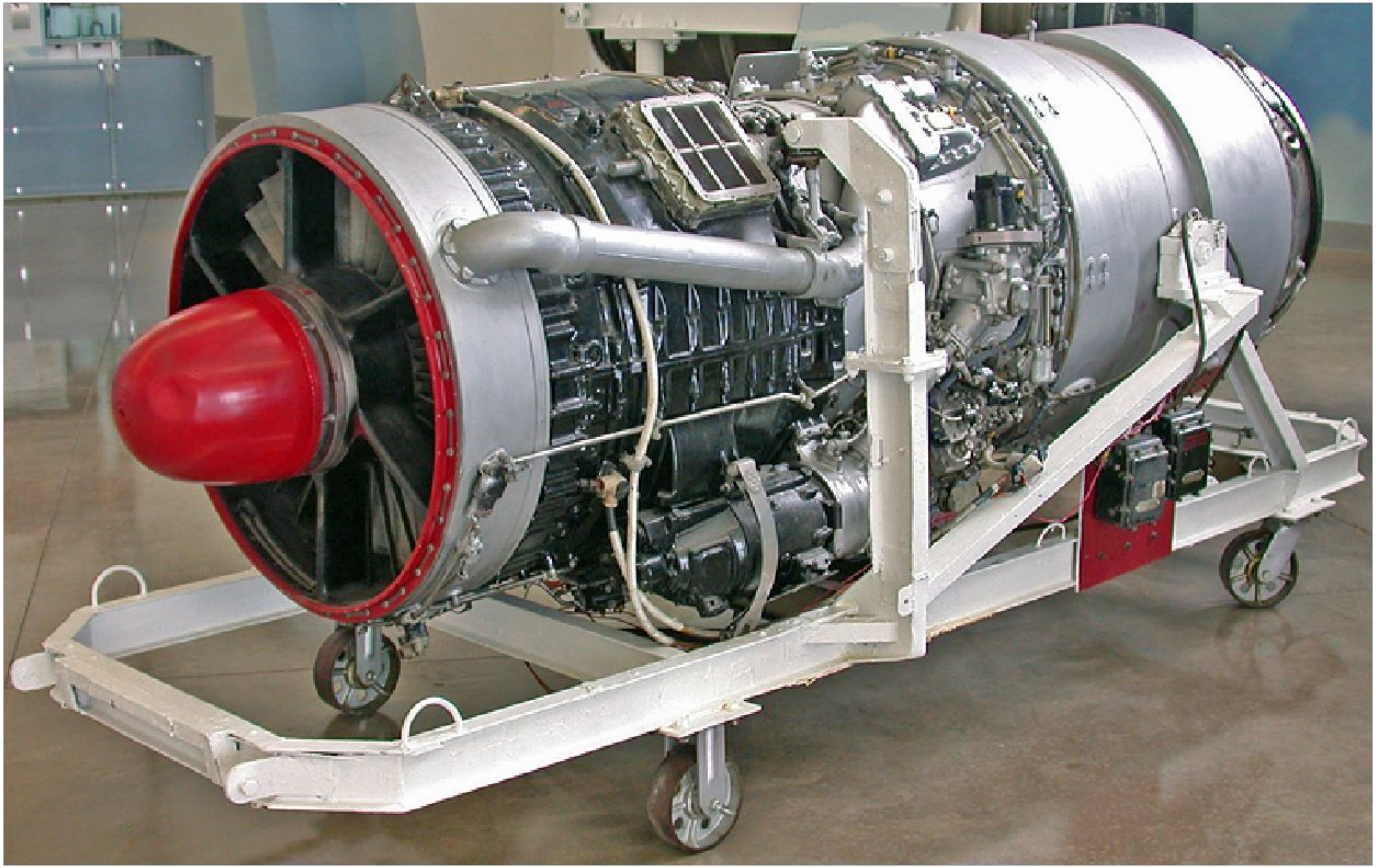
JET ENGINE MECHANICAL ARRANGEMENT

More generally known as ‘GAS TURBINE’ Engine

THE WORKING PARTS OF A JET ENGINE

Rolls-Royce AVON – Canberra – 1950's technology

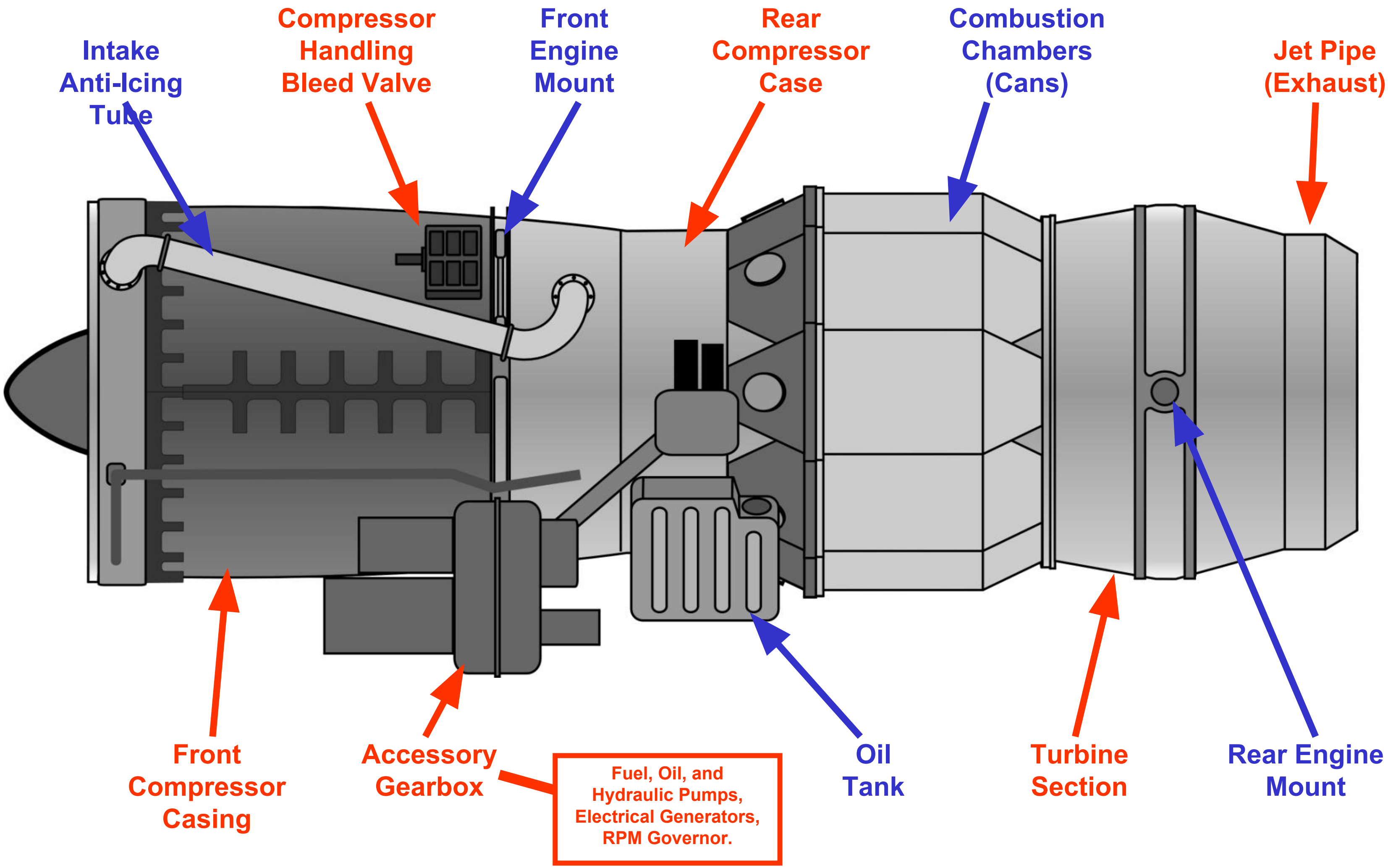


JET ENGINE MECHANICAL ARRANGEMENT

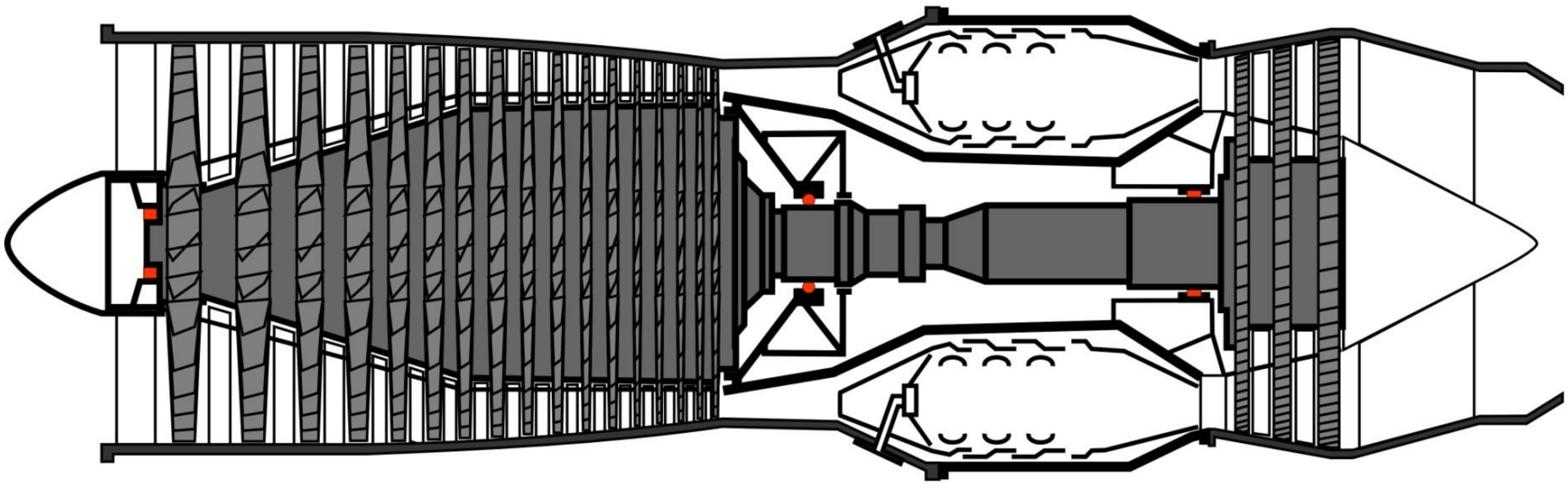
Rolls-Royce AVON - Cut away view

JET ENGINE MECHANICAL ARRANGEMENT

Rolls-Royce AVON - (Graphic Representation)



