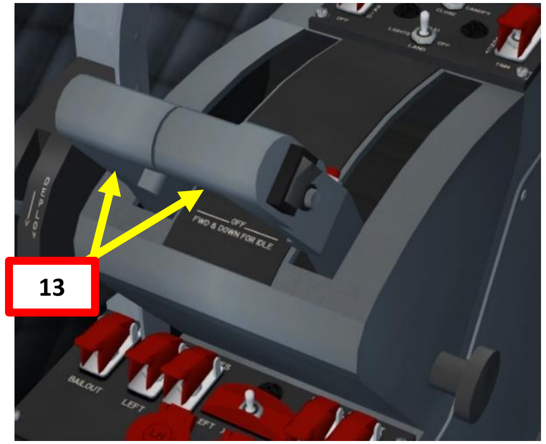


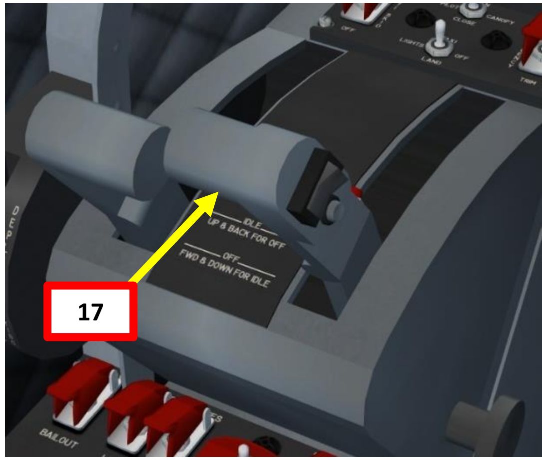
10. Begin Pushback by holding SHIFT and P to initiate pushback. Once you have enough room to steer the aircraft away from the gate, hold SHIFT and P a second time to stop the push.

11. Hold Brake Pedals and set Parking Brake – ENGAGED (PULLED)
12. Typically, the pilot will start the Right engine first in order to check functioning of the right-hand pumps on the flying control and utility systems.
13. Set throttle levers to Cut-Off Position (AFT)
14. Set left & right Low-Pressure Fuel Cock – ON (scroll mousewheel)
15. Set Crossfeed Switch - NORMAL
16. Set right starter switch – ON (FWD)
17. Set right throttle to IDLE position (left click) when RPM reaches approx. 10 % RPM
18. Engine RPM should accelerate to approx. 55 % (flight manual source). Verify that TOT (Turbine Outlet Temperature) does not exceed 600 deg C. Verify that no R OIL PRES caution is illuminated. *Note: In the sim, you get something closer to 65 % RPM.*
19. Once engine is stabilized, set right starter switch – OFF
20. Set right engine alternator switch – ON

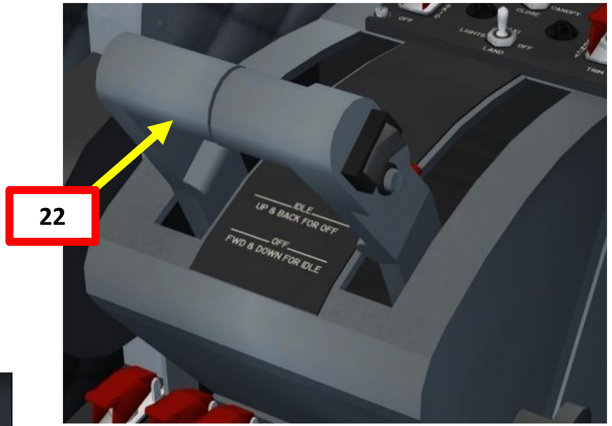


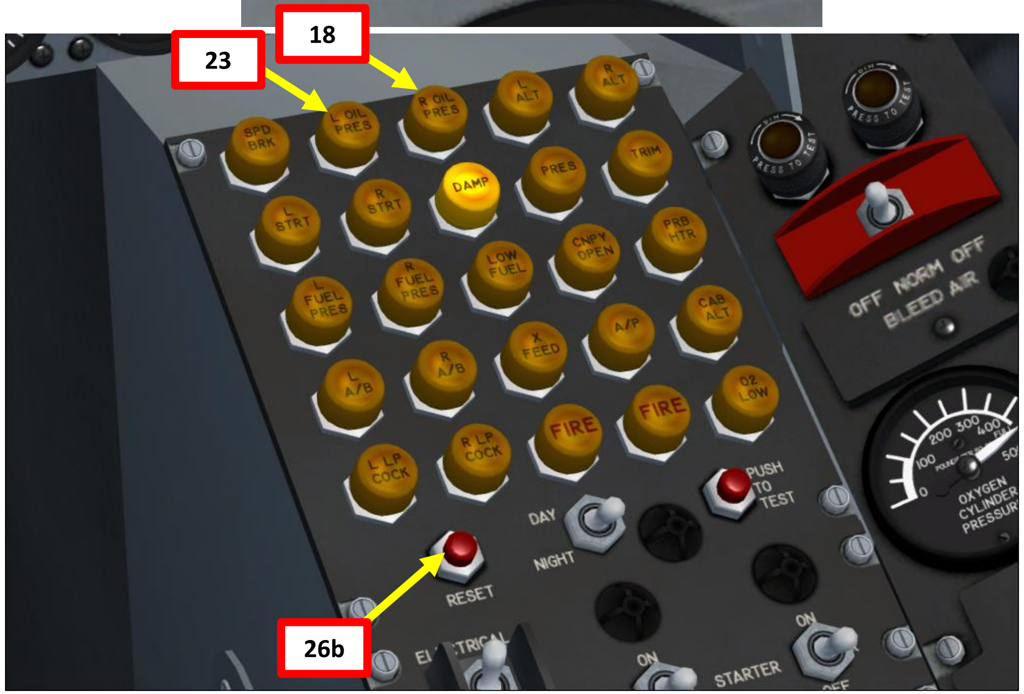






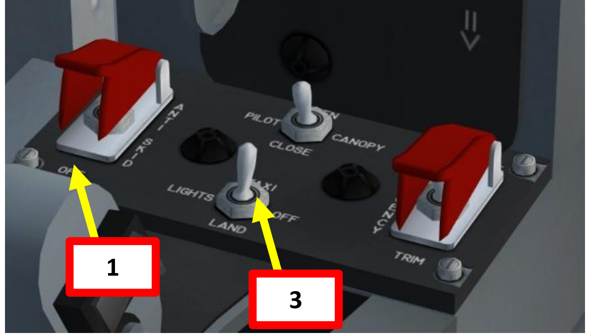
21. Set left starter switch – ON (FWD)
22. Set left throttle to IDLE position (left click) when RPM reaches approx. 10 % RPM
23. Engine RPM should accelerate to approx. 55 % (flight manual source). Verify that TOT (Turbine Outlet Temperature) does not exceed 600 deg C. Verify that no L OIL PRES caution is illuminated. *Note: In the sim, you get something closer to 65 % RPM.*
24. Once engine is stabilized, set left starter switch – OFF
25. Set left engine alternator switch – ON
26. Reset the Master Warning and Master Caution lights by pressing the RESET button on the annunciator panel.

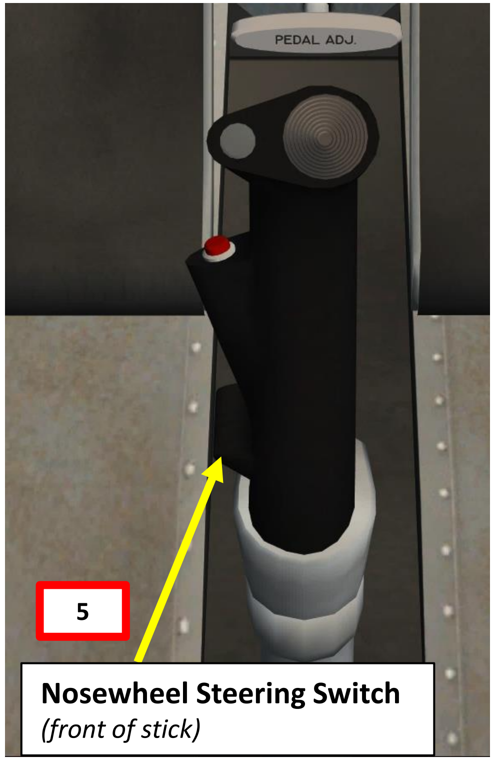




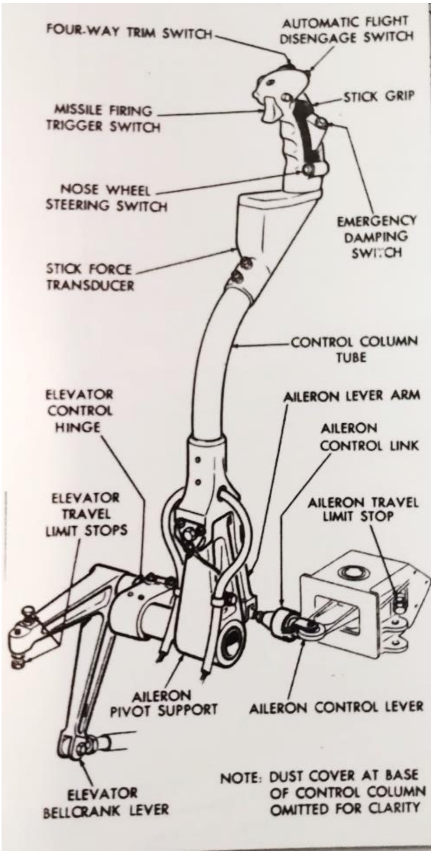
TAXI

1. Set Anti-Skid switch – ON (scroll mousewheel)
2. Set Rudder Feel Switch – ON
3. Set Taxi/Landing Light switch – TAXI (FWD, scroll mousewheel)
4. Release parking brake (pushed) and throttle up to reach a taxi speed of 25-50 mph.
5. Hold the Nosewheel Steering switch on the stick and use your rudder pedals to perform a tight turn (automatically done in FSX when you use rudder pedals). The nose wheels are steered with the rudder pedals, which are mechanically linked to a steering control valve. The steering angle was approximately +/- 55 deg, which permitted a 180-degree- turn to be made on about a 6.4 m (21 ft) radius.





Nosewheel Steering Switch
(front of stick)

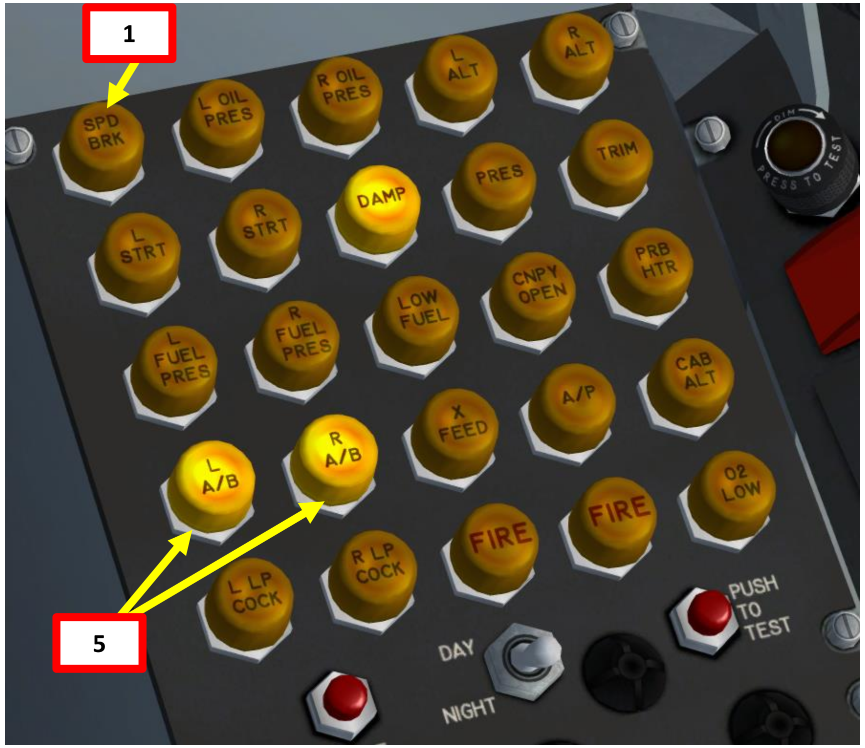


TAXI

TAKEOFF

TAKEOFF

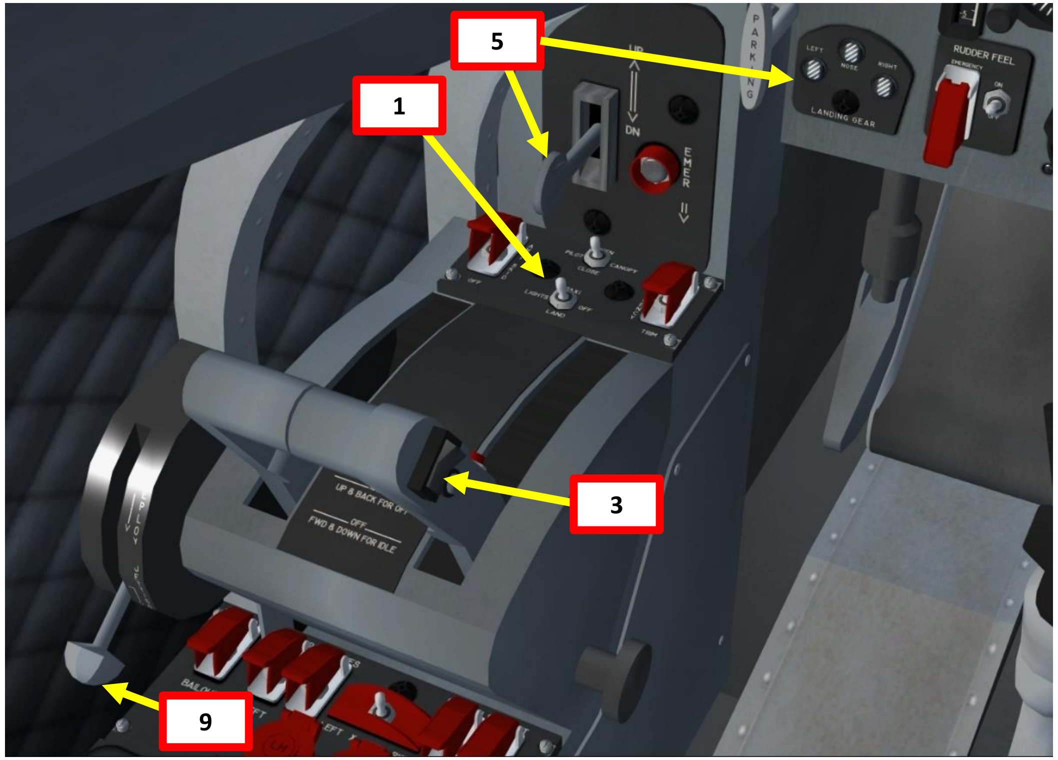
1. Confirm that your speed brakes are retracted (SPD BRK caution is extinguished)
2. When lined up on the runway, hold brakes and advance throttles smoothly to 75 % RPM
3. Check that TOT (EGT) does not exceed 900 deg C
4. Advance throttle levers fully forward
5. Confirm that L A/B and R A/B afterburner cautions illuminate
6. Release brakes and start rolling
7. Rotate at 150 kts
8. Confirm positive climb and raise landing gears before reaching 250 kts
9. Accelerate until climb speed is between 300 and 350 kts
10. Throttle back to disengage afterburners (until the L A/B and R A/B afterburner cautions are extinguished)
11. Set Taxi/Landing Light switch – OFF (scroll mousewheel)