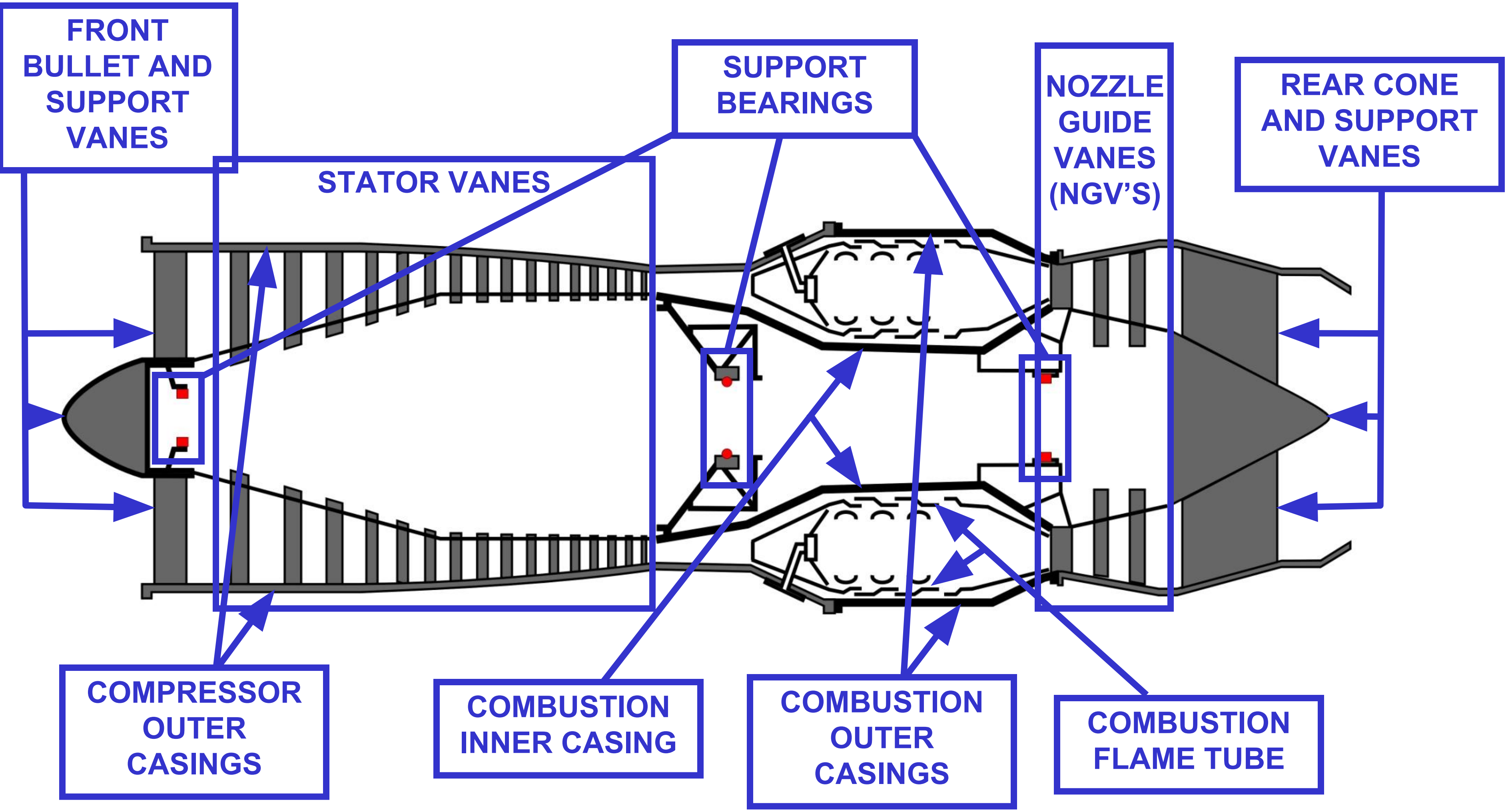
JET ENGINE MECHANICAL ARRANGEMENT



Turbo-jet = no Bypass Duct

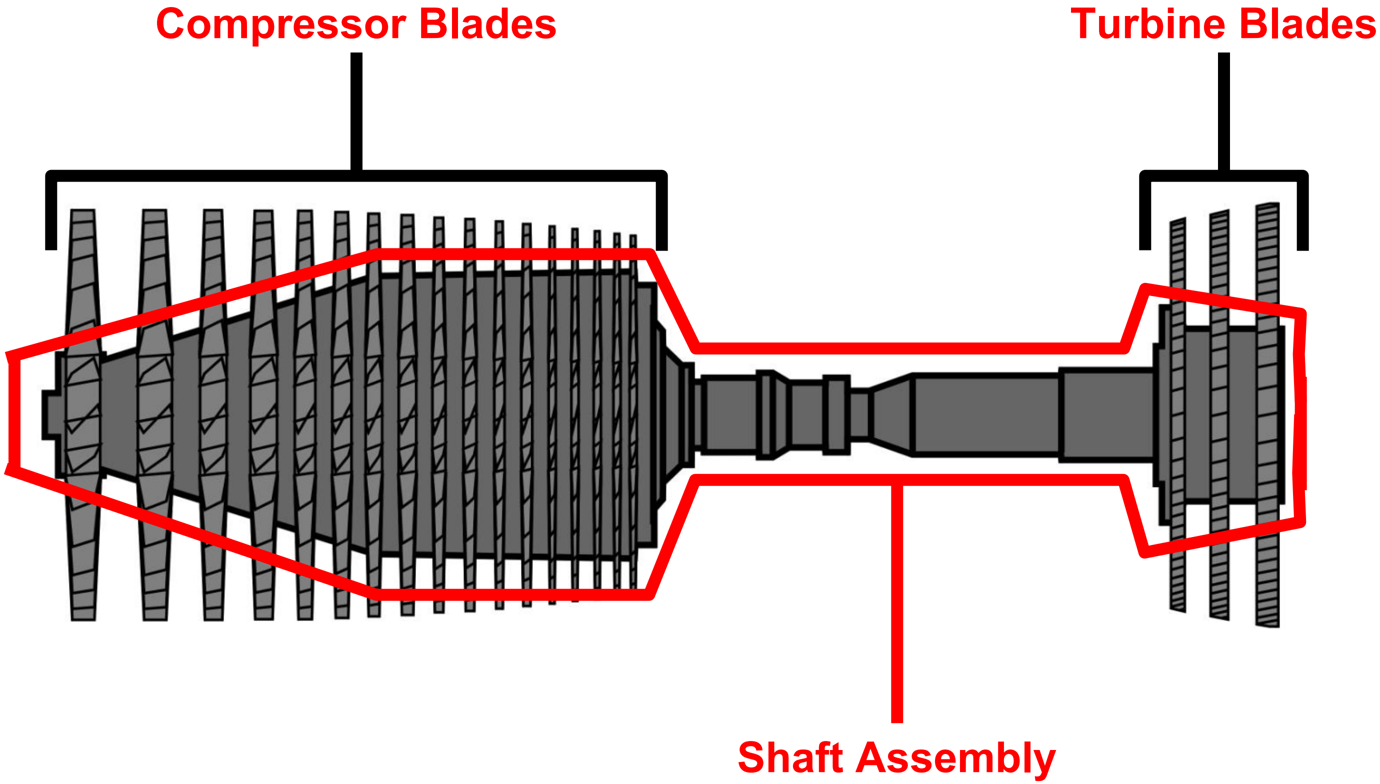
JET ENGINE MECHANICAL ARRANGEMENT

Engine Casings – Static Assembly



JET ENGINE MECHANICAL ARRANGEMENT

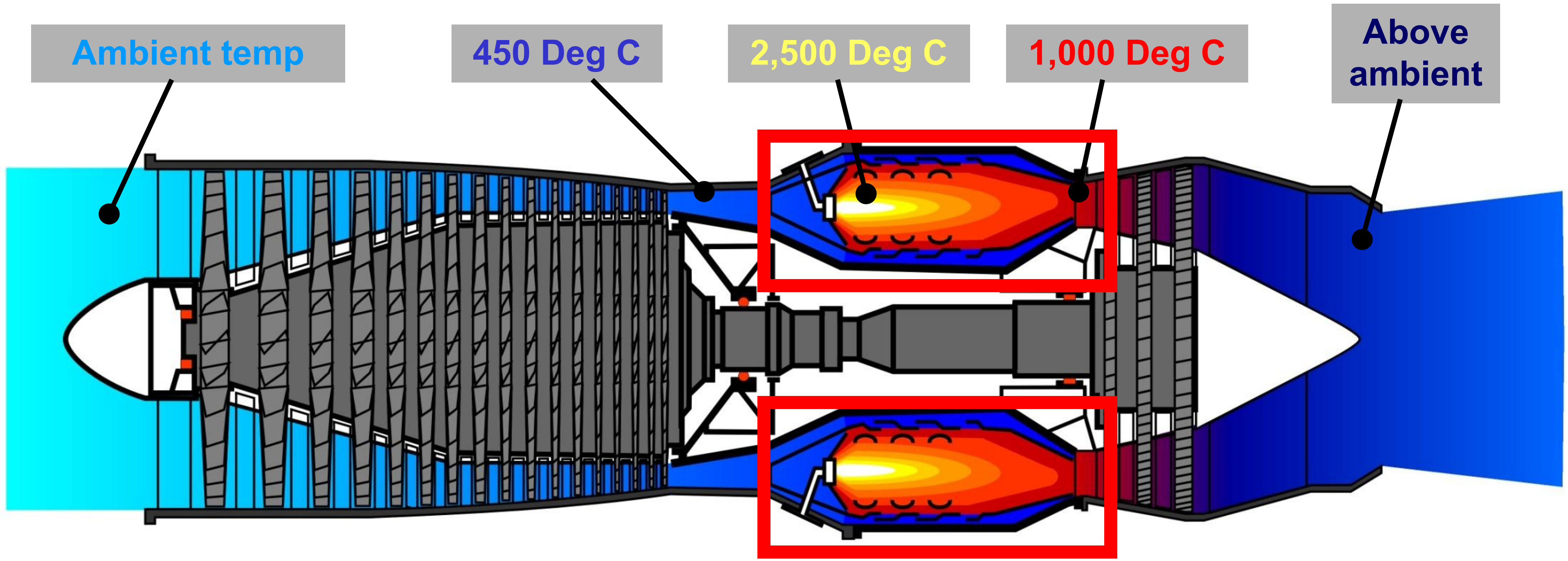
Rotating Assembly



JET ENGINE MECHANICAL ARRANGEMENT

Problem! Temperature changes cause the shaft and casings to expand and contract

But by different amounts!



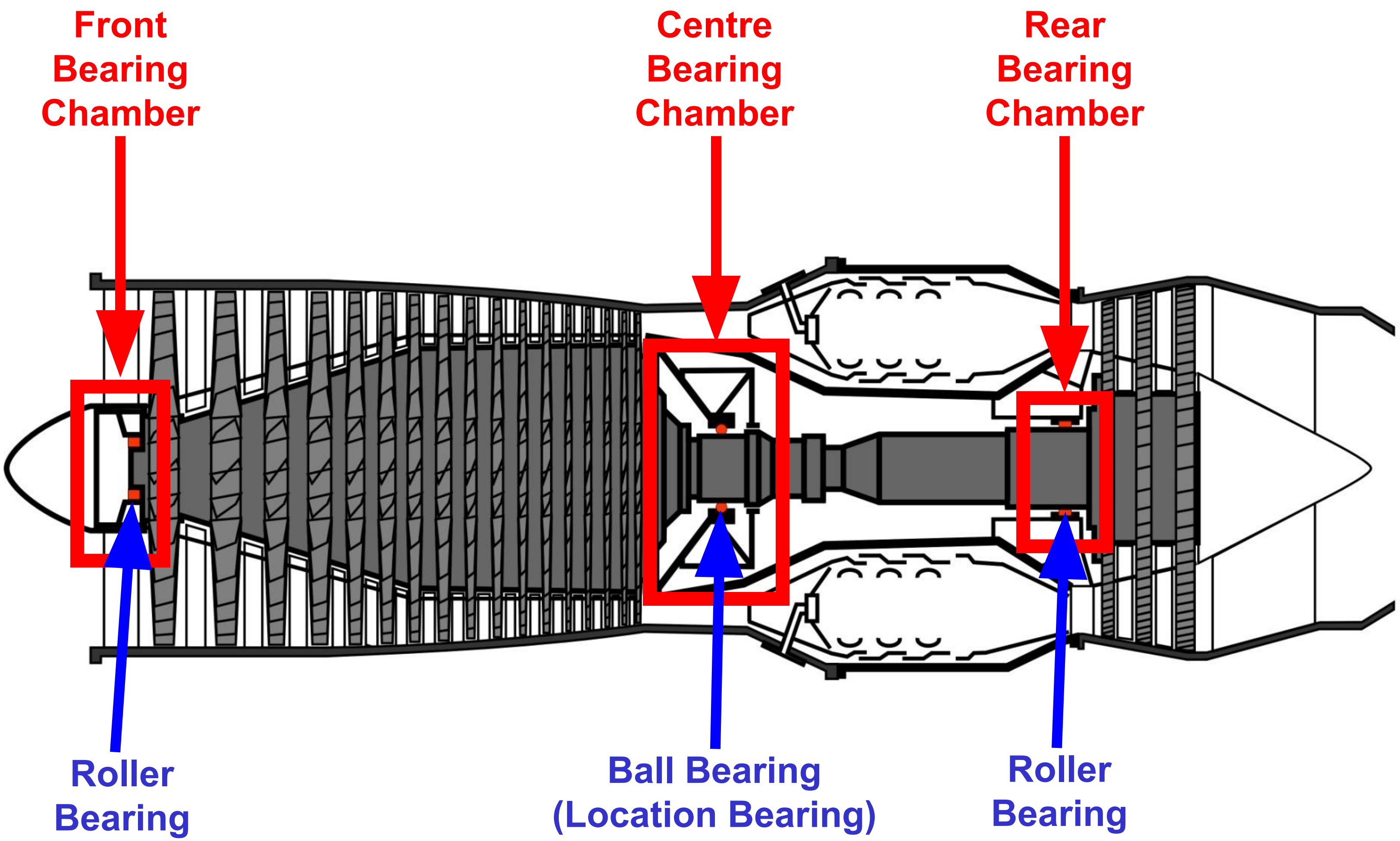
This could put tremendous unwanted forces on the casings and shaft leading to failures

(We'll look at what happens to the air passing through the GAS PATH in

Solution? Its all in the bearings!

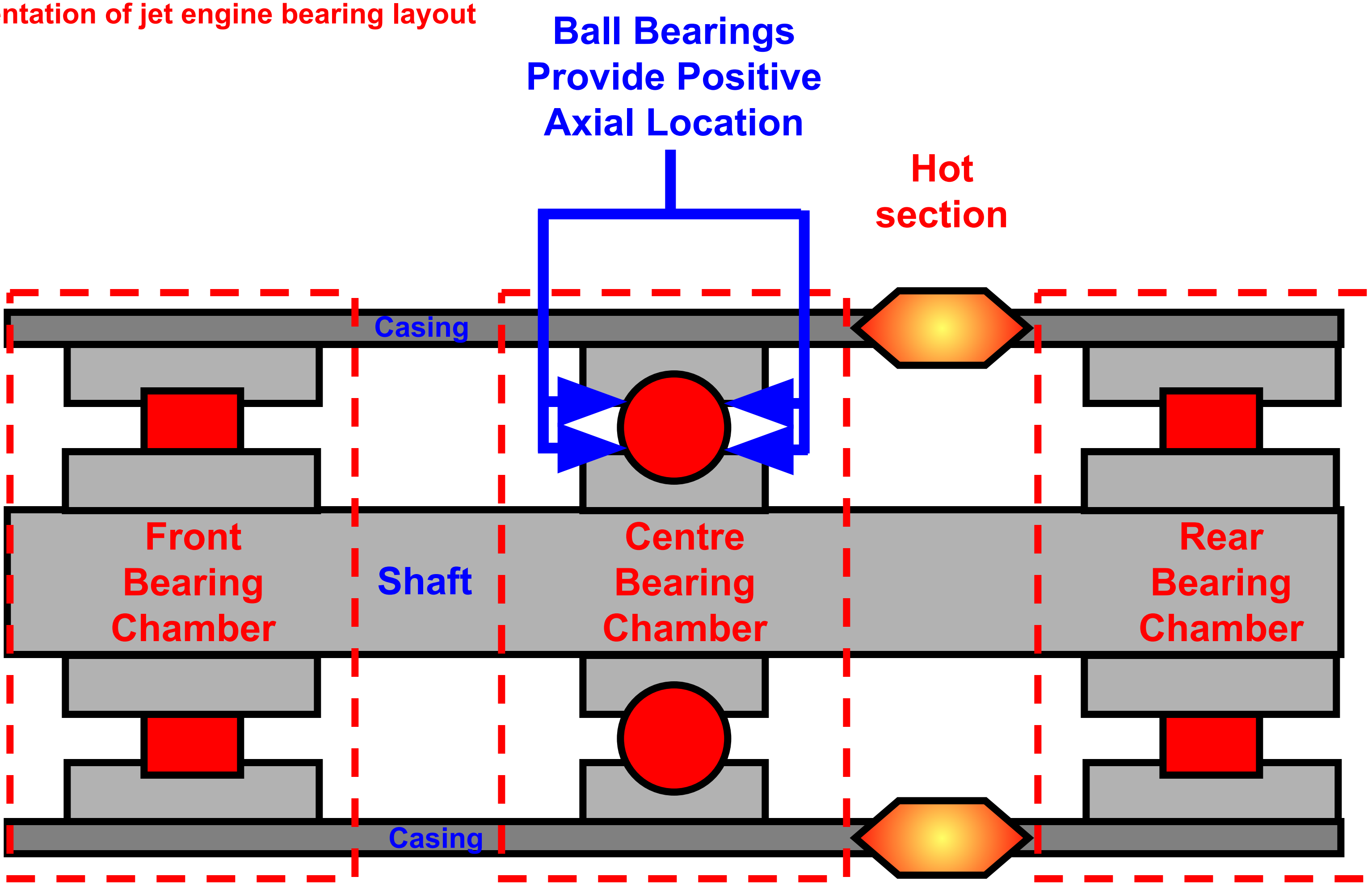
JET ENGINE MECHANICAL ARRANGEMENT

Bearing Chambers



JET ENGINE MECHANICAL ARRANGEMENT

Representation of jet engine bearing layout

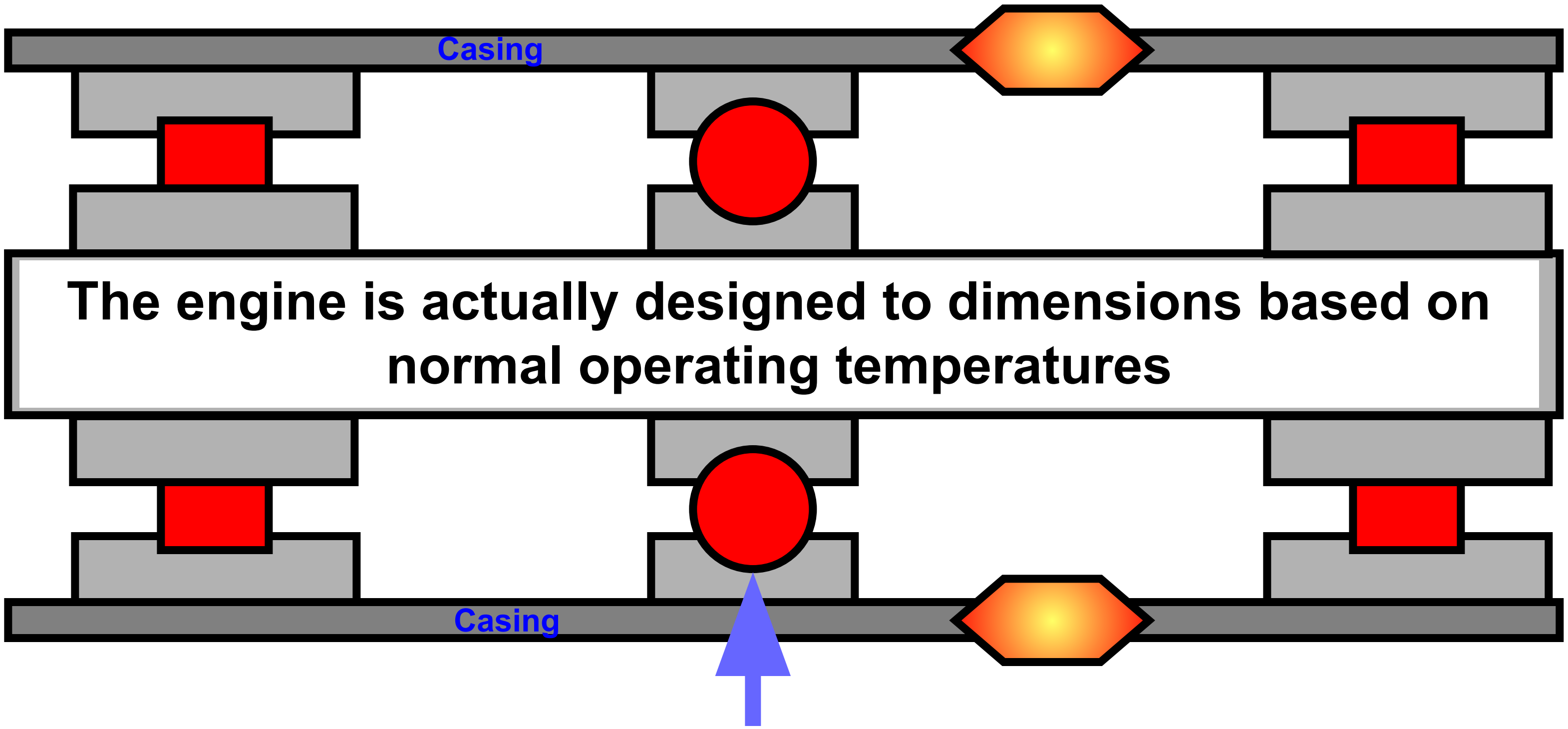


JET ENGINE MECHANICAL ARRANGEMENT

Representation of jet engine layout

The same happens at the front with pressured air and heat sink from the combustor heating the hardware

The casing expands first - pushing the rear outer bearing with it



Shaft and Casing have no differential movement at this point

JET ENGINE MECHANICAL ARRANGEMENT

JET ENGINE COMBUSTOR OPERATION

WHERE THE POWER IS PRODUCED

THE COMBUSTION PROCESS

IN A PISTON ENGINE: -

FUEL IS MIXED WITH AIR *BEFORE* ENTERING THE CYLINDERS

THE FUEL/AIR MIXTURE IS THEN COMPRESSED

THEN IT IS IGNITED BY A SPARK

ONCE FOR TWO REVS OF THE ENGINE (IN THE 4 STROKE CYCLE)