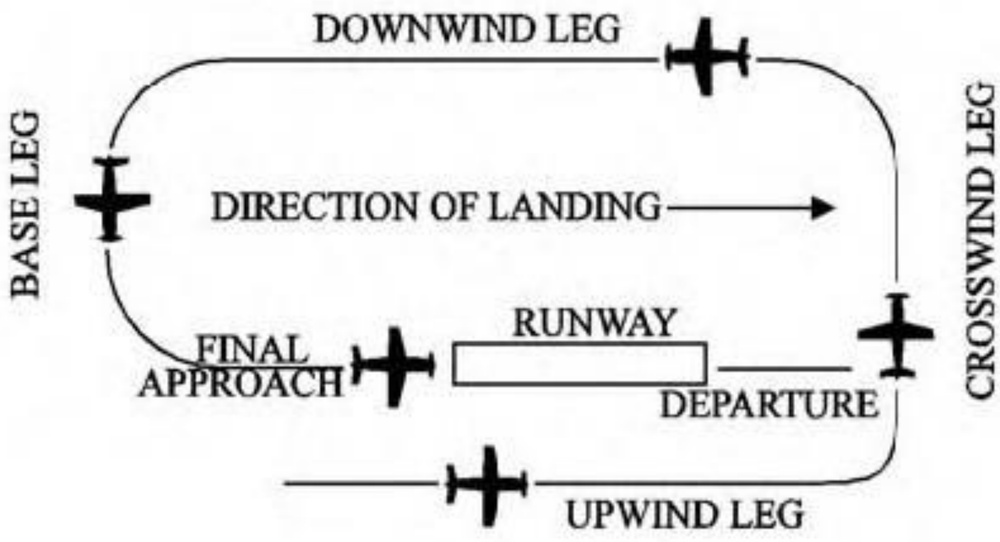


TAKEOFF

LANDING

1. Set Landing/Taxi Lights switch – LANDING (scroll mousewheel)
2. Enter downwind leg at 250 kts or slower
3. Speed brakes – as needed
4. Turn base leg at 200 kts or slower
5. Set landing gear lever – DOWN & LOCKED
6. Fly final leg at approx. 180 kts
7. Ajust thrust levers for a rate of descent of approx. 1000 ft/min
8. Touchdown at 160 kts
9. Set Parabrake Lever down to deploy drag chute (not simulated)
10. Release Parabrake (not simulated)





LANDING

LIMITATIONS

MAXIMUM PERMISSIBLE SPEEDS	
Maximum Design Speed	700 kts EAS or Mach 2.0 (Lowest limit to apply)
Extending or Retracting Landing Gear	250 kts EAS
Extending Speed Brakes	No Limit
Parabrake Selection	185 kts EAS (All wheels in ground contact)
Cross-wind component	30 kts

Note 1: The highest Mach number is a theoretical value. The Arrow has not been tested to go beyond these airspeeds.
Note 2: EAS means Equivalent Airspeed, which is calibrated airspeed (CAS) corrected for the compressibility of air at a non-trivial Mach number.

G Limits *Derived from graphs in CF-105 Flight Manual*	
Weight: 47000 lbs	+7 G / -3 G (Structural Limit)
Weight: 69000 lbs	+5 G / -2 G (Manoeuvre Limit)

CREW EJECTION	
Maximum Speed	No structural limit
Minimum Speed	80 kts at ground level

ANGLE OF ATTACK	
Maximum Indicated Angle	15 deg (in level flight), 0.5 deg less for each incremental G imposed

WEIGHTS	
Maximum Takeoff	69000 lbs (approx.)
Maximum Landing	65000 lbs (approx.)

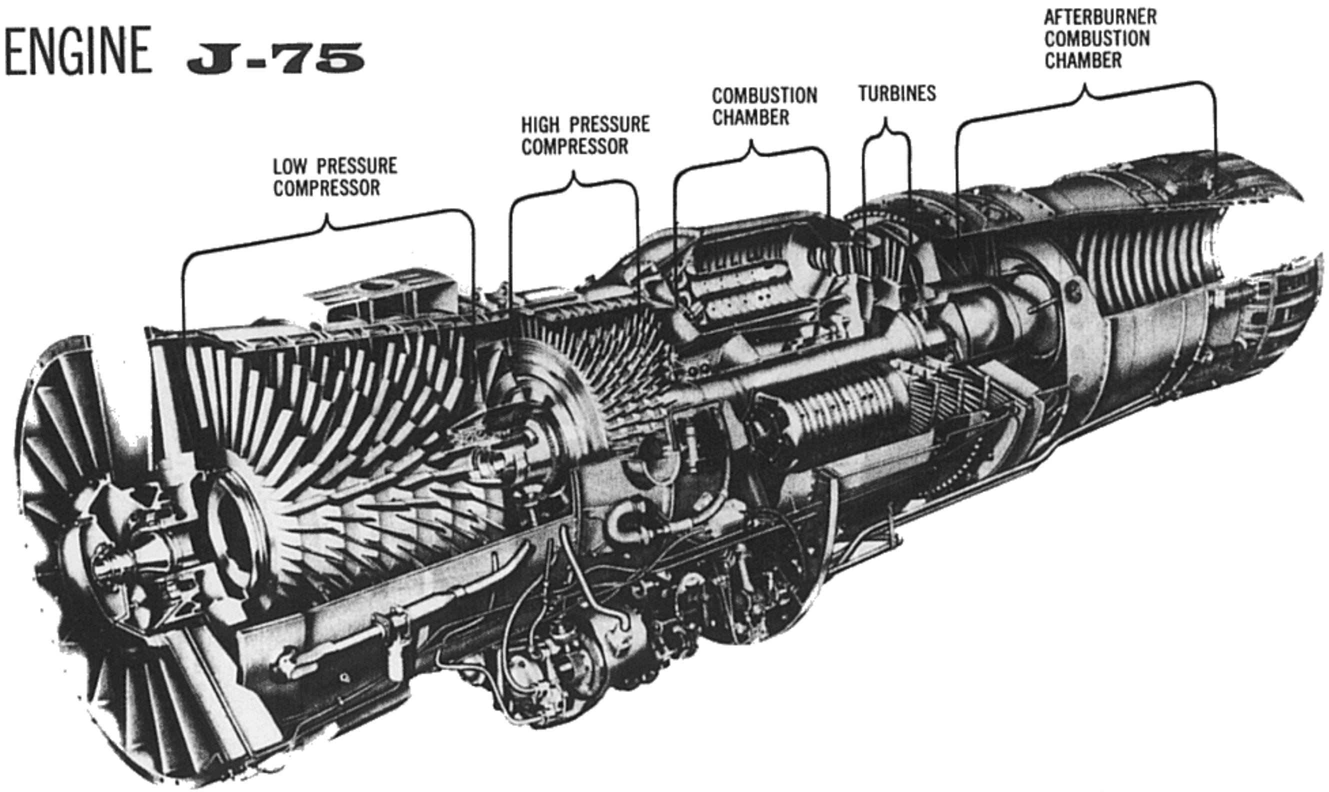
MACH LIMITATIONS VS ALTITUDE	
10000 ft	0.8 Mach
20000 ft	0.9 Mach
30000 ft	1.0 Mach
45000+ ft	2.3 Mach

THE PRATT & WHITNEY J75-P-5

The Rolls-Royce RB.106 was the original choice for the Arrow engine, but the design was abandoned in the UK early in 1954. The Curtiss-Wright J67 was then selected as a replacement. The J67 was also rumoured to be abandoned by the USAF, which forced Avro's hand in choosing an interim engine: the J75.

It was installed on the first five prototypes of the Arrow: RL-201 to RL-205.

JT4A (installed on DC-8)



In military use, the Pratt & Whitney J75 (known in civilian service as a JT4A) was used on the Convair F-106 Delta Dart Lockheed U-2, and Republic F-105 Thunderchief. It was also utilized in experimental aircraft like the Lockheed A-12, Martin P6M SeaMaster, North American YF-107, and Vought XF8U-3 Crusader III. This engine was selected as an "interim engine" for the initial test-flight models until the new Orenda engines' development was finished.

The J75 is an axial-flow twin-spool turbojet engine. The Arrow Mark I was equipped with it and both engines produced a thrust of 23500 lbf (105 kN) each in full afterburner. The low-pressure compressor had 8 stages, and the high-pressure compressor 7 stages. The turbine had a single high-pressure stage and 2 low-pressure stages. The cannular combustors had 8 burner cans in an annular combustion chamber.

THE PRATT & WHITNEY J75-P-5

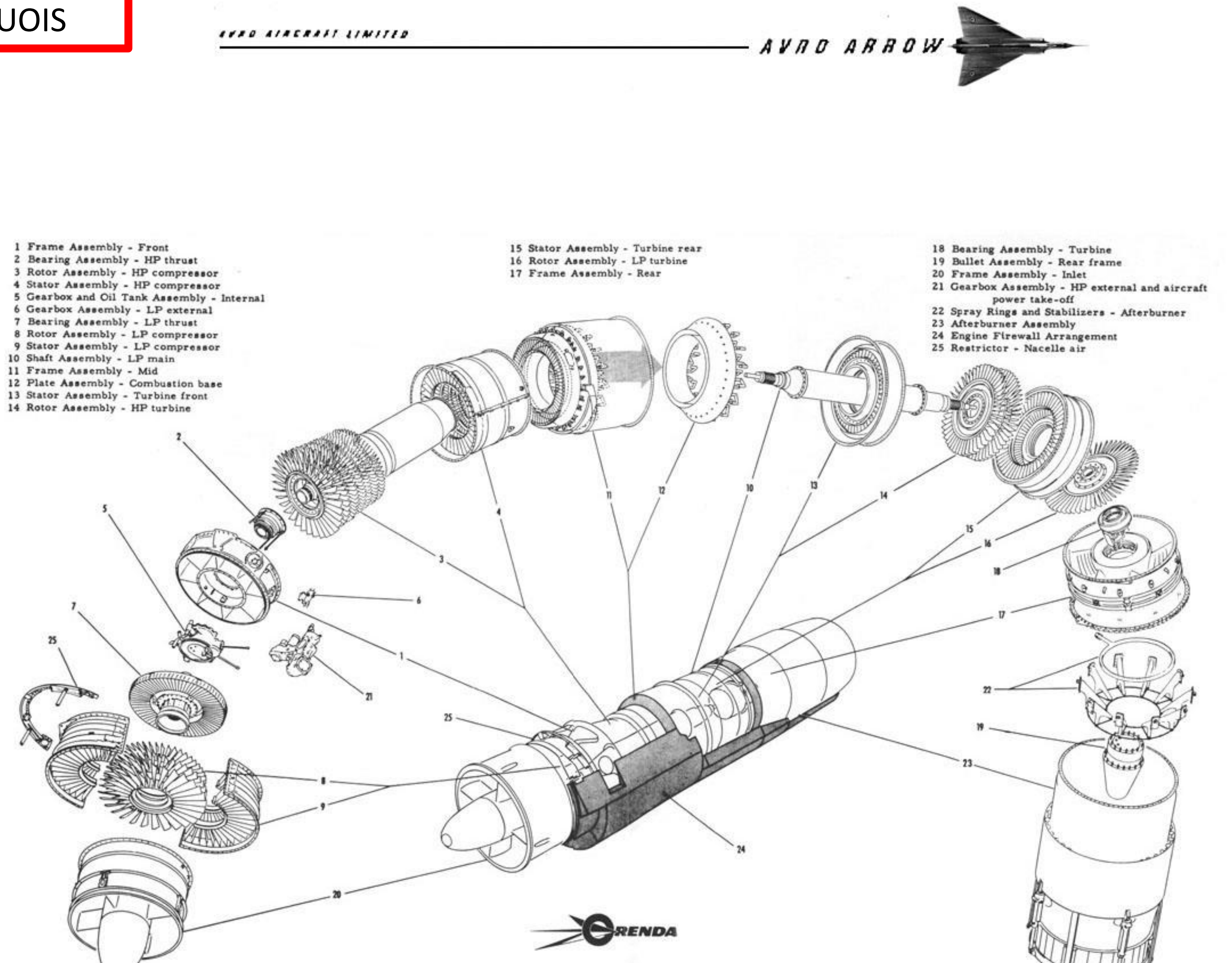
J75-P-5 ENGINE LIMITATIONS

CONDITION	MAXIMUM OBSERVED TURBINE DISCHARGE (TEMP DEG C)	TIME LIMIT (MINUTES)
MAXIMUM (with afterburner)	610	15
MILITARY	610	30
NORMAL RATED	540	UNRESTRICTED
CRUISE:		
90 % NORMAL RATED	540 (max) – 500 (normal)	UNRESTRICTED
80 % NORMAL RATED	540 (max) – 460 (normal)	UNRESTRICTED
70 % NORMAL RATED	540 (max) – 410 (normal)	UNRESTRICTED
IDLE	340	UNRESTRICTED
STARTING	600	MOMENTARY
TRANSIENT	625	1

THE ORENDA PS-13S IROQUOIS

Avro Canada had started, through its subsidiary Orenda Company, to design a new turbojet engine, known as the Orenda TR-13, financing the development from its own funds. It was *the* engine that Avro wanted for its Arrow; the J75 was merely a way to ensure that the aircraft could be tested quickly enough to make sure it flew right. The Arrow Mk. II preproduction and all production aircraft would be fitted with the Orenda engine, now designated as the PS-13 (and later named the Iroquois).

The ***Iroquois*** engine was intended to provide high performance at supersonic speeds. On 13 January 1954, an "instruction to proceed" was received from the Department of Defence Production and, on 17 December 1954, the prototype Iroquois made its initial run. By July 1958, the engine had completed over 5,000 hours of bench running in test cells at Malton and in flight tests; some 2,000 hours of additional testing had been completed by the time the Iroquois was cancelled and the turbojet had already been installed in a CF-105 Mk II in preparation for flight testing. The planned program cost for the development, tooling, prototype and pre-production engines was set at just under 117 million CAD.



Iroquois general assembly

THE ORENDA PS-13S IROQUOIS

The story of the Iroquois is just as long, hectic and complicated as the Arrow's. I highly recommend that you read on it; it's a fascinating subject.

The Iroquois was a twin-spool, axial-flow turbojet with an afterburner capable of generating 25,600 lbf (114 kN) of thrust per engine. It had a 10-stage split axial flow compressor, a single high-pressure stage turbine, a two-stage low-pressure turbine and an annular combustion chamber with a thrust-to-weight ratio of 6.45:1.

In contrast to the Arrow, with its complex systems and high number of parts, the Iroquois was based from the beginning on both simplicity and light weight. Orenda pioneered new territory in the use of titanium. Twenty per cent by weight of the completed Iroquois consisted of titanium. The earlier Orenda turbojets, which then powered Canadair Sabres and Avro CF-100s, also had more parts while producing less power. In addition to the testing of the Iroquois in cells at Malton, further altitude testing was carried out at the NACA Lewis Flight Propulsion Laboratory wind-tunnel at Cleveland, and the NACA wind-tunnel at Tullahoma. The Cleveland tests revealed the engine's successful operation under sustained high inlet temperatures, an ability to make normal relights up to 18,290 m (60,000 ft), which was the limit of the tunnel, and recorded the highest dry thrusts measured to that time in North America for a turbojet.