IN A JET ENGINE: -

AIR IS COMPRESSED AND FORCED INTO THE COMBUSTOR FIRST

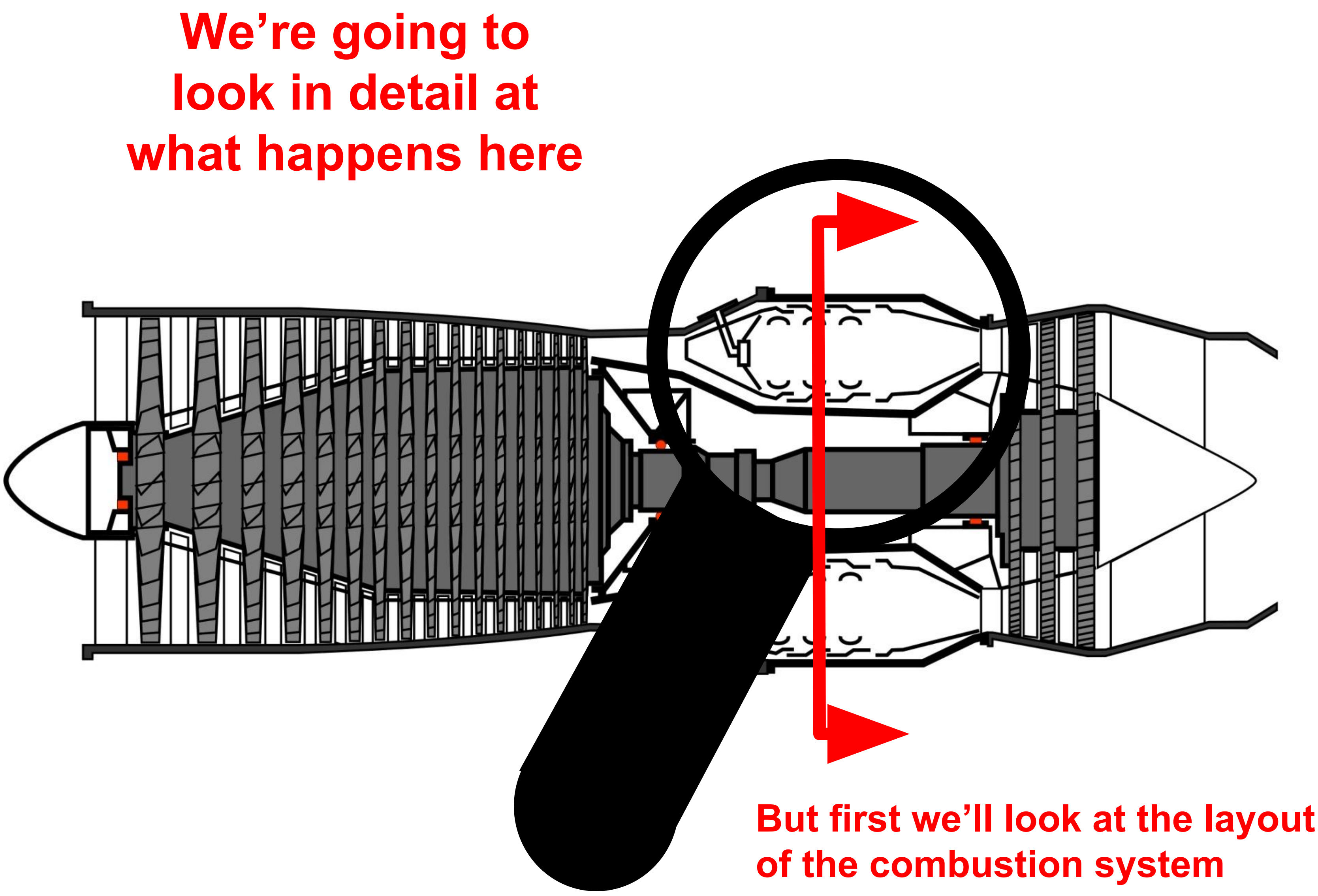
THEN THE FUEL IS SPRAYED IN UNDER PRESSURE

IT IS THEN IGNITED BY A SPARK (BUT ONLY ONCE FOR STARTING)

COMBUSTION IS THEN *CONTINUOUS* WHILST THE ENGINE IS RUNNING

THE SAME AS A PLUMBERS BLOW TORCH!

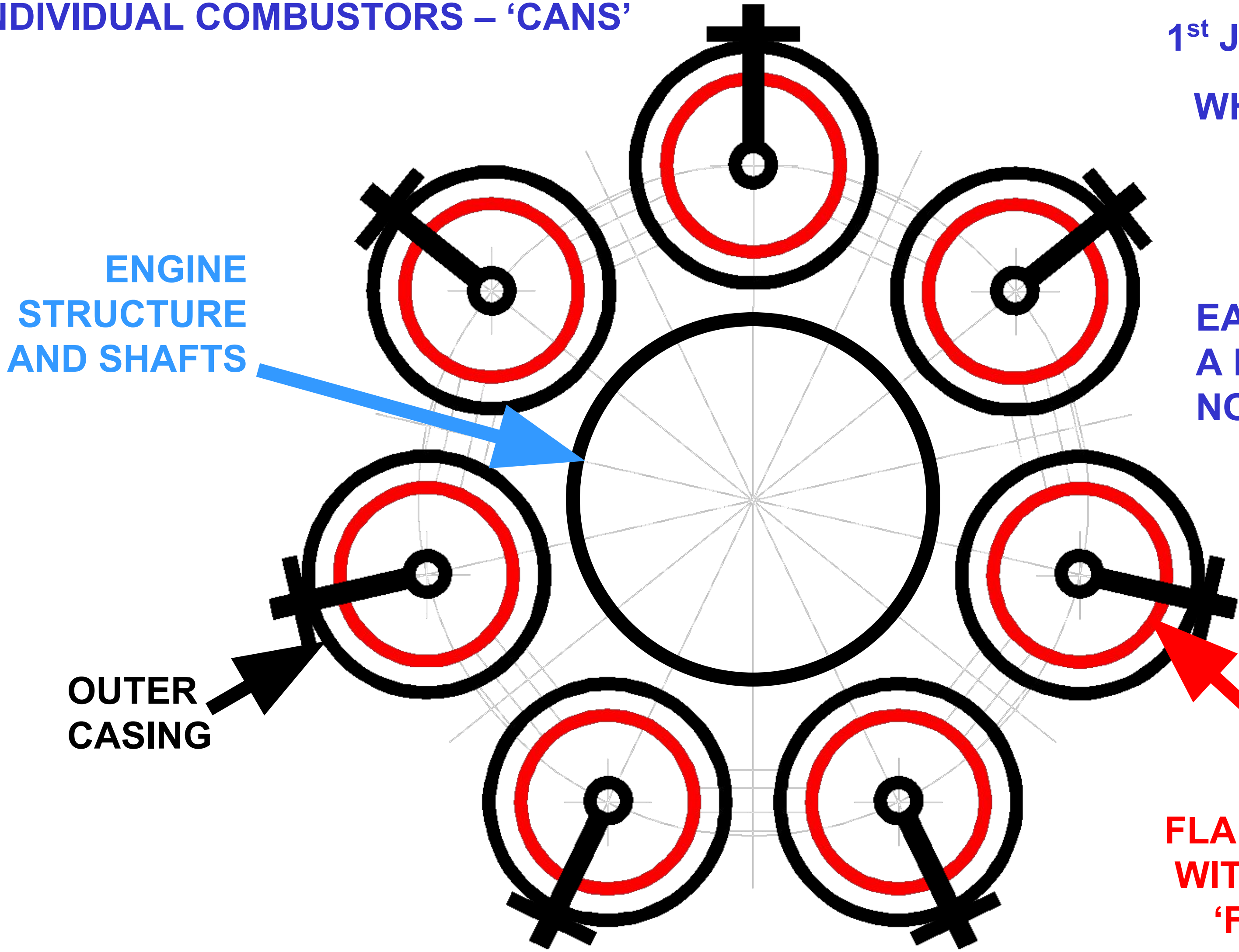
JET ENGINE – Combustion Process



JET ENGINE – Combustor Layout

COMBUSTOR LAYOUT – (ALSO HISTORICAL DEVELOPMENT)

INDIVIDUAL COMBUSTORS – 'CANS'



1st JET ENGINES

WHITTLE ETC

EACH CAN HAS A FUEL SPRAY NOZZLE (FSN)

FLAME CONTAINED WITHIN THIS TUBE 'FLAME-TUBE'

JET ENGINE – Combustor Layout

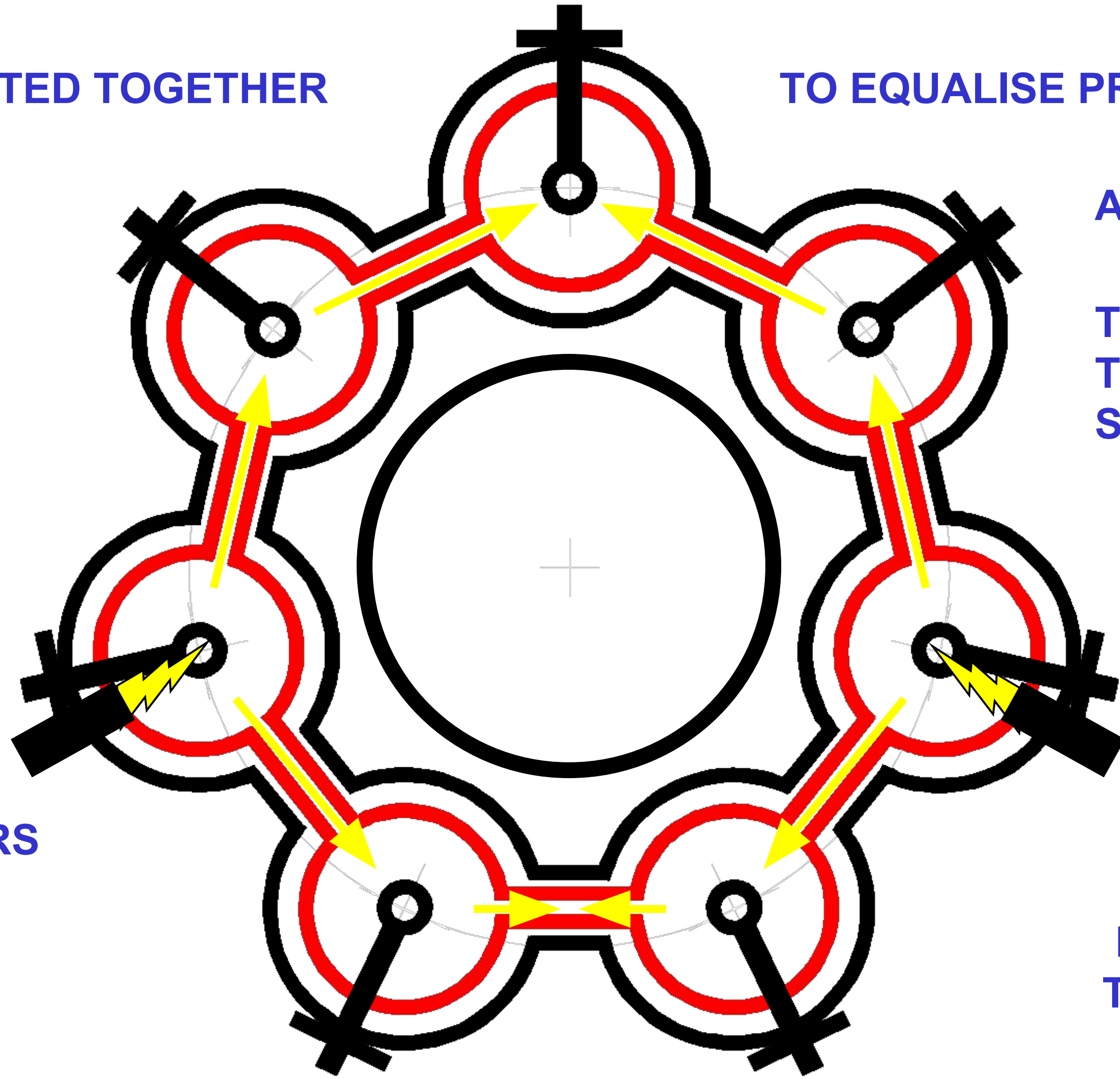
COMBUSTOR LAYOUT – (ALSO HISTORICAL DEVELOPMENT)

CANS CONNECTED TOGETHER

TO EQUALISE PRESSURES

AND

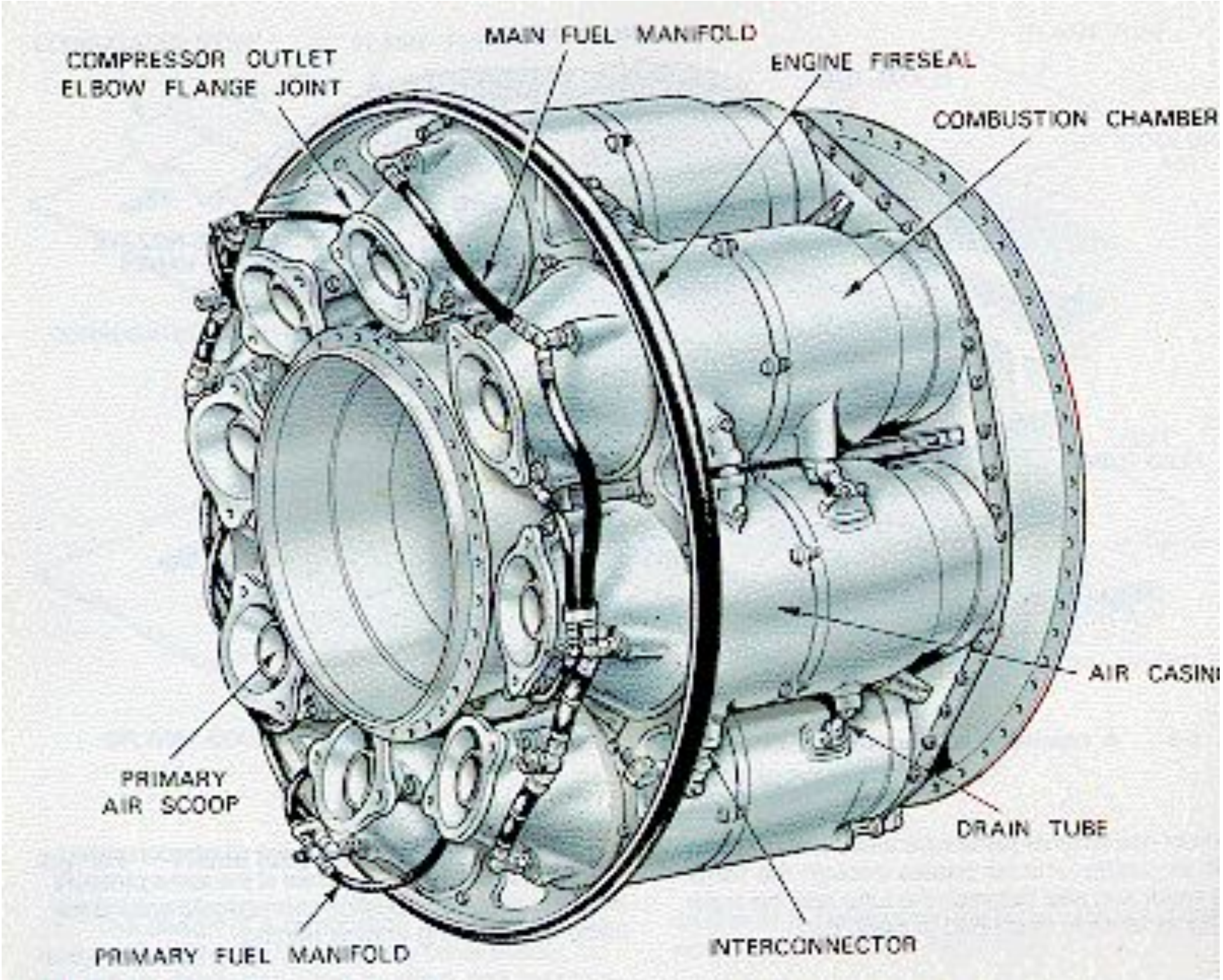
TO SPREAD
THE FLAME ON
START UP



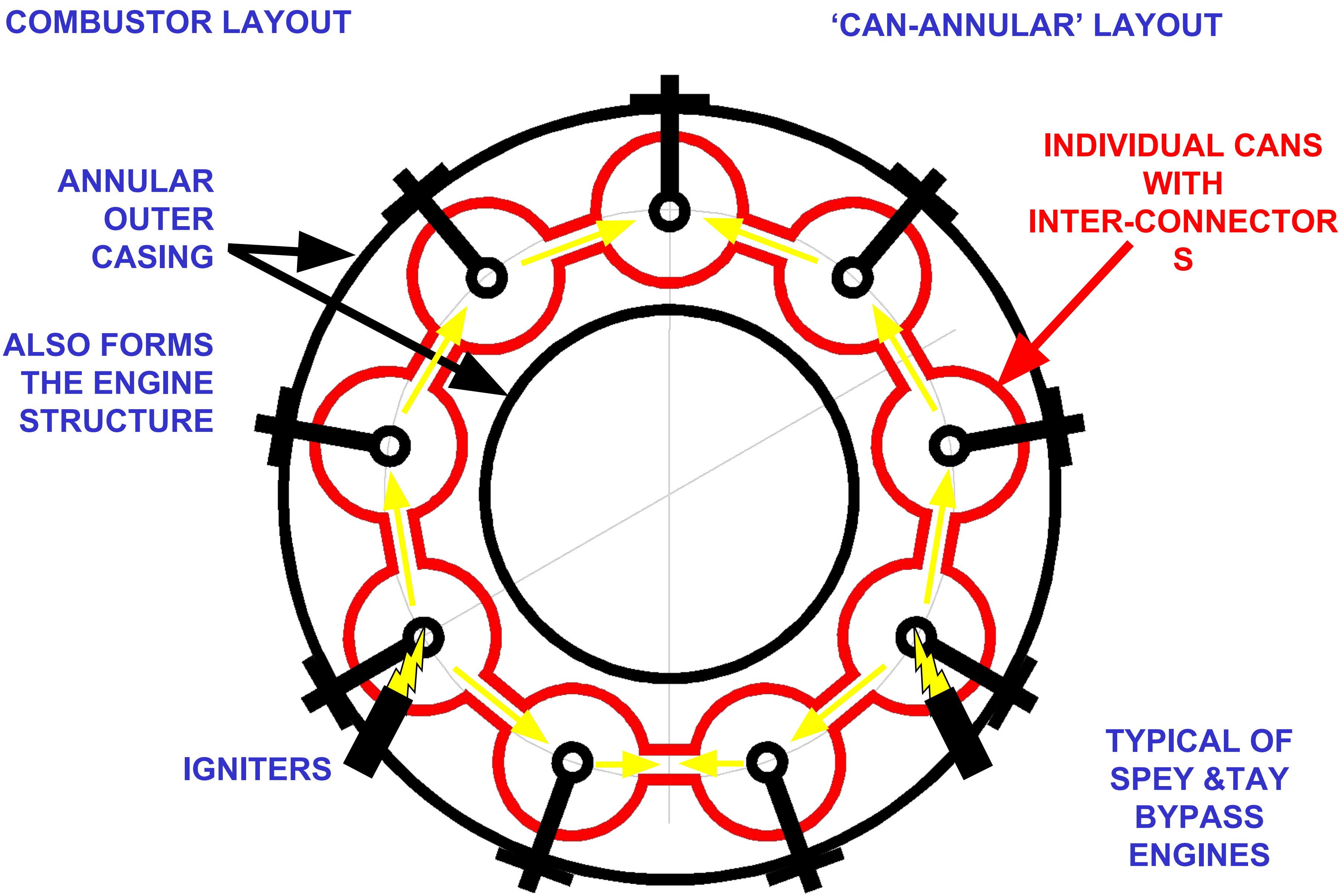
IGNITERS

TYPICAL OF
DART SERIES
TURBO PROPS

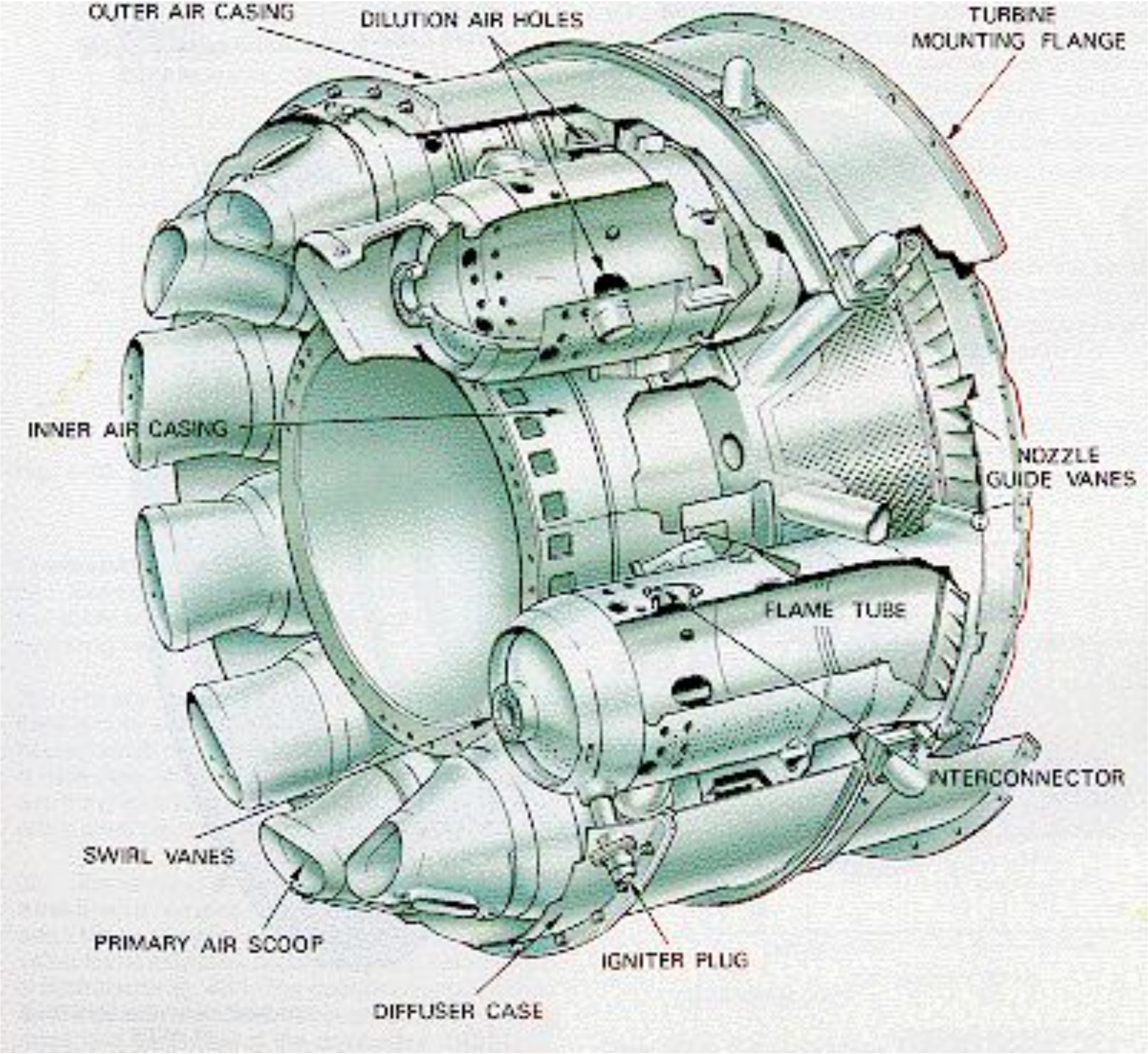
JET ENGINE – Combustor Layout



JET ENGINE COMBUSTER OPERATION



JET ENGINE – Combustor Layout