The innovations for the Iroquois were substantial:

- Its thrust-to-weight ratio was considerably higher than its contemporaries
- Its oxygen-injection relight system was a design first
- First variable stator blades on a twin-shaft engine
- First use of a transonic first-stage compressor
- First "hot streak" afterburner ignition system
- First fully variable afterburner rather than the standard "on/off" system
- First bleed-bypass system for both intake and exhaust
- First bypass engine design, albeit with a very low bypass ratio

Orenda Iroquois Engine – Exposed in the Canada Aviation Museum in Ottawa

Iroquois being Fitted on RL-206: the only Mk II Arrow ever built

Source: Canada Aviation & Space Museum Aircraft – Avro Canada CF-105 Arrow (T.F.J. Leversedge)
https://documents.techno-science.ca/documents/CASM-Aircrafthistories-AvroCanadaCF-105Arrownose.pdf

THE ORENDA PS-13S IROQUOIS

The Iroquois was installed on RL-206, the only Mark II Arrow ever built. However, it never got to fly since the program was cancelled. The Iroquois did however get tested in flight: it was installed on a Boeing B-47 Stratojet and flew for 35 hours. Canadair, the sub-contractor, attached an Iroquois to the right side of the bomber's rear fuselage, near the tail, simply because there was no other place to mount it. Designated CL-52 by Canadair, it was a nightmare to fly, since the thrust was asymmetrical; this created great problems for flight control.

In 1956 Boeing B-47 Stratojet 51-2059 was lent to the RCAF for trials at Canadair with the Orenda Iroquois engine, the aircraft being redesignated CL-52. The engine was mounted on the starboard rear fuselage and tested, although its position was far from ideal. After some 35hr of Iroquois test-flying the B-47 was returned to the USA, becoming the only example of the type to see foreign service.

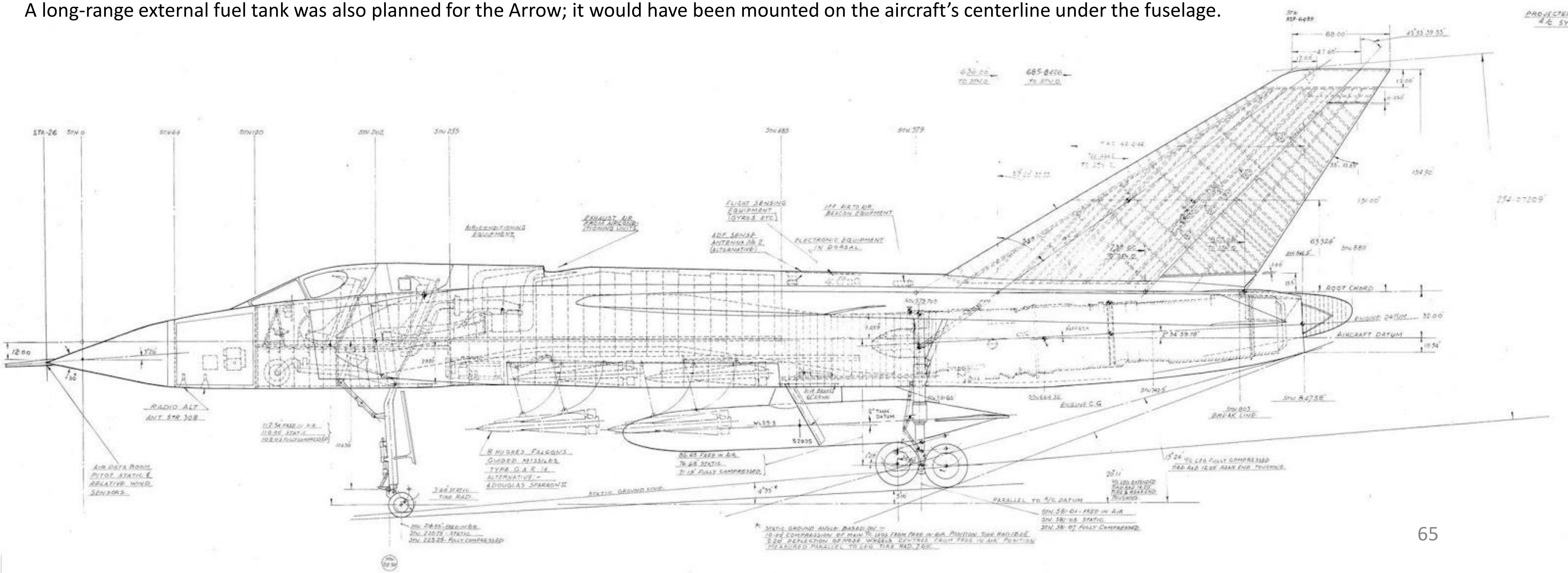
MIKE HOOKS COLLECTION

FUEL SYSTEM

Fuel is carried in two bladder type tanks in the fuselage and six tanks in each wing. The forward fuselage tank and the six wing tanks in the wing normally feed the right engine, while the aft fuselage tank and the six wing tanks in the left wing normally feed the left engine. The only interconnection between the sub-system is the crossfeed. One of the wing tanks in each sub-system functions as a collector tank. Each sub-system supplies fuel to its respective engine by means of a collector tank booster pump driven by a shaft from that engine. Each booster pump has sufficient capacity to supply the maximum fuel demand of its own engine and afterburner, or to supply the demand of both engines with partial afterburning fuel passes from the booster pump to an oil-to-fuel heat exchanger and a low pressure fuel cock before entering the engine compartment.

Fuel is supplied from the fuselage tanks and wing tanks to the respective sub-system fuel flow proportioner by tank pressurization. An electric transfer pump at each fuselage tank outlet increases the delivery pressure from these tanks to equalize the difference in pressurization between the fuselage and wing tanks, so that fuel from all the tanks flows into the proportioner at 19 psia.

A long-range external fuel tank was also planned for the Arrow; it would have been mounted on the aircraft's centerline under the fuselage.



FUEL SYSTEM

Source: CF-105 Arrow Mk. I – Pilot's Operating Instructions Handbook, April 1958 (K.A.R. Reproduction)

The fuel flow proportioner **meters fuel** from the tributary tanks to ensure that all tanks empty in the same elapsed time. Fuel flows from the proportioner by a single pipe into the sub-system collector tank. Fuel is then delivered from its sub-system collector tank by a booster pump, shaft-driven from the engine accessories gearbox of the engine on that side. From the collector tank, the fuel passes through a heat exchanger. Downstream of the heat exchanger, the two sub-systems are interconnected by a crossfeed valve, which is controlled by a switch in the pilot's cockpit and remains closed under normal conditions. A low pressure cock is fitted between the heat exchanger and each engine.

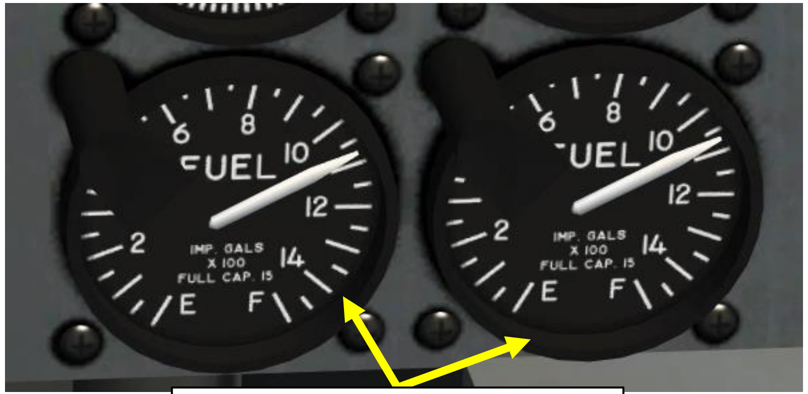
All fuel tanks are **pressurized** by engine bleed air taken from the air conditioning system downstream of the ram air heat exchanger. The purpose of this is to achieve fuel transfer and to prevent fuel boiling. To prevent over-pressurization through failure of air regulator, an air pressure relief valve is fitted in the air system to the wing tanks. This valve is also used as a means of venting pressure from the tanks during ground pressure refuelling. There is a similar valve fitted for the fuselage tanks and it performs the same functions as the wing tank valve and, in addition, prevents over-pressurization during rapid climbs by releasing air to limit the differential between tank pressure and atmospheric pressure.

I highly recommend that you read the "CF-105 Arrow Mk. I – Pilot's Operating Instructions Handbook, April 1958 (K.A.R. Reproduction) " for more details on systems. There are lots of relevant drawings and cool bits of information on the fuel system.

Left/Right Firewall Fuel Shutoff Valve (Low-Pressure Cock) Switch
Lift safety guard and set switch by scrolling mousewheel

Fuel Cross-feed Switch
Left/OFF/Right

Left/Right Low-Pressure Cock Reset Switch
Lift safety guard and set switch by scrolling mousewheel

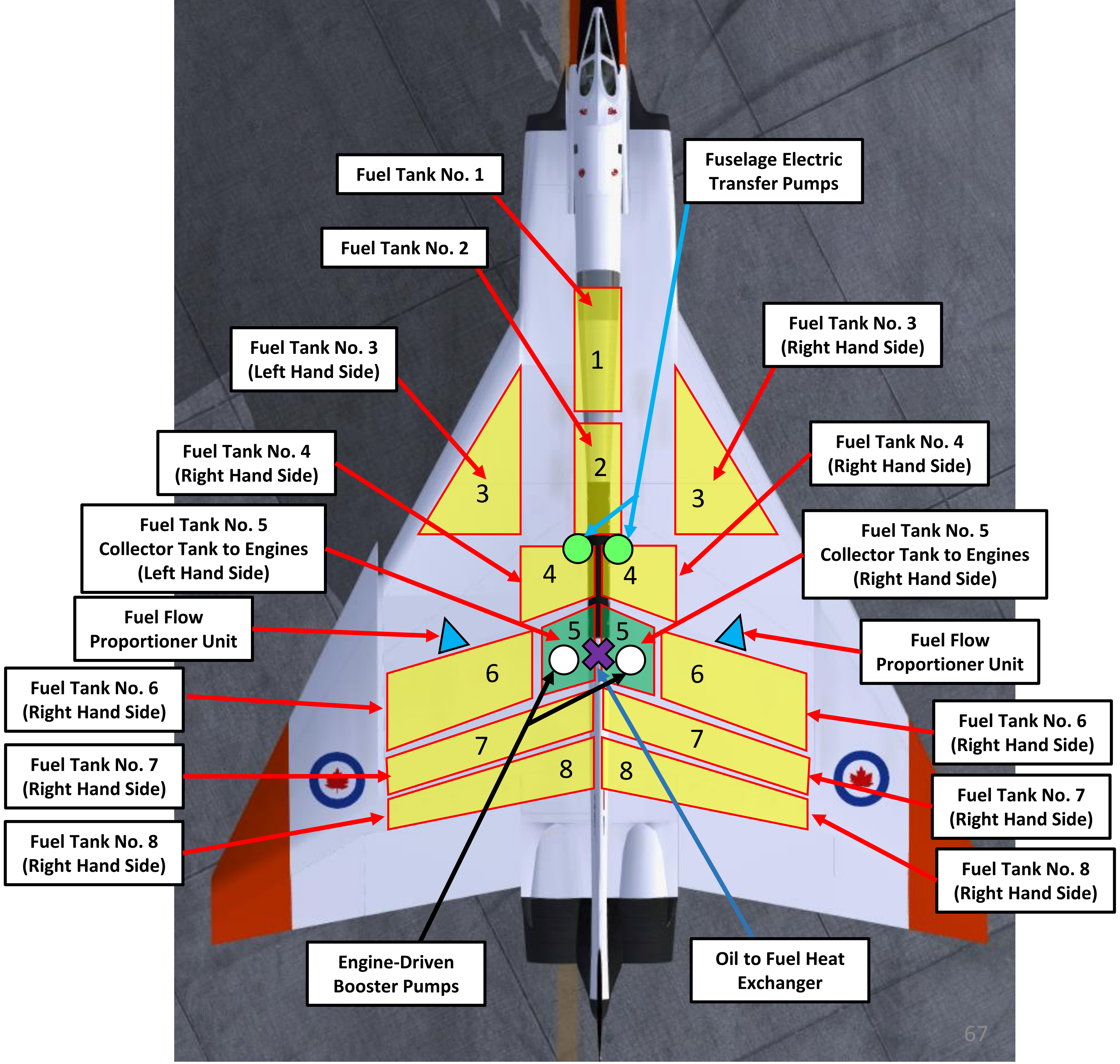


Left/Right Total Fuel Quantity (x100 Imperial Gallons)

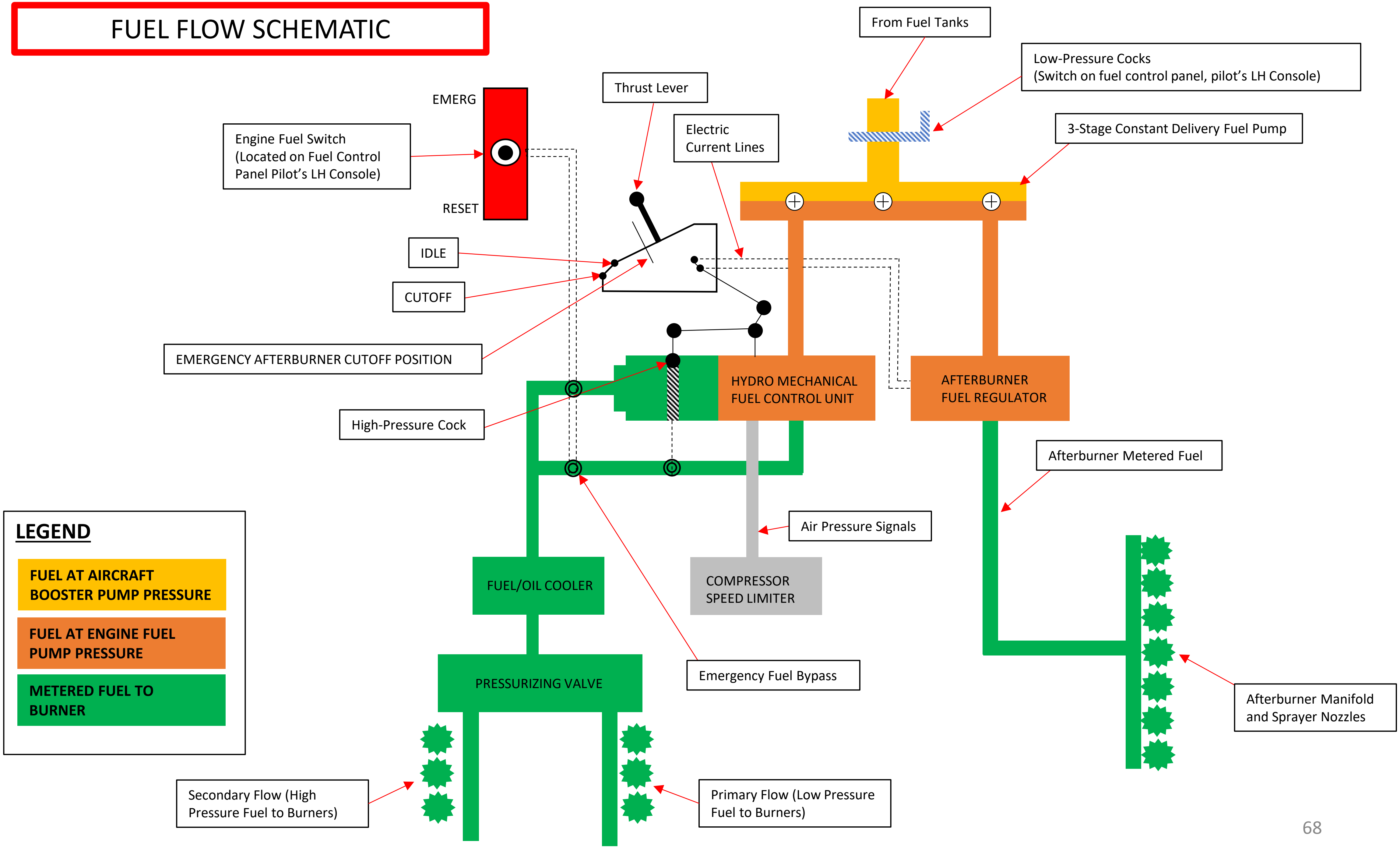
FUEL SYSTEM FEEDS

FUEL QUANTITY

	Gallons	Lbs
Tank No. 1	263	2051
Tank No. 2	259	2020
Tank No. 3 (151 gal – 1162.5 lbs)	302	2355
Tank No. 4 (90 gal – 693 lbs)	180	1404
Tank No. 5 (146 gal – 1124 lbs)	292	2278
Tank No. 6 (154 gal – 1186 lbs)	308	2402
Tank No. 7 (279 gal – 2148.5 lbs)	558	4352
Tank No. 8 (173 gal – 1332 lbs)	346	2699
TOTAL:	2508 gal	19561 lbs
Long Range Tank:	500 gal	3900 lbs