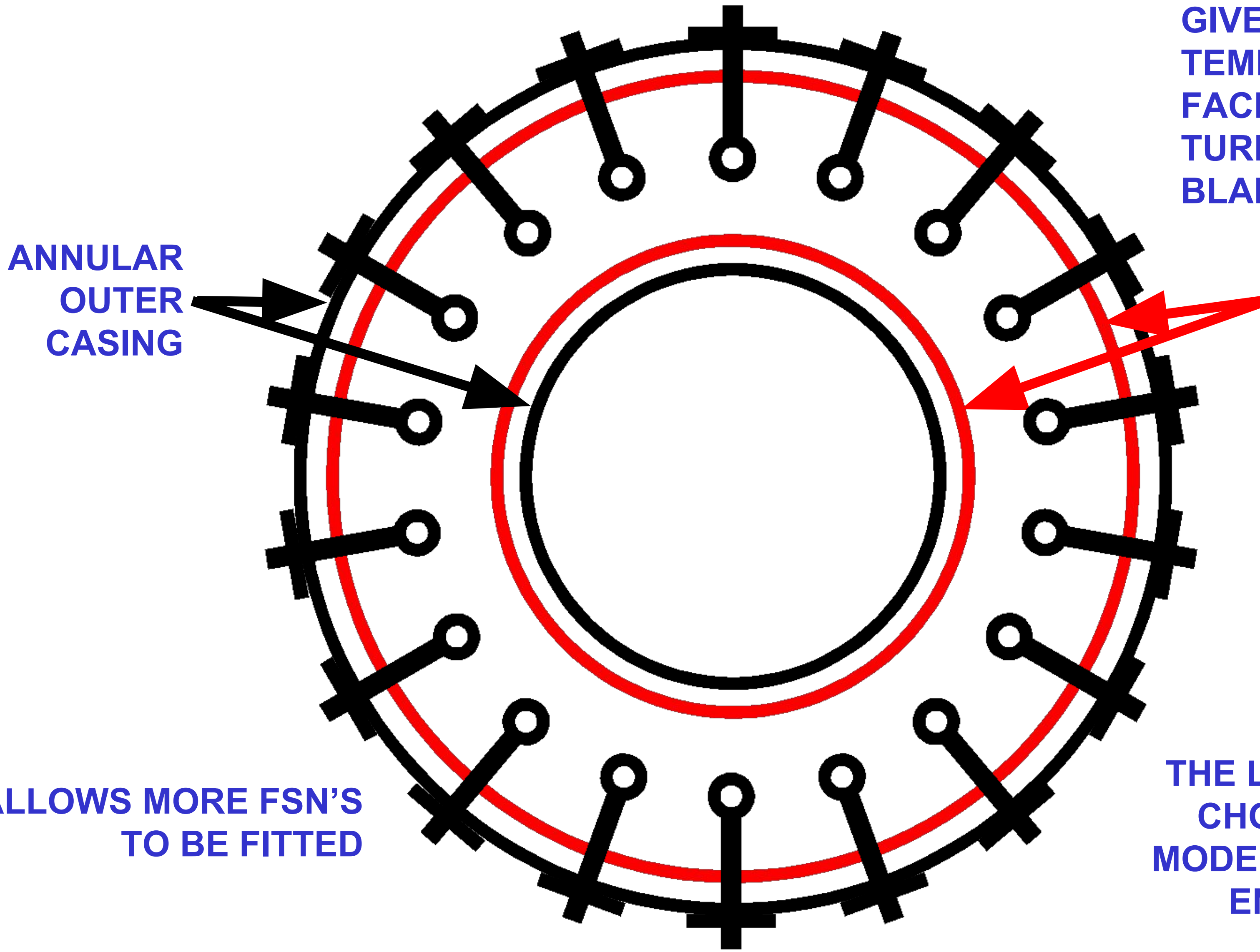


JET ENGINE COMBUSTER OPERATION

COMBUSTOR LAYOUT

ANNULAR LAYOUT

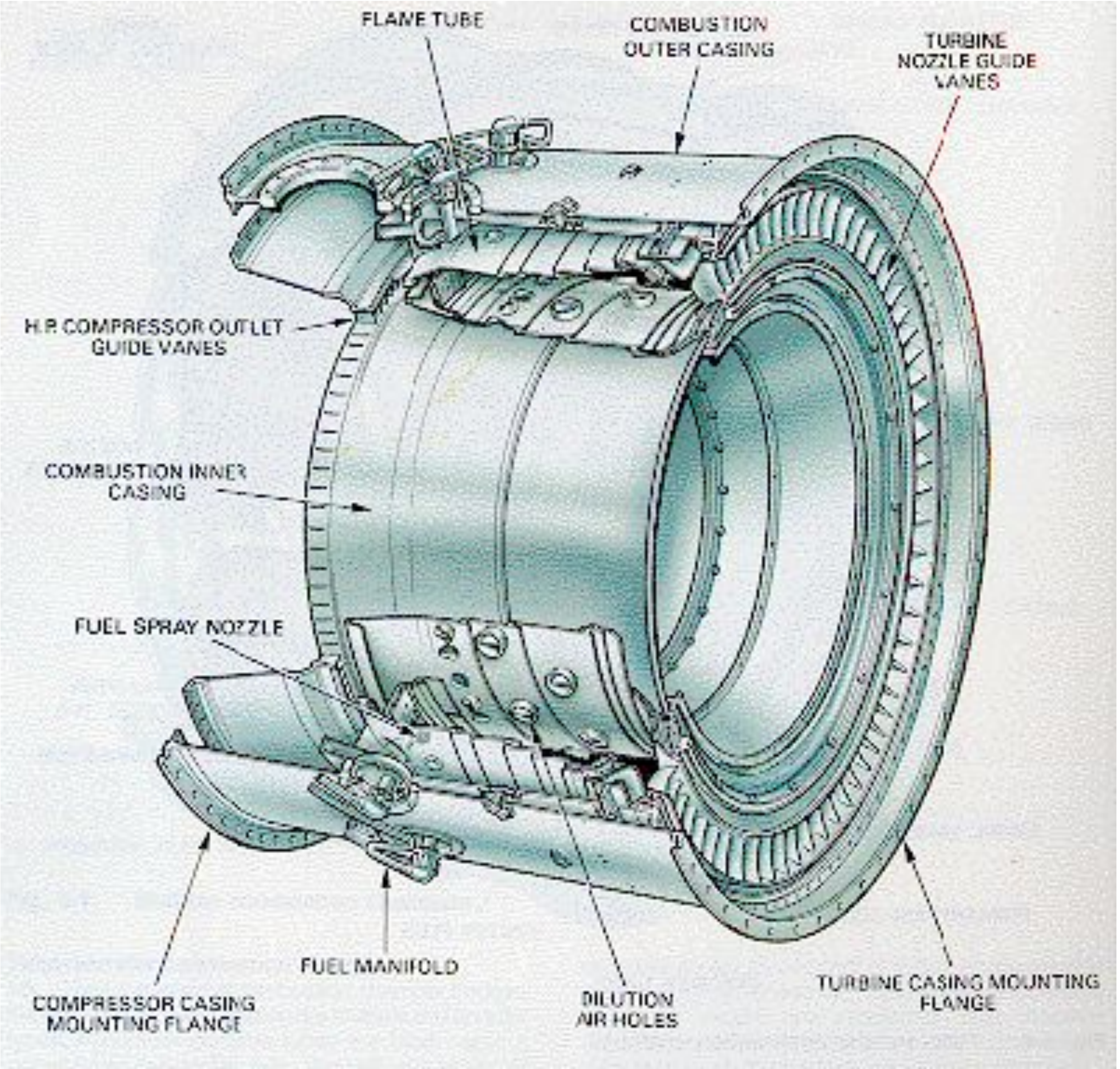
GIVES EVEN TEMPERATURE FACE TO TURBINE BLADES



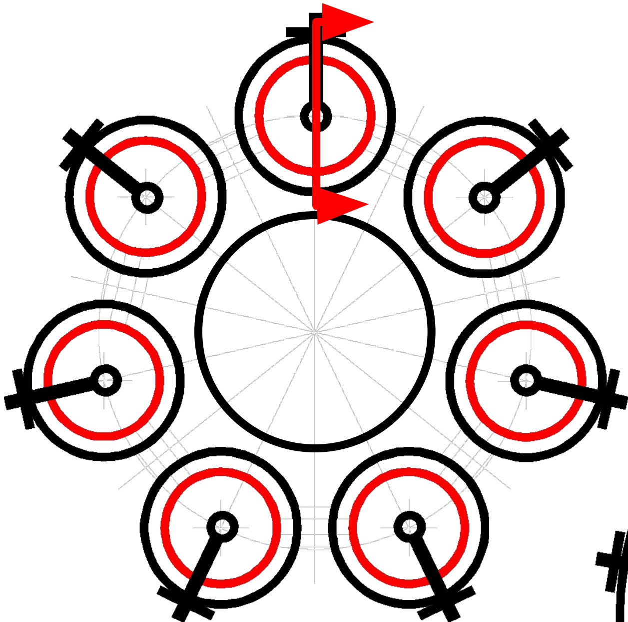
ALLOWS MORE FSN'S TO BE FITTED

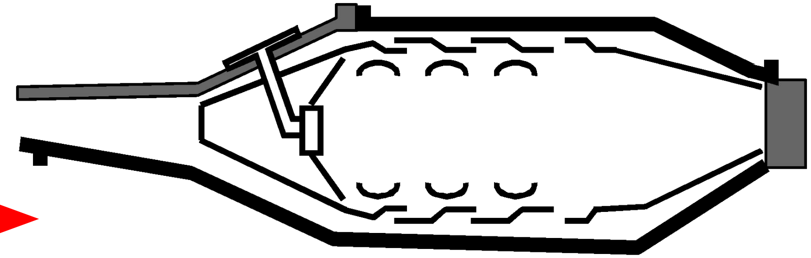
THE LAYOUT OF CHOICE FOR MODERN BYPASS ENGINES

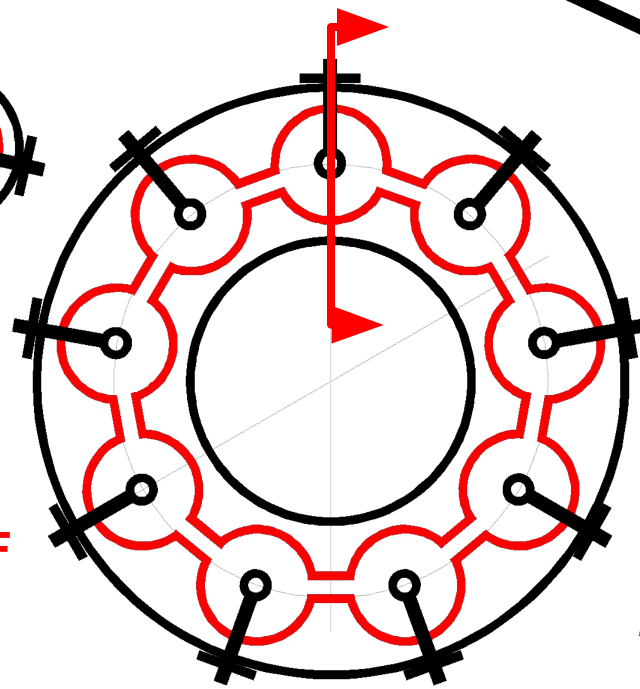
JET ENGINE – Combustor Layout

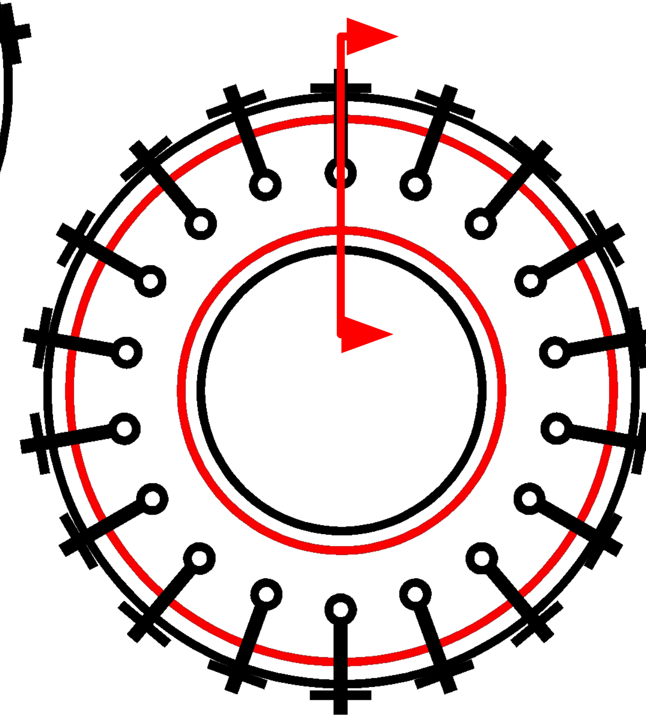


JET ENGINE COMBUSTER OPERATION





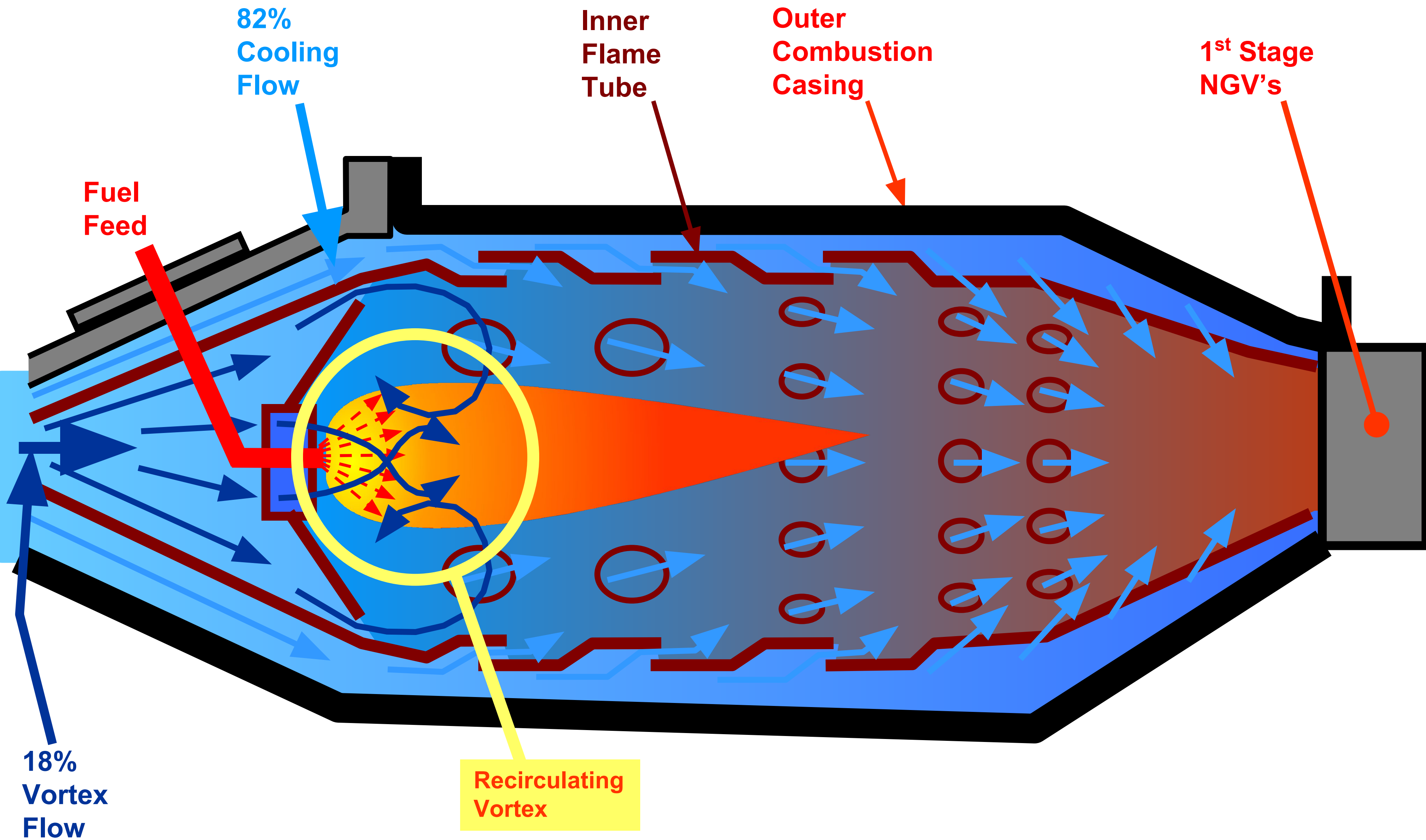




THE CROSS SECTION OF ALL THESE LAYOUTS IS VIRTUALLY IDENTICAL

AND THEREFORE SO IS THE AIRFLOW!