FUEL FLOW SCHEMATIC

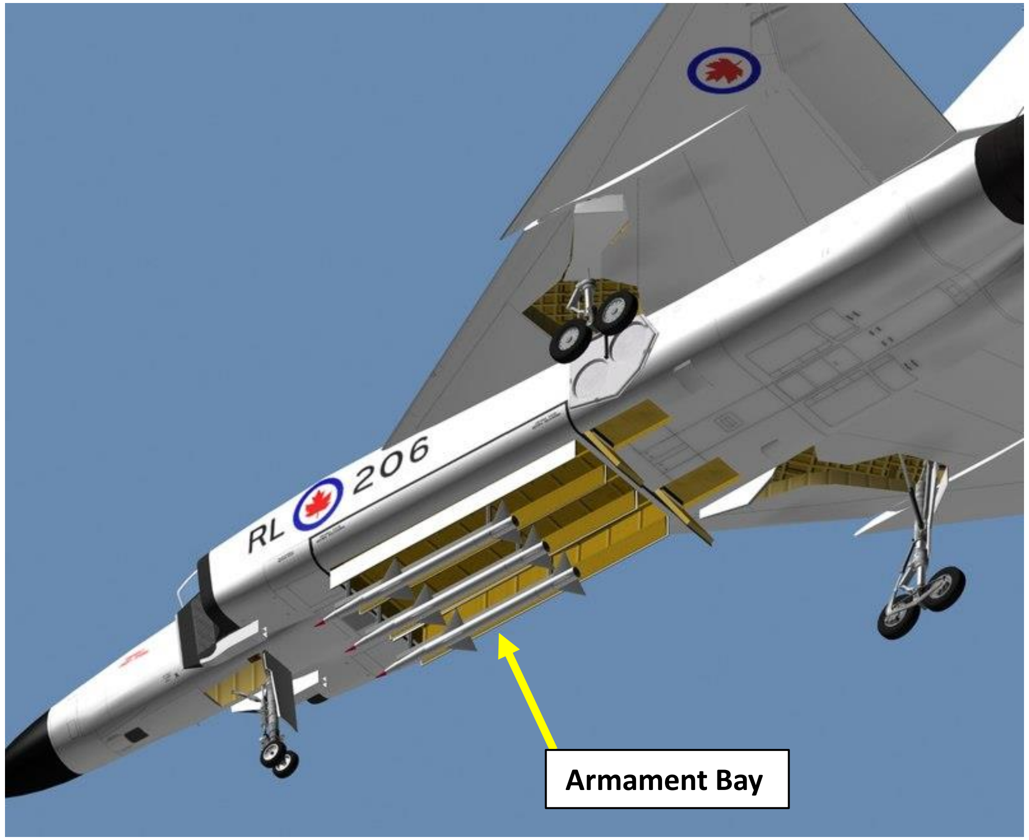


ARMAMENT OVERVIEW

The Arrow was designed to operate like an interceptor: the aircraft would be vectored towards an incoming bomber with a **GCI** (ground control intercept) controller, the radar of the aircraft would be operated by the **RIO** (Radar Intercept Officer) in the aft seat to acquire the target's location, and the **Pilot** Officer in the front seat would have to manoeuver the aircraft to acquire a firing solution. This was the same set-up as other two-seater interceptors of the time. Now, what weapons would the Arrow have used?

After evaluating the engineering mock-ups and the full-scale wooden mock-up in February 1956, the RCAF demanded additional changes, selecting the advanced RCA-Victor Astra I fire-control system firing the equally advanced United States Navy AIM-7 Sparrow II… in place of the Hughes MX-1179 fire-control system and AIM-4 Falcon missile combination. In plain terms: the RCAF preferred a high-risk new system with performance uncertainties instead of a technology that was pretty much ready for use.

Avro vocally objected on the grounds that neither of these (Astra I / AIM-7 Sparrow II) were even in testing at that point, whereas both the MX-1179 and Falcon were almost ready for production and would have been nearly as effective for "a very large saving in cost". The Astra proved to be problematic as the system ran into a lengthy period of delays, and when the USN cancelled the Sparrow II in 1956, Canadair was quickly brought in to continue the Sparrow program in Canada, although they expressed grave concerns about the project as well and the move added yet more expense. The CARDE Velvet Glove radar-guided air-to-air missile was also suggested. The Velvet Glove had been under development with the RCAF for some time, but was believed unsuitable for supersonic speeds and lacked development potential. Consequently, further work on that project was cancelled in 1956.



Armament was stored in a large internal bay located in a "belly" position, taking up over one third of the aircraft fuselage. A wide variety of weapons could be deployed from this bay, including bombs. Overall, the three main options that would have been possible for the Arrow in terms of armament were:

- 8 x **AIM-4 Falcon** Semi-Active Radar Homing Air-to-Air Missile
- 3 x **AIM-7 Sparrow II** Semi-Active Radar Homing Air-to-Air Missile (cancelled)
- **Velvet Glove** Semi-Active Radar Homing Air-to-Air Missile (cancelled)
- 4 x 1000 lbs unguided bombs

- Fire-Control System
    - RCA-Victor Astra I (cancelled with Arrow program)
    - Hughes MX-1179 (rejected by RCAF)

Little to no information exists on what the final design for Astra I was… which makes the Arrow's potential radar anyone's guess at that point.

AIM-4 FALCON

AIM-4D Falcon Missile

The Hughes AIM-4 Falcon was the first operational guided air-to-air missile of the United States Air Force. Development began in 1946; the weapon was first tested in 1949. The missile entered service with the USAF in 1956. Produced in both heat-seeking and radar-guided versions, the missile served during the Vietnam War with USAF McDonnell Douglas F-4 Phantom II units. Designed to shoot down slow bombers with limited maneuverability, it was ineffective against maneuverable fighters over Vietnam. Lacking proximity fusing, the missile would only detonate if a direct hit was scored. Only five kills were recorded. With the AIM-4's poor kill record rendering the F-4 ineffective at air-to-air combat, the fighters were modified to carry the USN-designed AIM-9 Sidewinder missile instead. It is quite likely that the missile’s poor performance would have affected the Arrow’s combat capabilities as well.

AIM-7 SPARROW II

The Sparrow II was meant to be a "fire and forget" weapon, allowing several to be fired at separate targets at the same time. By 1955 Douglas proposed going ahead with development, intending it to be the primary weapon for the F5D Skylancer interceptor. For Canadian use and as a second source for US missiles, Canadair was selected to build the missiles in Quebec. The small size of the missile forebody and the K-band AN/APQ-64-radar limited performance, and it was never able to work in testing. After considerable development and test firings in the U.S. and Canada, Douglas abandoned development in 1956. Canadair continued development until the Arrow was cancelled in 1959.

Velvet Glove Missile

VELVET GLOVE

The Velvet Glove was a short-range semi-active radar homing air-to-air missile designed by CARDE (today DRDC Valcartier) and produced by Canadair starting in 1953. 131 Velvet Gloves had been completed when the program was terminated in 1956, officially because of concerns about its ability to be launched at supersonic speeds, but also from the design being overtaken by developments in the United States. The RCAF had always demanded that the Arrow had to fire the much more advanced active-radar Sparrow II missile under design for the US Navy. Interest in the Velvet Glove waned, as the Sparrow outperformed it in all ways. In the end Canadair was instructed to take over the Sparrow II, ending development of the Velvet Glove for good.

NAVIGATION INTRODUCTION

The name for RCA's integrated electronic system responsible for automatic flight control, fire control, telecommunications and navigation sub-systems in the Arrow was the **Astra I**.

The overall Astra system integration requirements were demanding and complex. Consequently, the way forward was broken down into an incremental approach. RCA (Radio Corporation of America) was required to deliver a partial Astra system with the minimum communication, navigation, Identification Friend or Foe (IFF) systems, flight instruments, and air data sensors to permit the test aircraft to fly the initial research and development phases. This was to be followed by a “developmental” Astra system and then by a “pre-production” variant before proceeding to “full-production sets”.

The Astra navigation sub-system consisted of a dead reckoning navigation computer, a doppler radar and an integrated destination indicator. This system was intended to be self-contained and to be capable of indicating the actual geographic location of the aircraft (with bearing and distance to target or base) at all times. The navigation computer received inputs from telecommunications, radar and air data equipment and supplied outputs for the fire control radar, AFCS (Automatic Flight Control System) and navigation display indicator. Display data was to include the present position and track of the aircraft, range to target data along with radio compass and UHF homer azimuth data.

Unfortunately problems in development of the Astra I mounted. Changes led to more changes, and the costs escalated. The constant alterations initiated by RCA also directly affected Avro, since the CF-105 airframe had to be modified each time to accommodate the revised designs. Ultimately, progress on the integrated system proved to be very disappointing and ultimately led to the program’s demise. The Astra was cancelled in September 1958.

Since the Astra I was never fully developed for the Arrow, Xtreme Prototypes had to provide two plausible navigation systems:

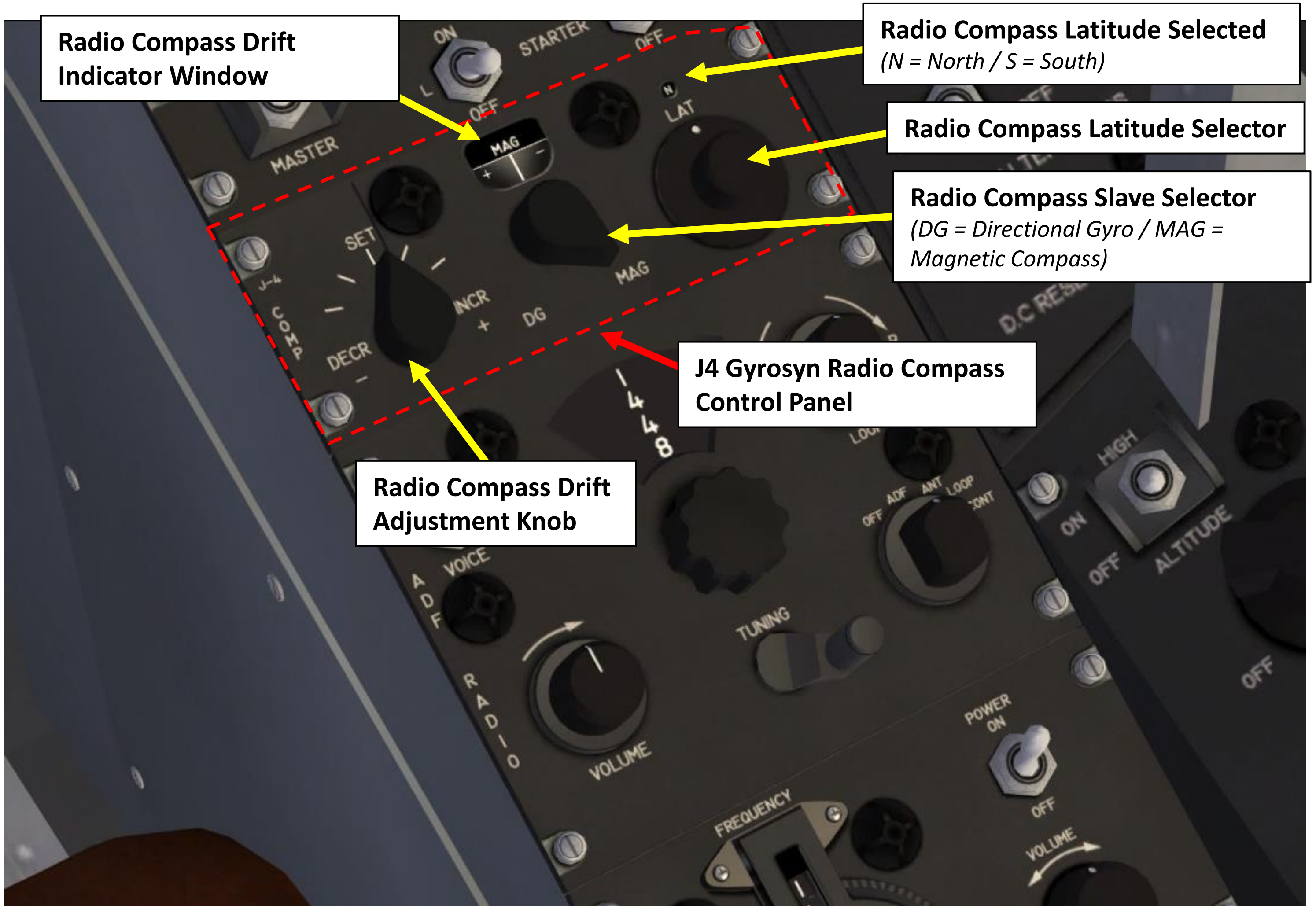
- **ADF** (Automatic Direction Finder): Tracks NDBs (Non-Direction Beacons)
- **VHF Navigation**: Tracks VOR (VHF Omnidirectional Range) Beacons, used for frequencies between 108.0 and 117.95 MHz

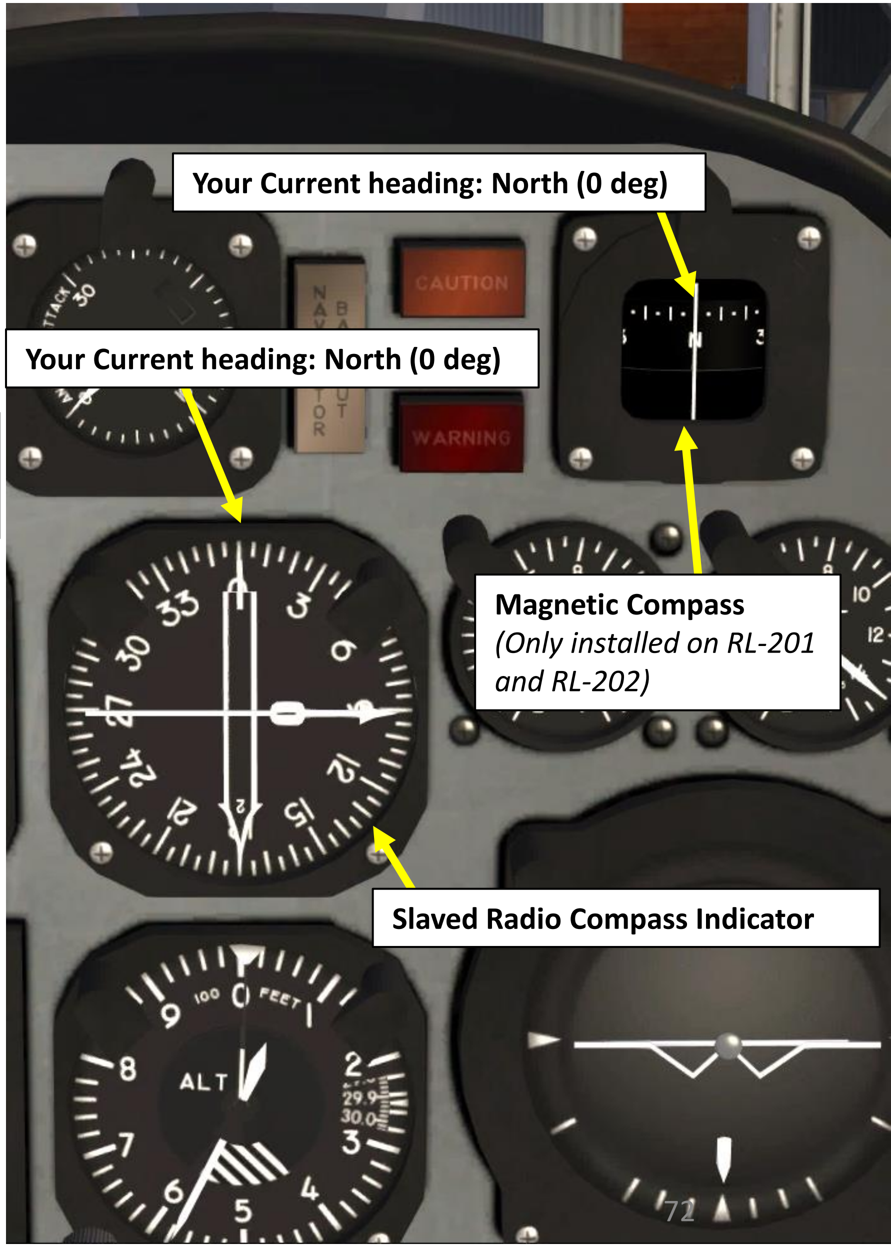
And, of course, the aircraft comes with a period-standard **J4 Gyrosyn Radio Compass.**

Source: Canada Aviation & Space Museum Aircraft – Avro Canada CF-105 Arrow (T.F.J. Leversedge)
https://documents.techno-science.ca/documents/CASM-Aircrafthistories-AvroCanadaCF-105Arrownose.pdf

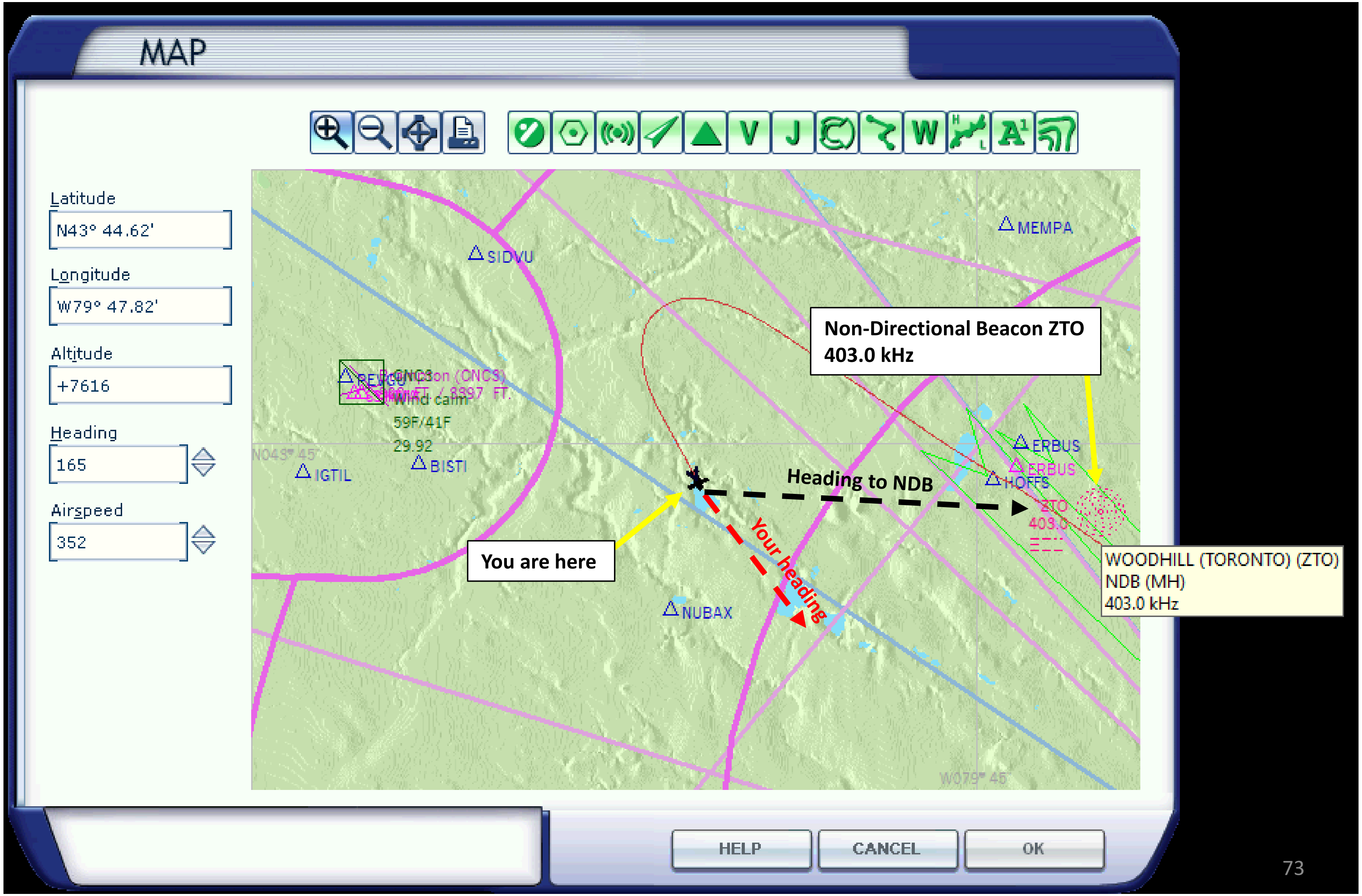
J4 GYROSYN RADIO COMPASS

The J4 Gyrosyn Radio Compass is simply a magnetic compass. Take note that the RL-201 and RL-202 cockpits are slightly different from the rest of the other prototypes.



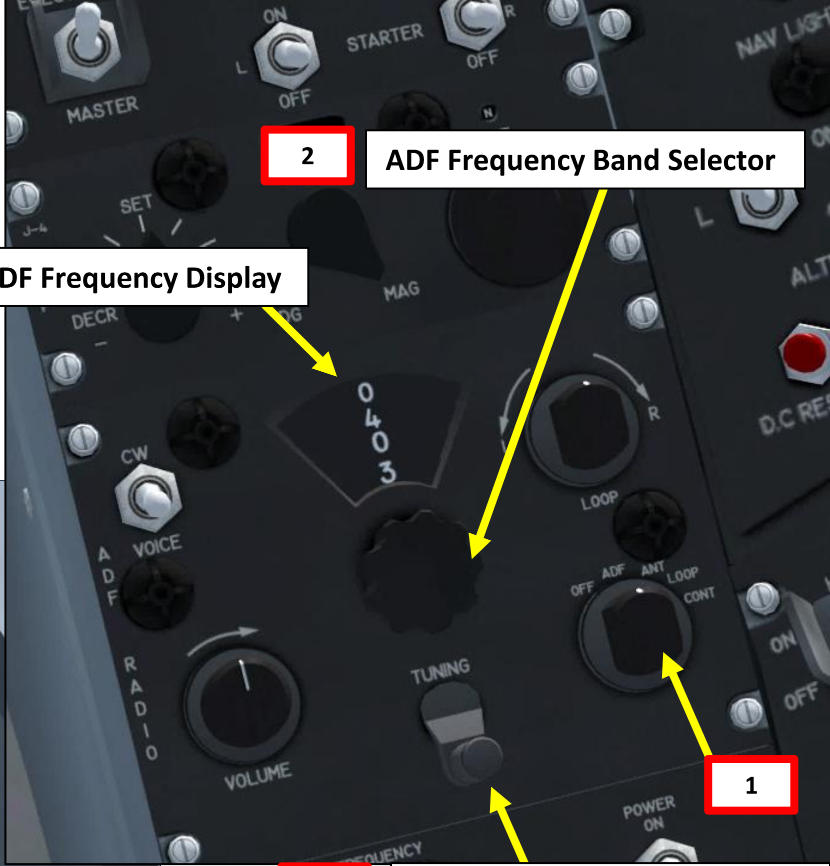


ADF NAVIGATION (NDB)

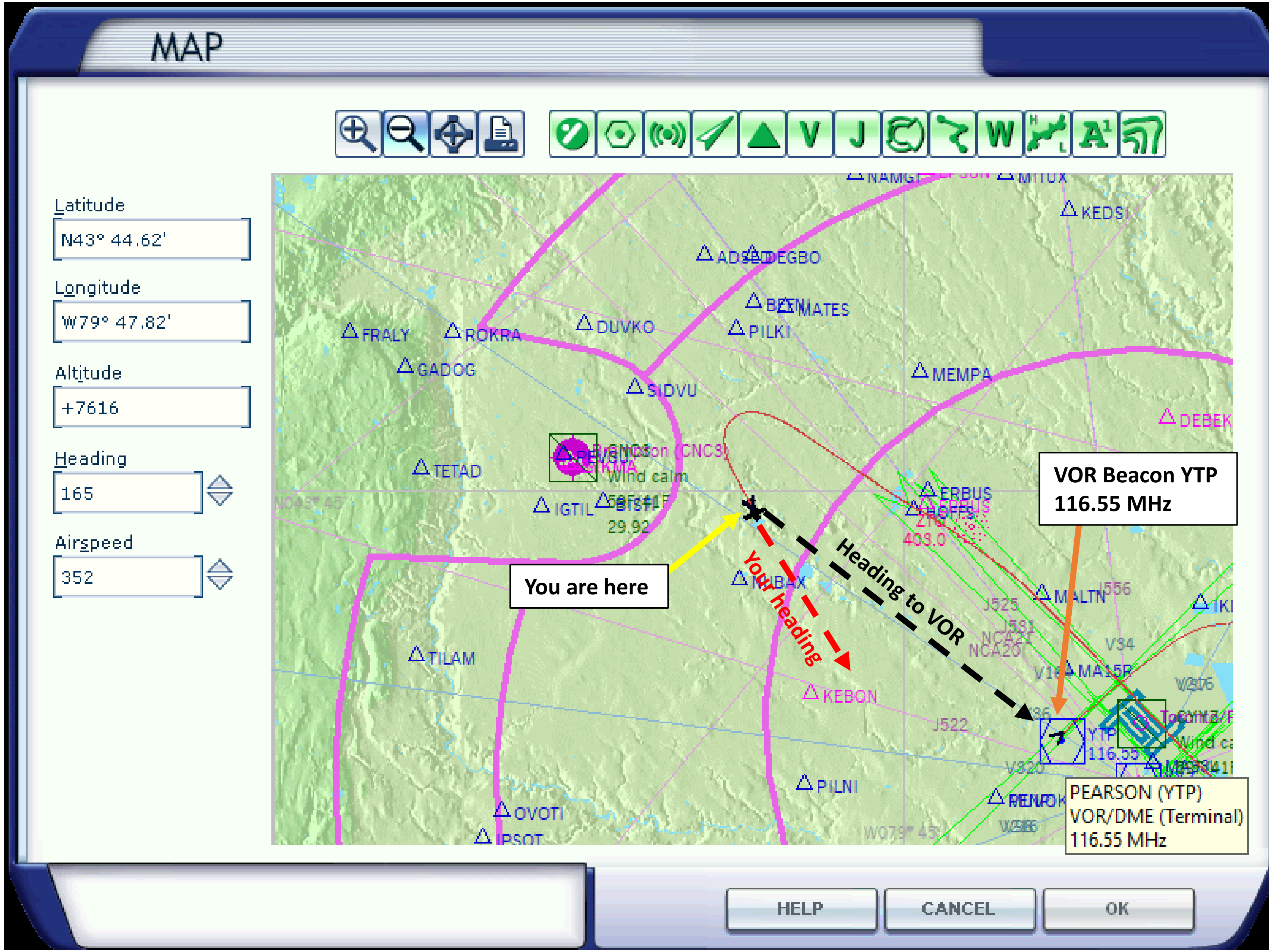


ADF NAVIGATION (NDB)

1. Set ADF Radio Selector to ADF
2. Set ADF frequency to the ZTO NDB frequency (403.0 KHz) using the Frequency Band selector and the Frequency Tuning Crank
3. ADF needle on the RMI (Radio Magnetic Indicator) will point towards the NDB. Simply follow the needle.



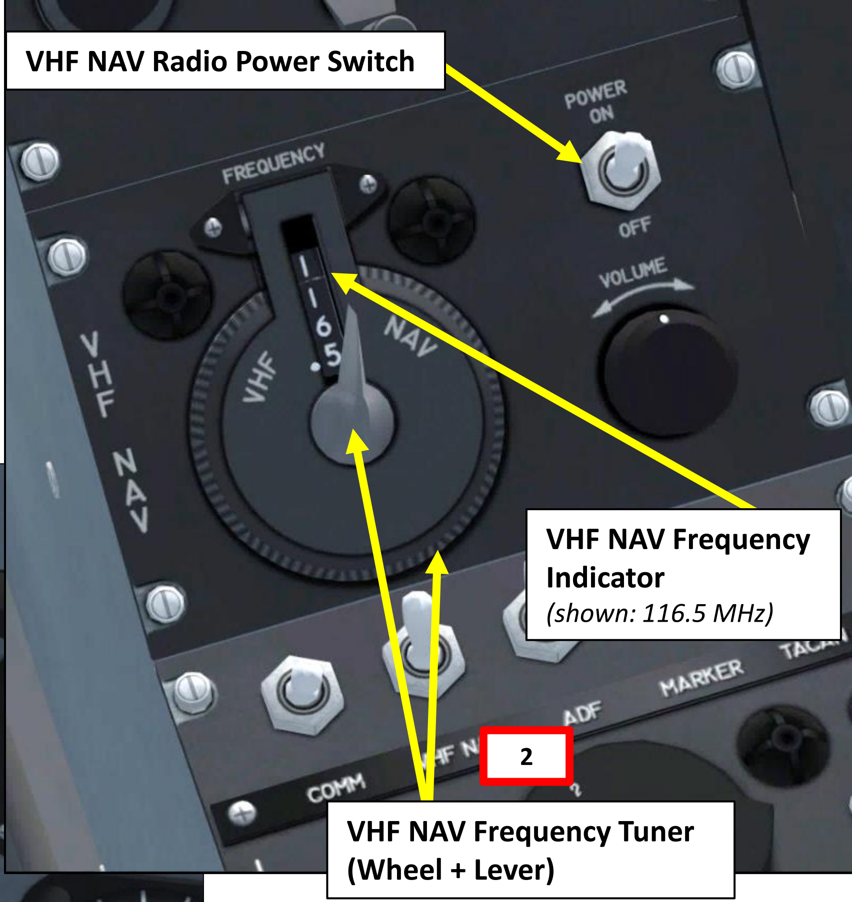
VHF NAVIGATION (VOR)

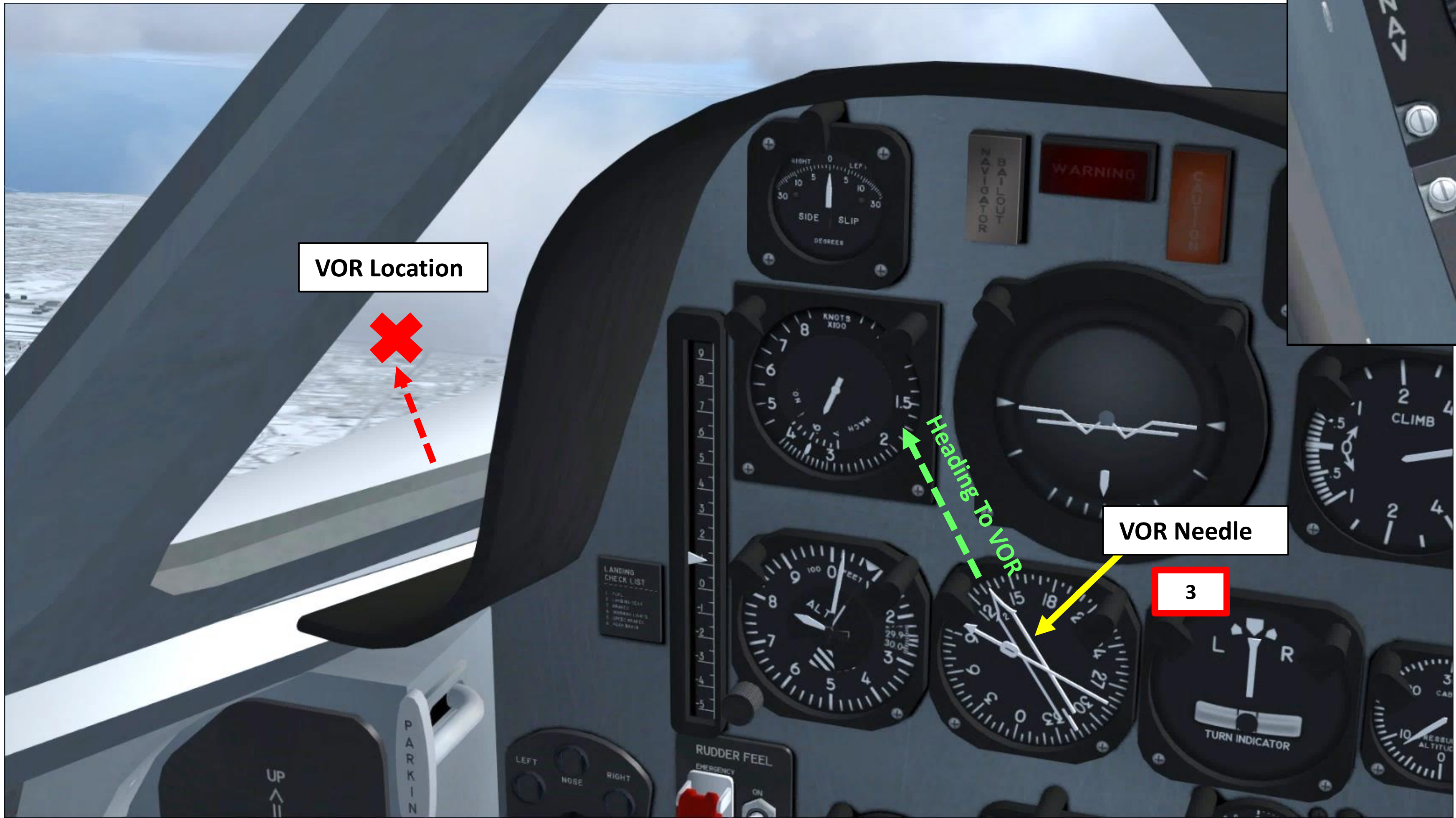


VHF NAVIGATION (VOR)

1. Set VHF-Nav Power switch – ON
2. Set VOR frequency to the YTP VOR frequency (116.55 MHz) using the Frequency tuner wheel and lever (left/right click changes frequency units, while mousewheel changes decimals)
3. VOR needle on the RMI (Radio Magnetic Indicator) will point towards the VOR. Simply follow the needle.

1

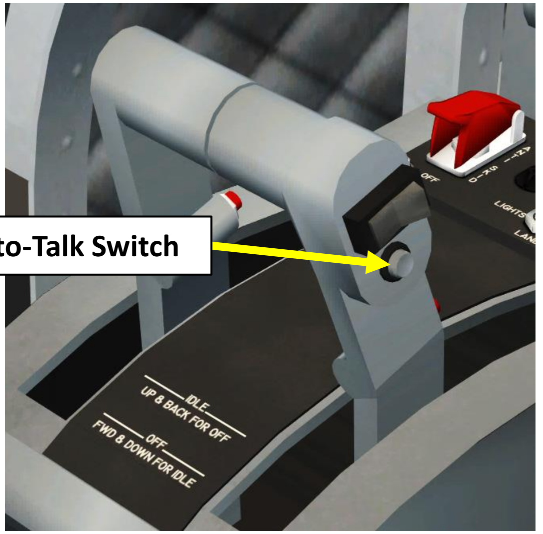


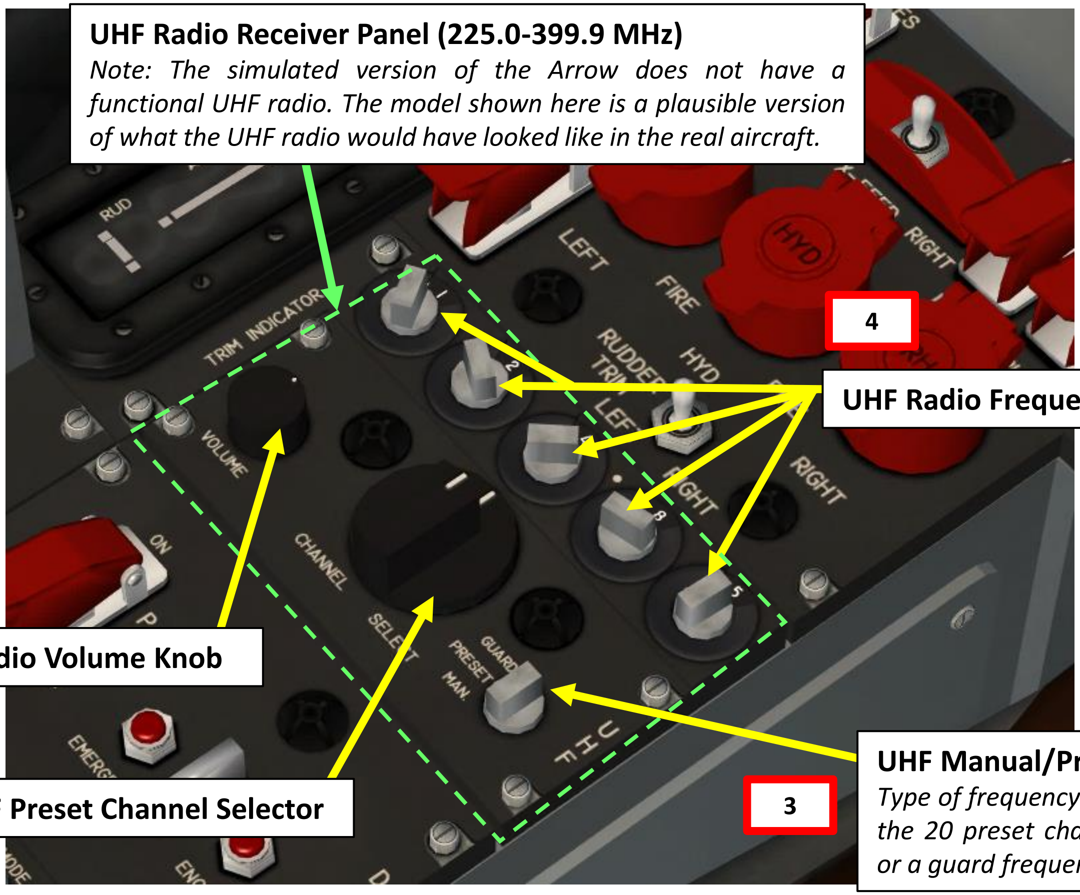


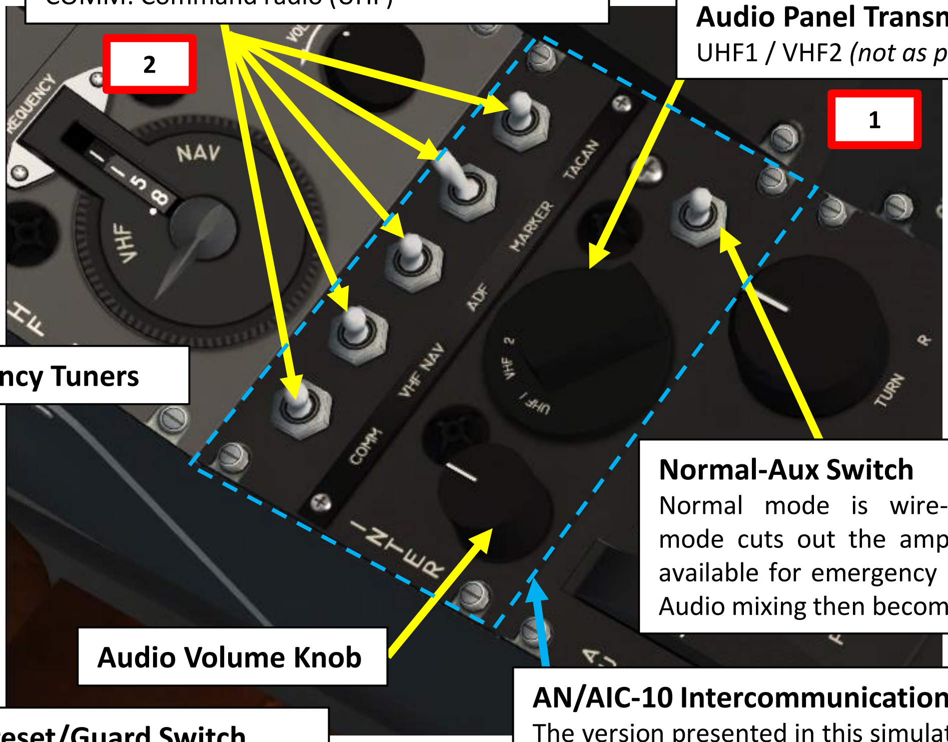
RADIO (UHF)

Note: The radio simulated by Xtreme Prototypes is a plausible radio set, but not exactly as per the real aircraft. The radio is not functional in the simulation, but I thought I would show how it would have likely been operated.

1. Set AN/AIC-10 Intercommunication Panel Transmission Selector to UHF1
2. Set AN/AIC-10 Audio Source COMM Selector switch – ON (FWD)
3. Set UHF Manual/Preset/Guard Switch to desired frequency (Manual in our case)
4. Set UHF Radio Frequency Tuners to desired frequency
5. Press the Radio Push-to-Talk Switch to transmit on desired UHF frequency.







HYDRAULIC SYSTEM OVERVIEW

Source: CF-105 Arrow Mk. I – Pilot's Operating Instructions Handbook, April 1958 (K.A.R. Reproduction)

There are two main hydraulic systems:

- The **Flight Control Hydraulic System**
- The **Utility Hydraulic System**

Flight Control Hydraulic System

Two independent hydraulic systems are employed: System A and System B. **System A** supplies the control surface actuators and damping servo for **emergency yaw damping** only. **System B** supplies the control surface actuators and damping servos for **pitch, roll and yaw damping**.

One pump on each engine supplies System A, while the other pump on on each engine supplies System B. The supply pressure is 4000 psi; an accumulator in each system prevents fluctuations. The lowering or loss of pressure in a system to 1000 psi or less will illuminate the appropriate warning light on the warning panel.

In the event of loss of one engine or loss of one system, adequate control is still available. Rates of control movement may be slower with one engine failed. With either system failed, the available G at high speeds will be restricted. With the B system failed, the aircraft will be in the emergency mode of flying control.

More details are available for the flying controls in the next section.

Flight Control Hydraulic System

System A

- Emergency Rudder actuators
- Emergency Yaw Damping

System B

- Elevator actuators
- Pitch damping servos
- Aileron actuators
- Roll damping servos
- Rudder actuators
- Yaw damping servos

HYDRAULIC SYSTEM OVERVIEW

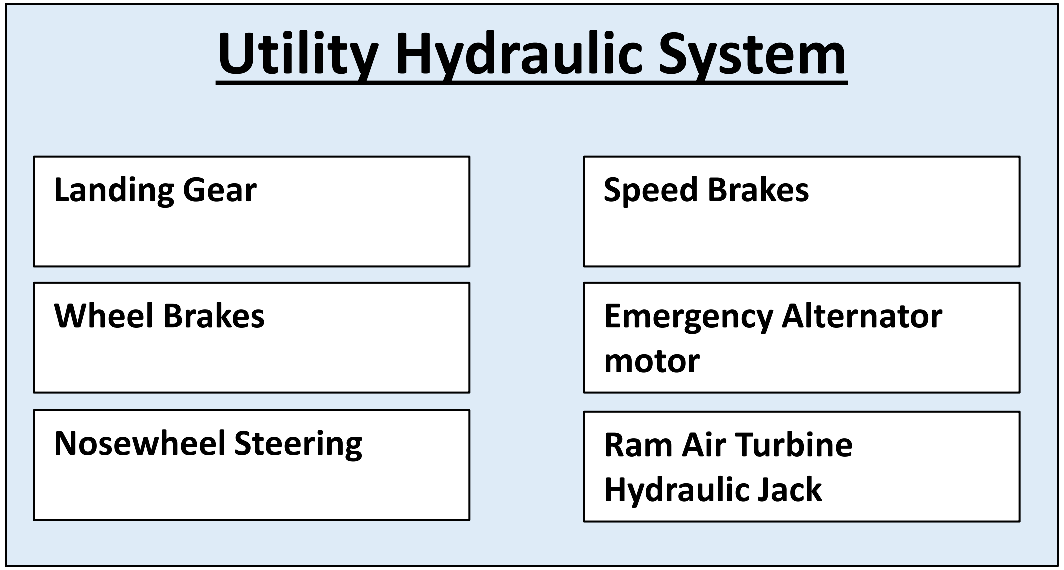
Utility Hydraulic System

The utility hydraulic system is separate from the flying control hydraulic system. The utility system is powered by two pumps, one mounted on each engine driven gearbox. An operating pressure of 4000 psi is maintained by the pumps.

Any one pump has to supply the requirements of the following utility hydraulic sub-systems:

- Landing Gear
- Wheel brakes
- Nosewheel Steering
- Speed brakes
- Hydraulic motor to drtive the emergency alternator (operation is automatic in case of complete electrical failure)
- Hydraulic jack for extending a ram air driven turbine to give flying control hydraulic pressure in an emergency.

Note: A 5000 psi nitrogen charged storage bottle is provided for emergency extension of the landing gear. Two 4000 psi accumulators are included in the system for emergency braking.



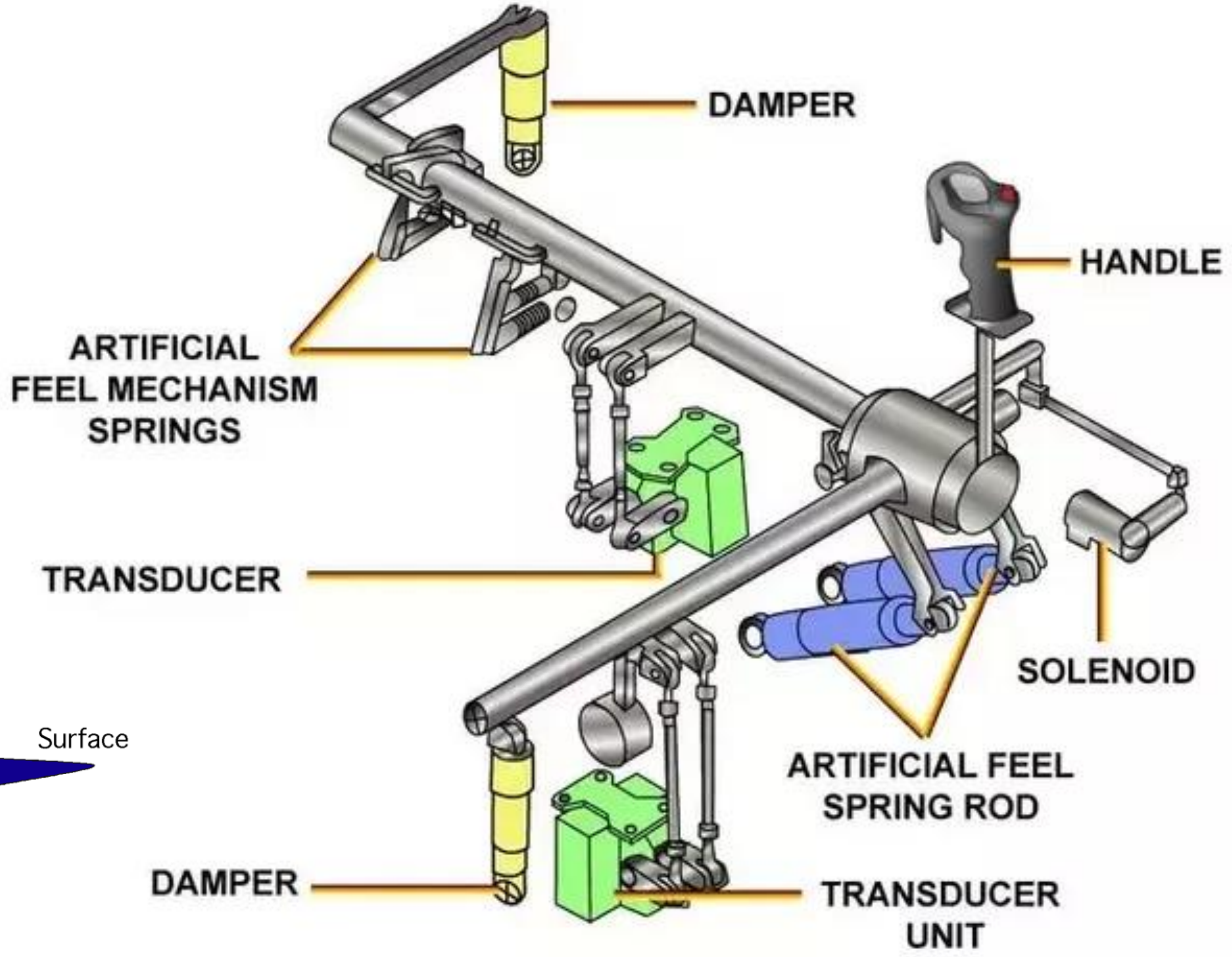
FLIGHT CONTROL SYSTEM

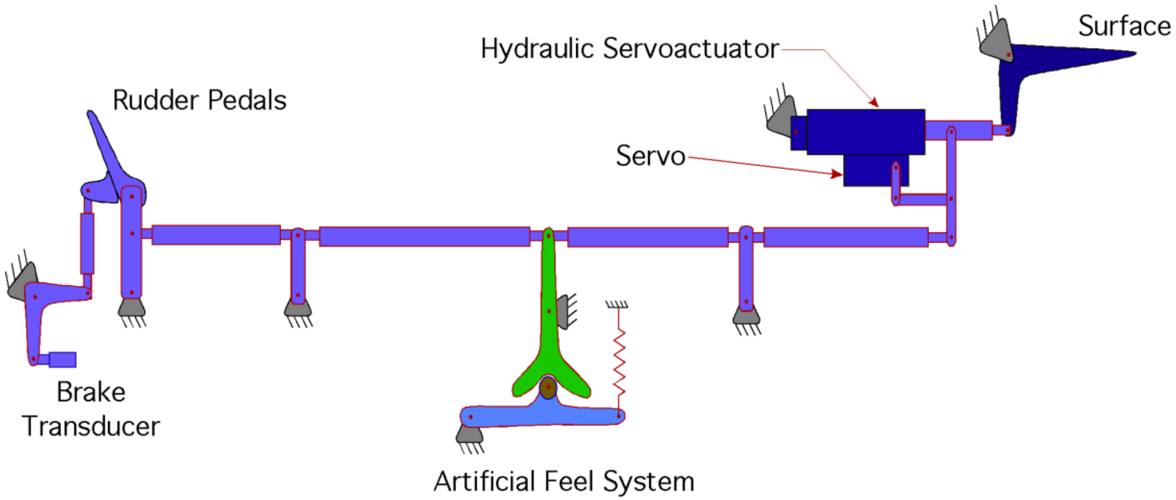
Source: CF-105 Arrow Mk. I – Pilot's Operating Instructions Handbook, April 1958 (K.A.R. Reproduction)

The Arrow had a rudimentary **fly-by-wire** system, in which the pilot's input was detected by a series of pressure-sensitive transducers in the stick, and their signal was sent to an electronic control servo that operated the valves in the hydraulic system to move the various flight controls. This resulted in a lack of control feel; because the control stick input was not mechanically connected to the hydraulic system, the variations in back-pressure from the flight control surfaces that would normally be felt by the pilot could no longer be transmitted back into the stick.

To re-create a sense of feel, the same electronic control box rapidly responded to the hydraulic back-pressure fluctuations and triggered actuators in the stick, making it move slightly. This system is called "artificial feel", and it was a first in the Canadian aircraft design field. You will notice a "rudder feel" switch in the cockpit that powers such a system for the rudder.

The ailerons, elevators, and rudder were all fully powered, using hydraulic pressure supplied by two pumps on each engine. The hydraulic components were controlled electrically, or mechanically through cables and linkages, there being no direct mechanical control or feedback.





FLIGHT CONTROL MODES

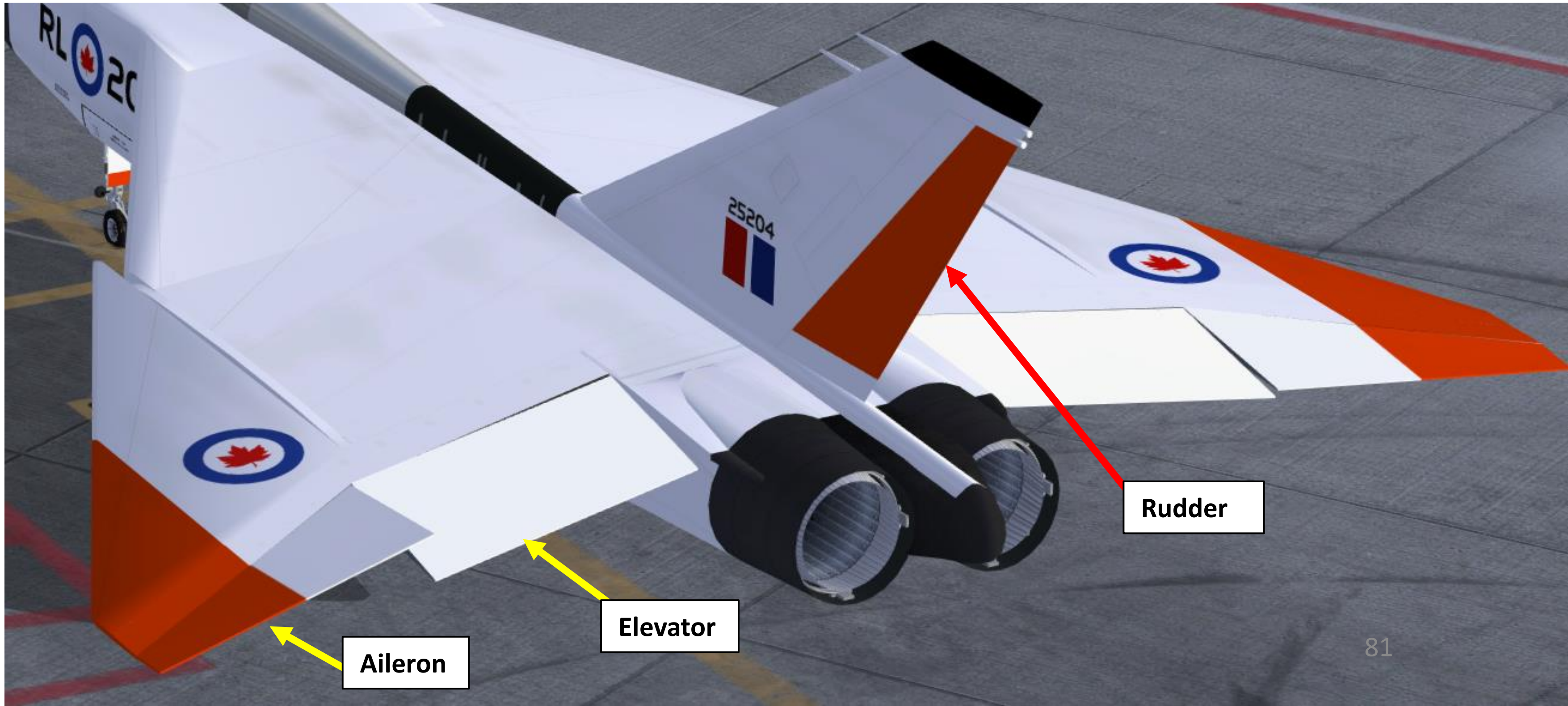
There were three modes of control planned for the final Arrow configuration:

- The **normal mode** was characterized by a damping system, automatically stabilizing the aircraft in all three axes and co-ordinating rudder movement with movement of the ailerons and elevators. Pilot feel at the control column is provided by the damping system in the normal mode.

- The planned **automatic mode** was never ultimately fitted to the design. However, there is documentation on how it was intended to work. In this mode, the damping system is operative as in the normal mode, but aileron and elevator position is controlled by an Automatic Flight Control Sub-system (AFCS). The AFCS allows the aircraft to be controlled from the ground for Automatic Ground Control Interception (AGCI) or fot Automatic Ground Control Approach (AGCA). It also provides certain pilot assist functions by holding any set course or altitude or it may hold any set Mach number by varying the aircraft's pitch attitude. It also provides for automatic navigation by controlling the aircraft according to information fed into a dead reckoning computer by the navigator.

- The **emergency mode**'s role is self-explanatory: the hydraulic components for operating the ailerons and elevators were controlled mechanically. Yaw stability and turn coordination was maintained by an emergency yaw damper. Pilot feel at the control column is provided by spring feel in emergency mode.

An AFCS (Automatic Flight Control System) disconnect push button switch is fitted on the control column handgrip. When the AFCS is disconnected by this switch, the damping system reverts to the normal mode.



DAMPING & G LIMITER

DAMPING SYSTEM

The damping system provides **artificial stabilization in flight**. Unstable tendencies are picked up by sensors and adjustments are made to the control surfaces. The pilot is unaware of the corrections being made. As the damping in the yaw axis is of major importance in the higher speed range, duplicated electrical and hydraulic supplies are installed for the rudder control.

The damping system comprises three distinct **channels**:

- **Pitch** Channel (controls elevators)
- **Roll** Channel (controls ailerons)
- **Yaw** Channel (controls rudder)

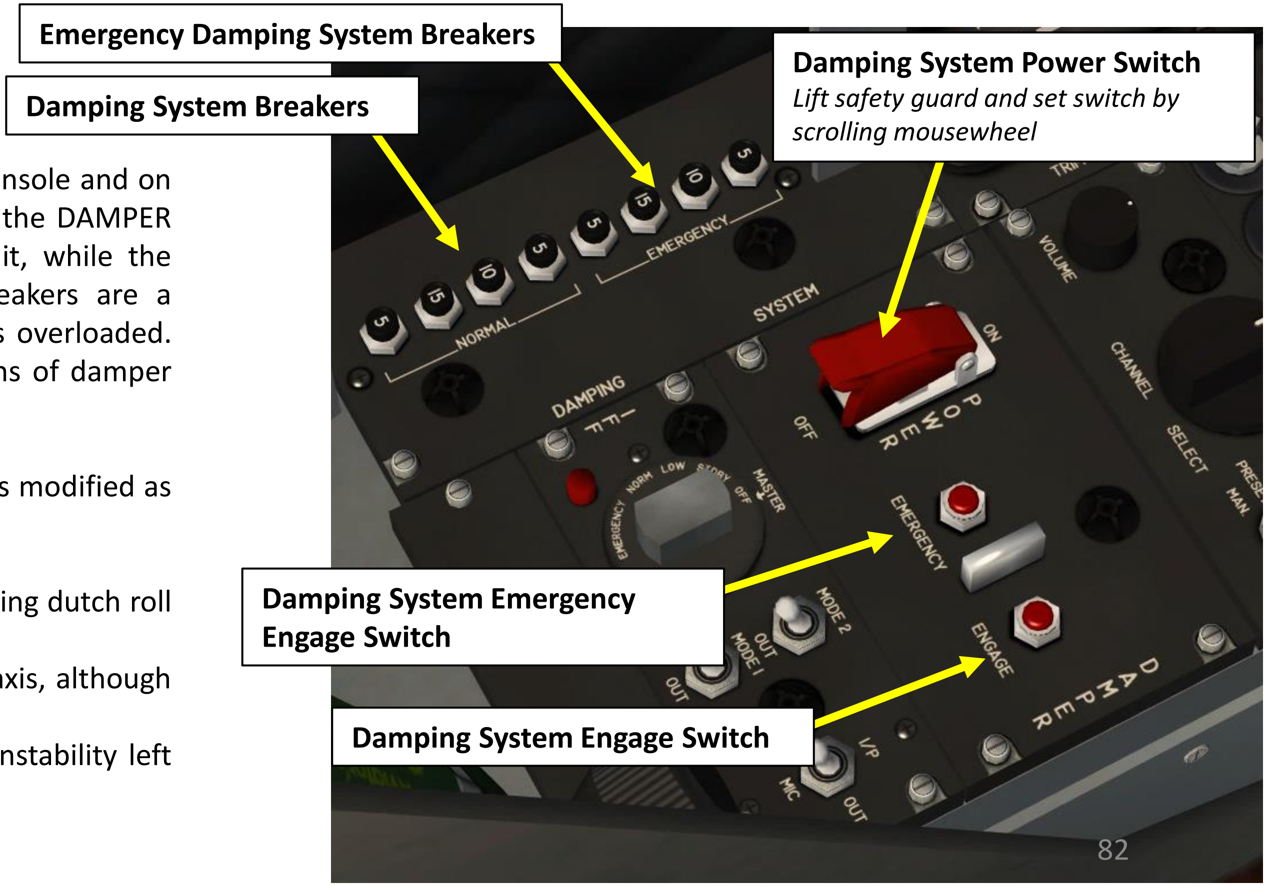
Switches for controlling the damping system are located on the pilot’s left console and on the control column. Eight DAMPING **circuit breakers** are fitted outboard of the DAMPER control panel. The rear group of four are in the NORMAL damping circuit, while the forward group of four are in the EMERGENCY damping circuit. The breakers are a protection against excessive current drain and will not reset if the circuit is overloaded. They also provide a secondary means of switching should the normal means of damper disengagement fail to operate.

When the **landing gear is down and locked**, damping of all control surfaces is modified as follows:

- Sufficient damping is retained in the roll axis in order to help in counteracting dutch roll in conjunction with the yaw axis.
- Modified damping allows intentional sidelip to be introduced in the yaw axis, although any transient yaw will be corrected.
- Damping is retained in the pitch axis to a limited extent: any excessive instability left uncorrected by the damper will be easily counteracted by the pilot
- Pilot « feel » at the controls changes

G LIMITER

The stick force transducer is set to limit pilot imposed G to a value of 4.5 to 5 G, but if through component malfunctions this value is exceeded, the normal mode of control in the pitch axis disengages automatically and control reverts to emergency mode. Upon change-over, the aircraft may require to be manually re-trimmed. In the emergency mode, the G bob-weight is felt at the control column under G conditions. G limiting is then under the control of the pilot.



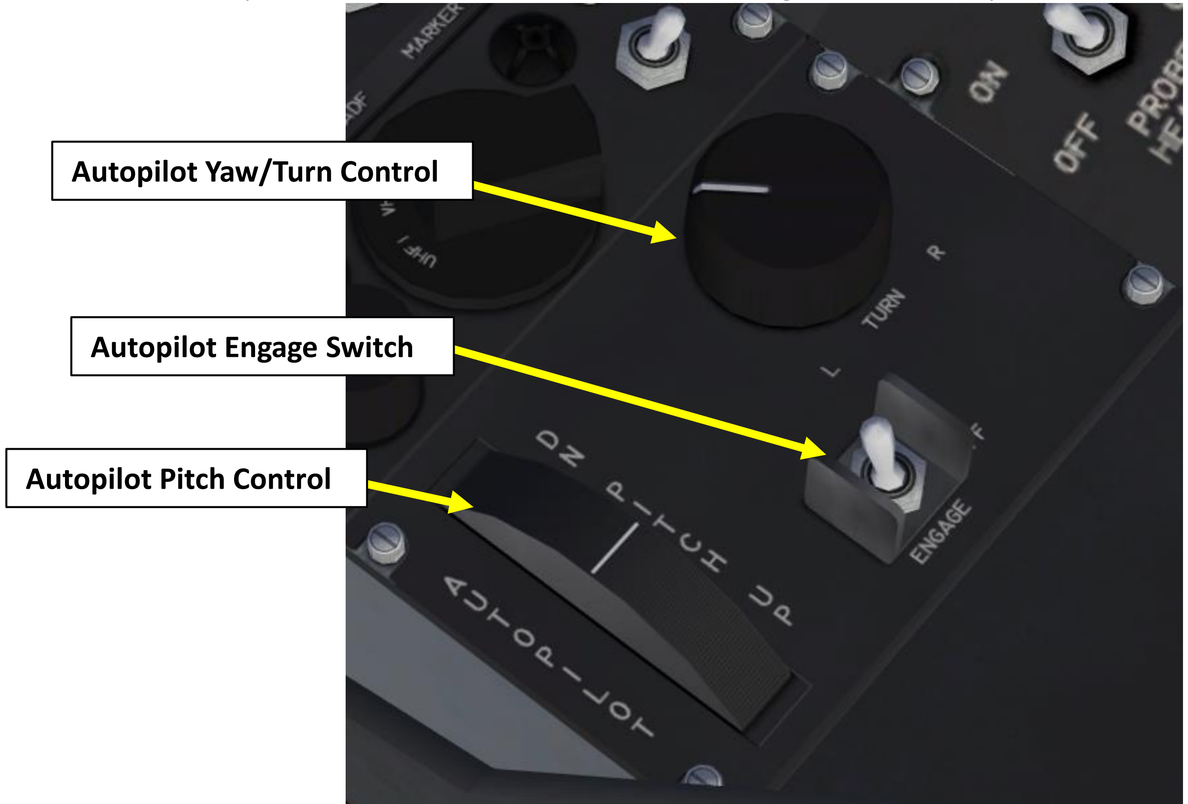
AUTOPILOT

In the 1950's, there were increasing fears that the Soviets might not use bombers at all to attack North America, but rather would do so using long-range rockets. Sputnik's first orbital flight in 1957 did nothing to appease these fears. These changing defense scenarios prompted authorities to question the very concept of the manned interceptor.

The Avro Arrow was planned to be compatible with the American SAGE (Semi-Automatic Ground Environment) system, which allowed an aircraft's autopilot to be controlled from the ground according to a ground computer's predictions of the enemy's track. The Arrow project was cancelled before it could be integrated with the SAGE system.

The autopilot system installed on the Arrow is quite simple:

1. Engage Autopilot, which will hold the current aircraft pitch and level the wings
2. Use the Autopilot Pitch control or Turn control to change the aircraft's pitch and heading.



The SAGE Direction Center's **Subsector Command Post** ("Blue Room")

ELECTRICAL ARCHITECTURE

Source: CF-105 Arrow Mk. I – Pilot's Operating Instructions Handbook, April 1958 (K.A.R. Reproduction)

- The aircraft is equipped with two 30 KVA 120/208 volt, ram air cooled alternators. One alternator is fitted to and is driven by each engine through a CSD (Constant Speed Drive) for AC power supply.
- In addition to supplying the aircraft services, each alternator supplies a transformer rectifier unit. The TRUs operate in parallel and provide 27.5 volts DC for the DC services.
- A hydraulically driven emergency alternator is fitted and supplies essential AC services in case of complete electrical failure. The aircraft battery supplies essential DC services for a limited period during this emergency.

AC System

The engine driven alternators supplying AC power are controlled by two switches marked ALTERNATORS ON – RESET – OFF. Normally, the right alternator supplies the AC power requirements. Should the right alternator fail, the left alternator assumes the load. Should the left alternator fail, no change in power supply will be apparent. The operating alternator supplies through its TRUs all DC services except the landing and taxi lights.

DC System

The transformer rectifier units (TRUs) are fed from their respective main AC bus-bars, and the output is fed to the main DC bus. The DC system maintains the battery charged, therefore if the battery starts discharging, the following services will be available from the battery through the DC Emergency Flight Bus for approximately 20 minutes:

DC SYSTEM

Landing Gear Indicator	Speed Brake Actuation	Turn & Slip Indicator	AIC/10 Intercomm Panel	Hinge Moment Limiter
Fire Detection	Warning Light System	Ignition (Relight)	DC Damping (Yaw)	Engine Emergency Fuel Selection
Canopy Seal	Emergency Cockpit Lights	ARC/34 UHF Radio	IFF (APX/6A)	Bail Out Indication

AIR CONDITIONING SYSTEM

Source: CF-105 Arrow Mk. I – Pilot's Operating Instructions Handbook, April 1958 (K.A.R. Reproduction)

The Air Conditioning System is supplied with hot air bled from both engine compressors. A certain proportion of this hot air is cooled by means of three **components**:

- An air-to-air heat exchanger, which cools engine bleed air by ram airstream
- An air-to-water heat exchanger, which coolas conditioned air by heat transfer to distilled water
- A cooling turbine and fan

Various types of controllers and air valves served by thermostats and sensors are fitted, which serve to maintain the selected conditions of bleed air in the system during various airspeed and altitude conditions.

Its main **functions** are:

- Supplies hot and cold air to maintain cockpit pressure and temperature within required limits
- Maintains the required temperature levels in areas where heat is generated by electrical and electronic equipment (equipment bay cooling)
- Supplies air for fuel tank pressurization, windscreen rain repellent (if fitted), defogging, the low pressure pneumatic system and the liquid oxygen converter. Discharged air from the cockpits is used to cool and scavenge the armament bay.

Cabin pressurization remains the same as the outside up to 10000 ft. Above this altitude, the differential between cabin pressure and aircraft pressure altitude increases linearly until a differential pressure of 4.5-5 psi would be reached at 60,000 ft. A CABIN PRESSURE amber warning light is fitted ont he warning panel and will illuminate if at any time the cabin altitude reaches 31000 ft or higher.

LOW PRESSURE PNEUMATIC SYSTEM

A Low-Pressure Pneumatic System supplies low pressure air tapped from the inlet side of the air conditioning cooling tyurbine, to the **anti-g suits** and the **canopy seals**.

The pilot's and navigator's canopy seals are inflated by low pressure air at 18-22 psi through a control valve. The vvalve is operated electrically and the seals are inflated when both canopy handles are in the LOCKED position. If either canopy is unlocked, the seals will deflate and vent the pressure to the atmosphere.

ICE DETECTION & DE-ICING

The Arrow was intended to operate in the cold Canadian winter, where icing hazards are a harsh reality.

ICE DETECTION

Two identical electrically heated **ice detectors** are fitted; one mounted on the lip of each engine intake duct. Each detector has two probes, one of which is electrically heated whenever power is ON, and the other which is only heated when ice covers the forward holes.

A pressure differential switch signals the **ice controller** when ice forms on the normally unheated probe. The automatic heating of this probe melts the ice on the probe, restores the normal pressure, and the probe is then ready to send another signal to the ice controller. The signals continue as long as icing conditions exist, at a rate proportional to the rate of icing.

ENGINE DUCT DE-ICING

De-icing of the engine ducts is accomplished by erlectricallyt heated rubber ice protectors which are automatically controlled. The protectors are heated after a preset number of ice signals are received and will shed the ice. The icing and de-icing cycle will be repeated according to the number of signals received by the controller.

ANTI-ICING

ENGINE COMPRESSOR INLET ANTI-ICING

Engine anti-icing is accomplished by the use of engine bleed air. The first icing signal from the controller automatically opens air supply valves and provides hot aire to the compressor inlet section of the engine. The system functions continuously during icing conditions. The flow of hot air is regulated according to the compressor discharge temperature. Flow will be reduced as the temperature increases.

However, during descent at high airspeeds and low power settings, the heat supplied may be inadequate if the ice formation is severe. Increased thrust should be applied to provide more heat.

WINDSCREEN & CANOPY ANTI-ICING

The piplot's windscreen and canopy wiundows are continuously heated by electrical means when the aircraft master electrical switch is ON. A conductive transparent coating is incorporated on the inner surface of the outer glass lamination of the panels and sensing elements control the maximum temperature to 110 deg F.

PITOT-HEAD AND VANE ANTI-ICING

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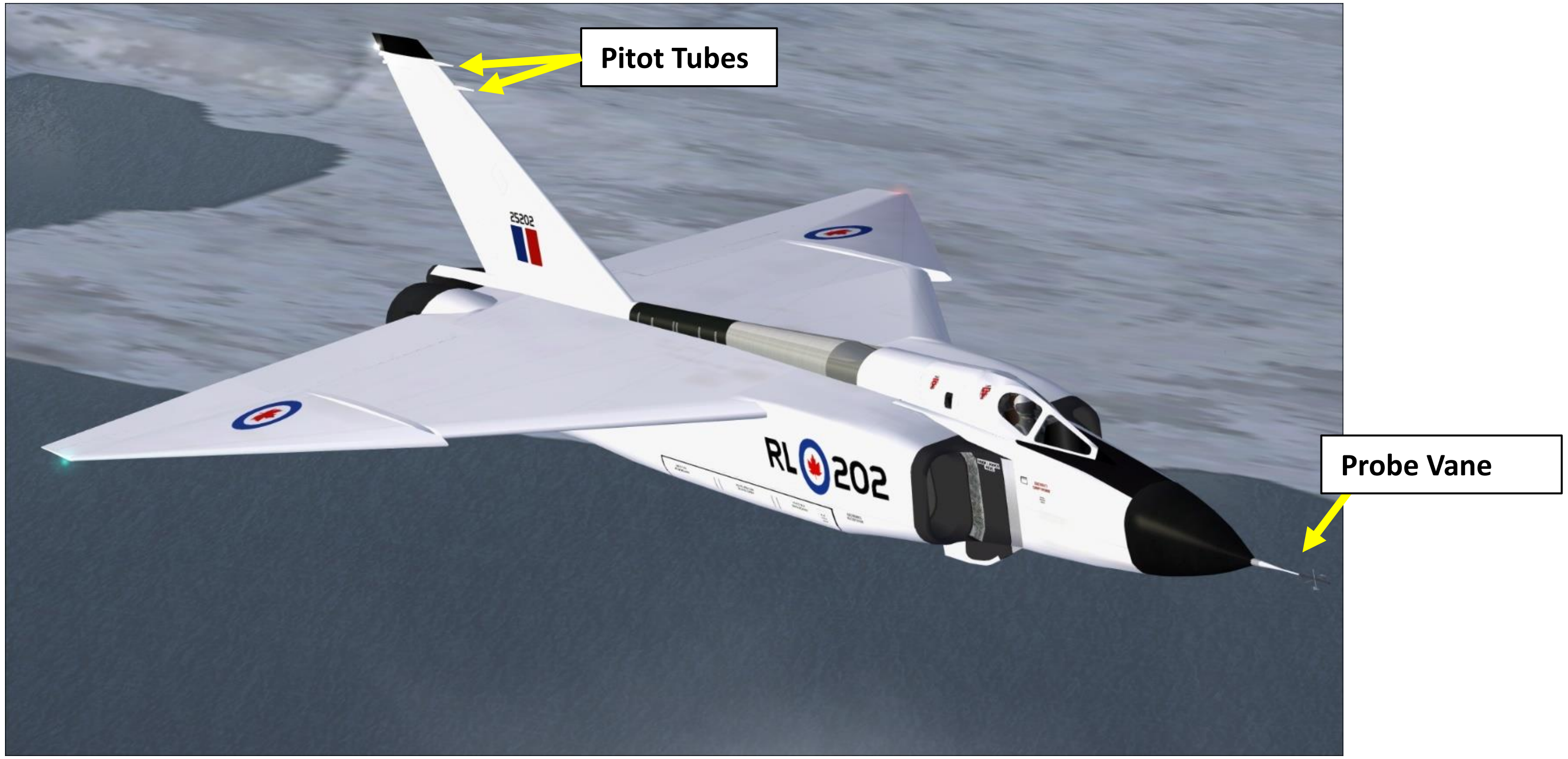


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