JET ENGINE – Combustor Layout



JET ENGINE – Combustion Process

JET ENGINE OPERATION

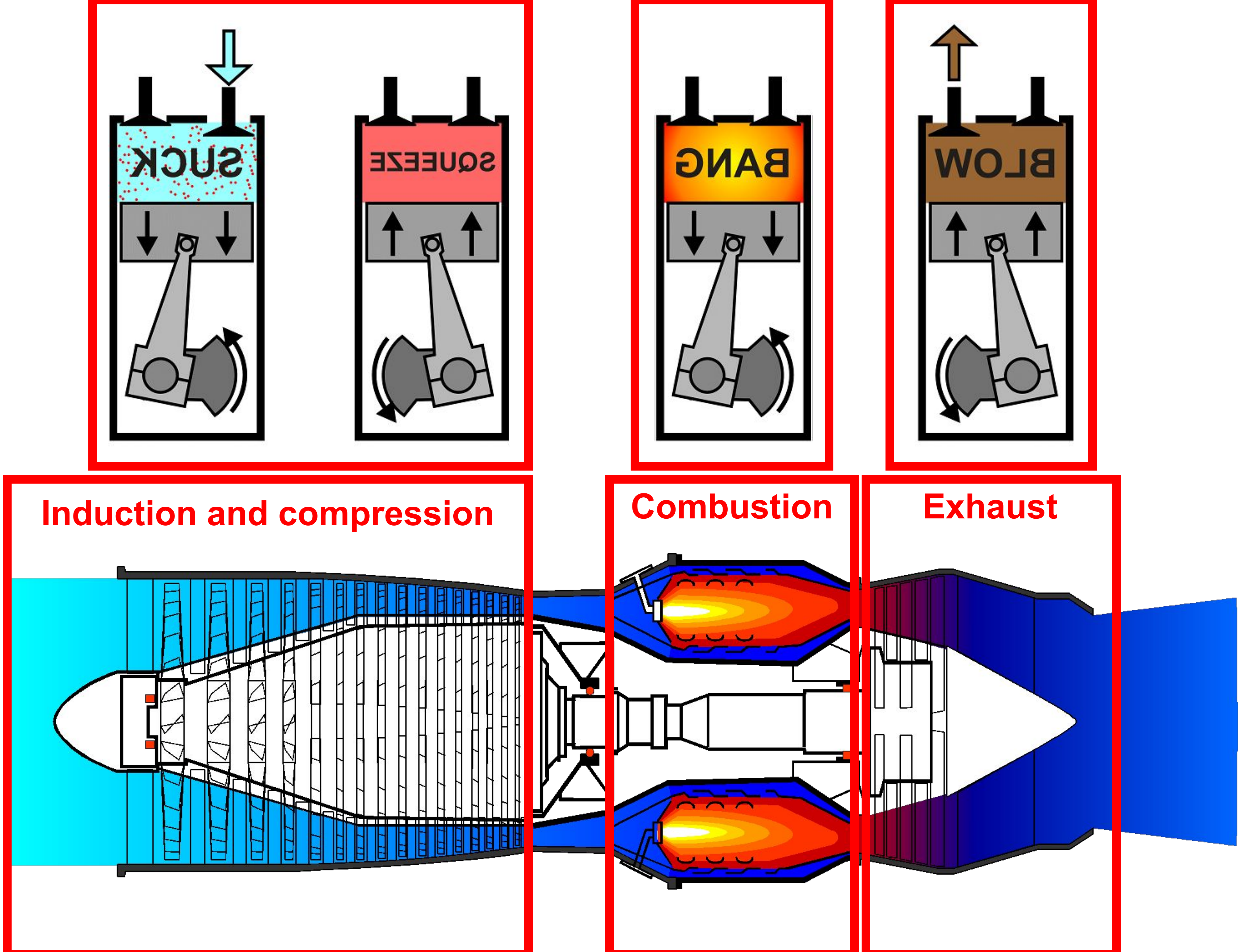
JET ENGINE HAVE THE SAME OPERATING CYCLE AS A PISTON ENGINE

I.E. SUCK - SQUEEZE - BANG - BLOW

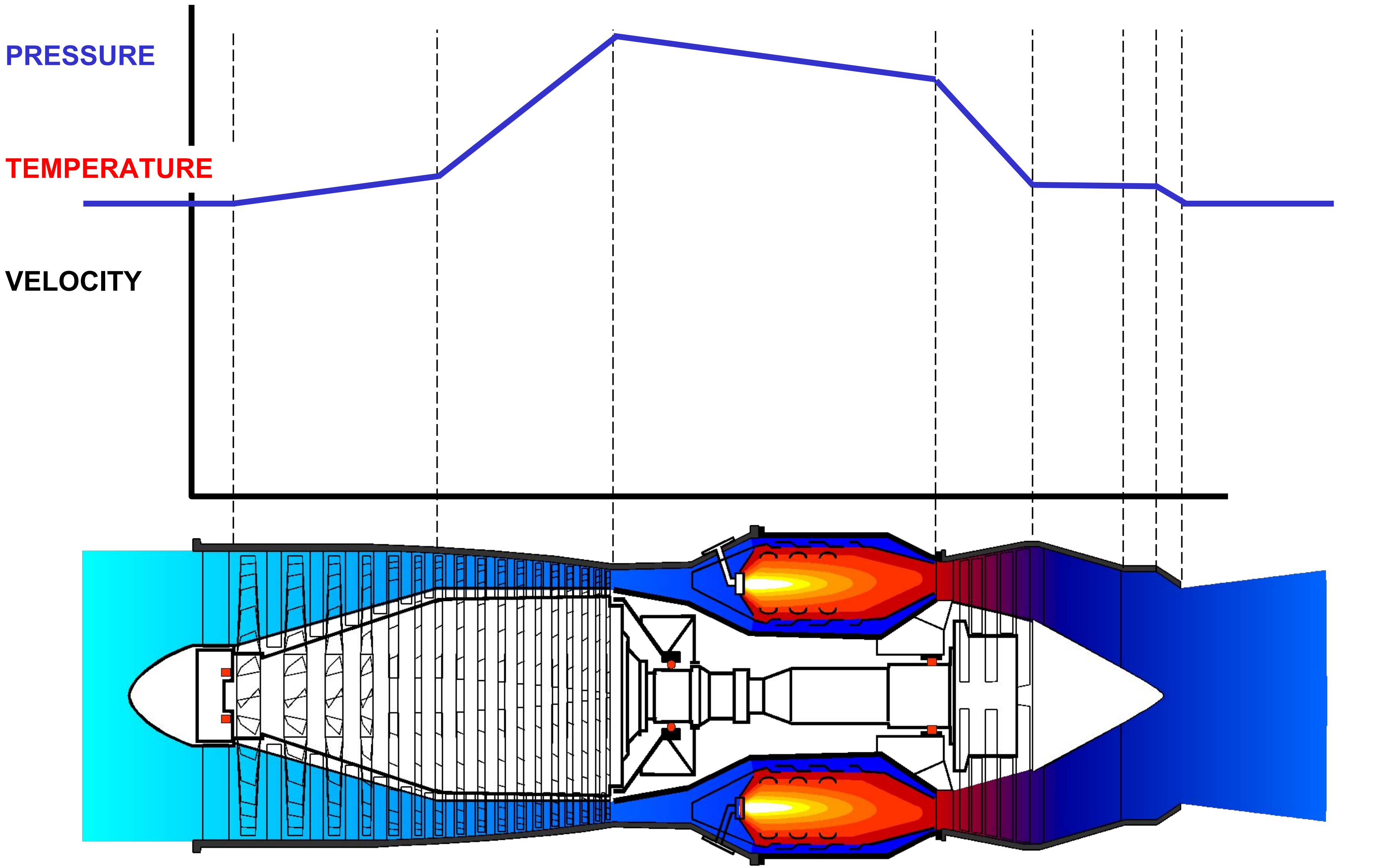
EXCEPT: -

PISTON ENGINES HAVE AN *INTERMITTENT* CYCLE

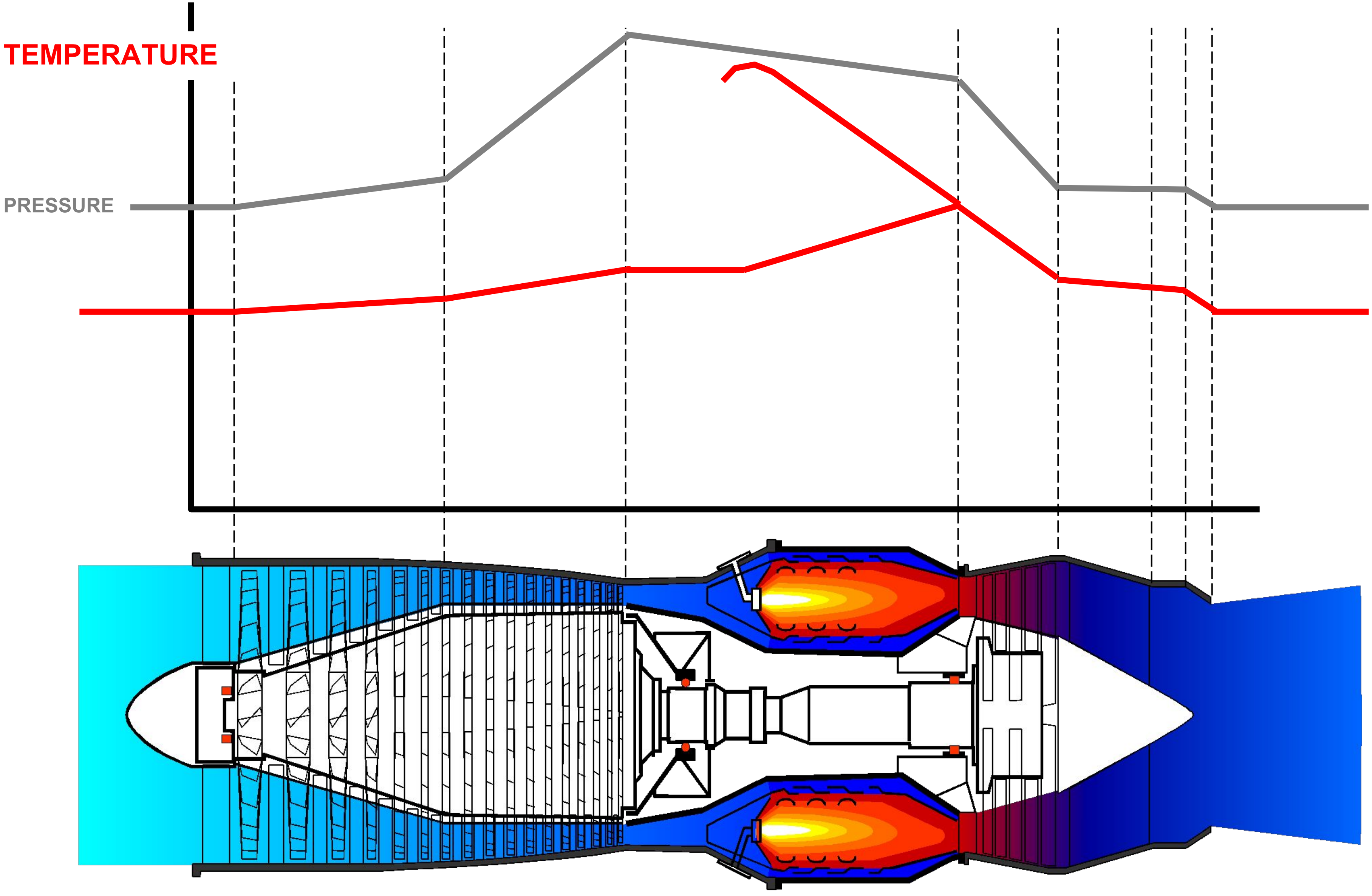
JET ENGINES HAVE A *CONTINUOUS* CYCLE



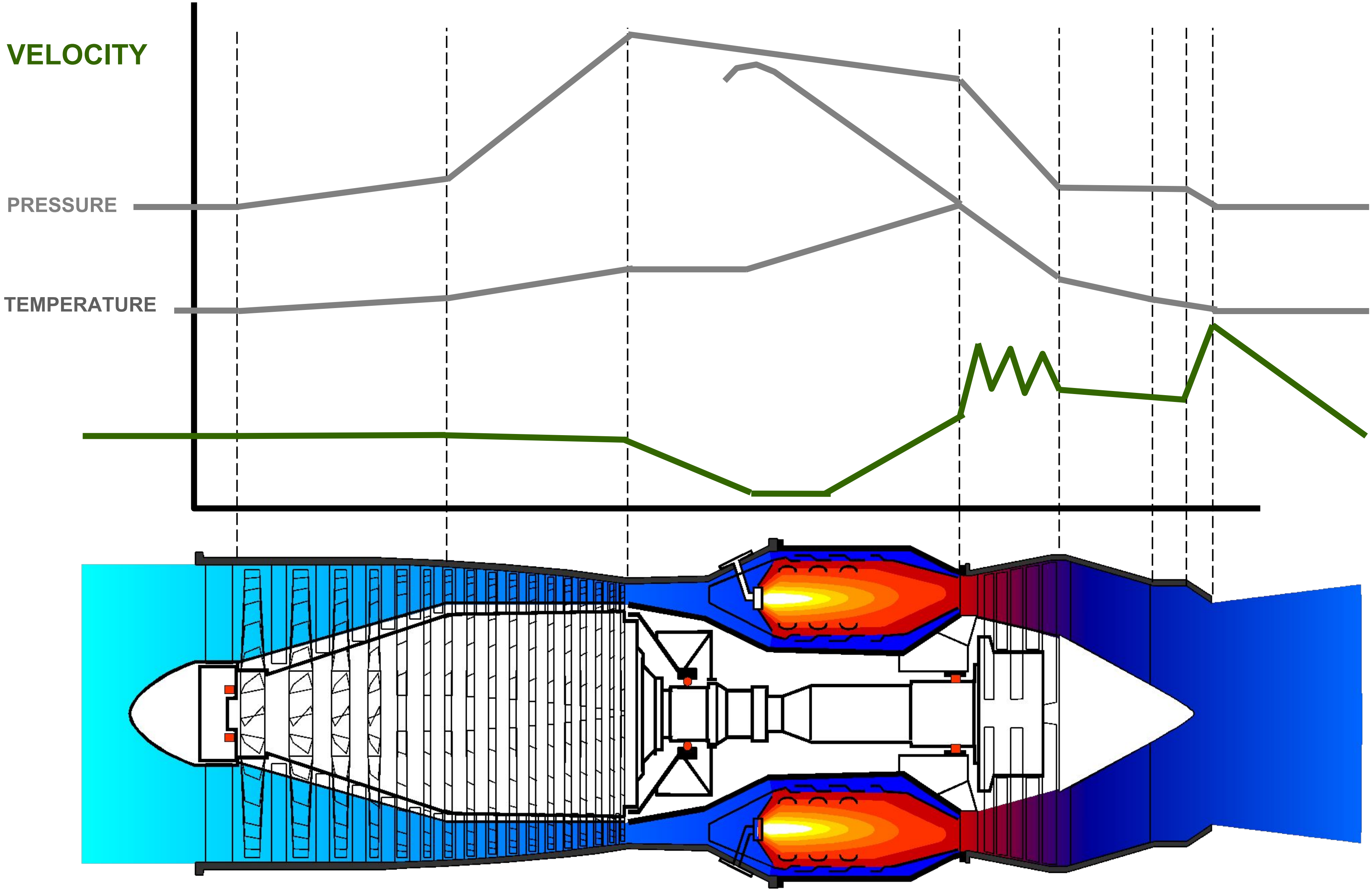
GAS TURBINE OPERATION



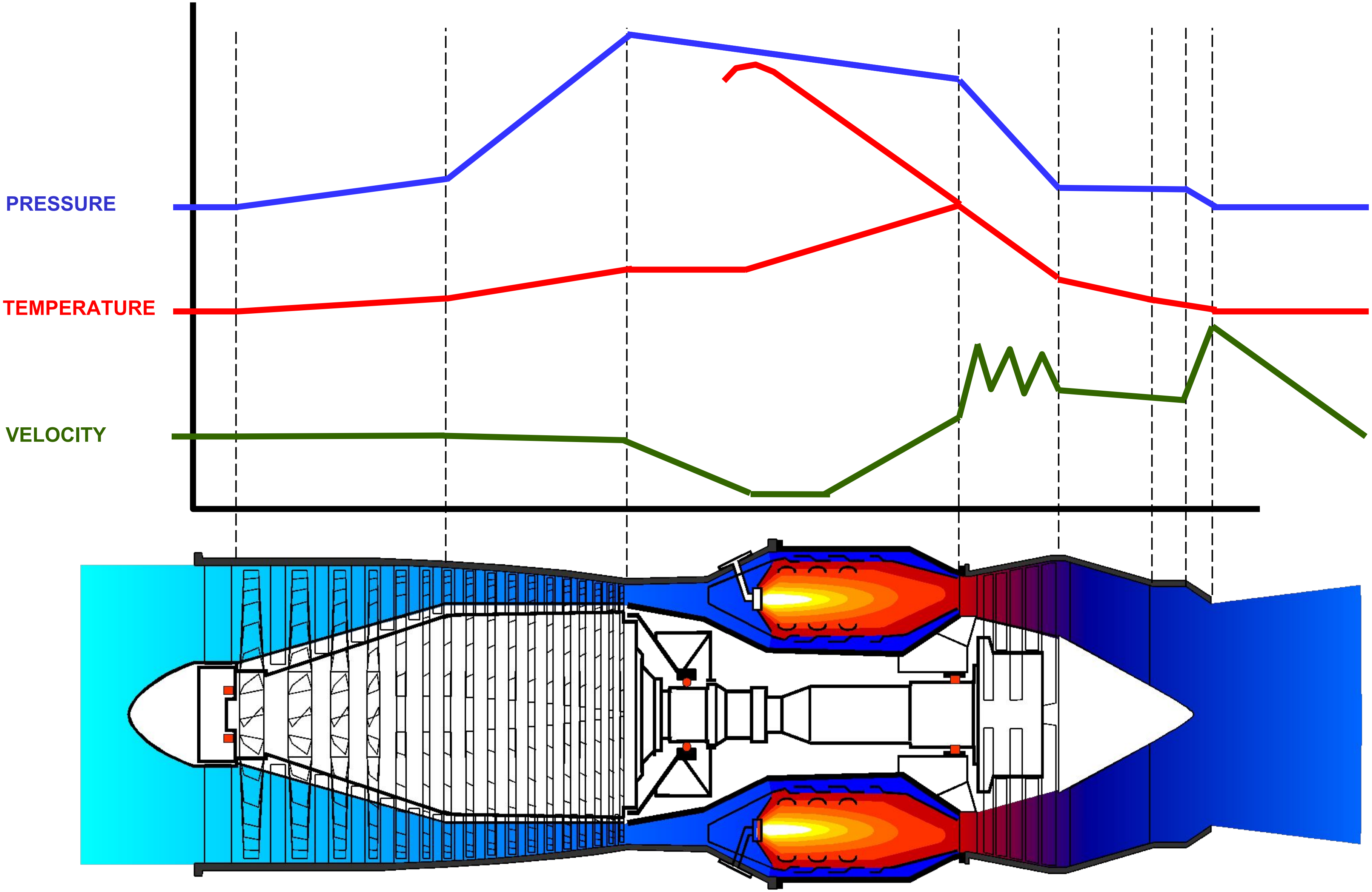
GAS TURBINE OPERATION



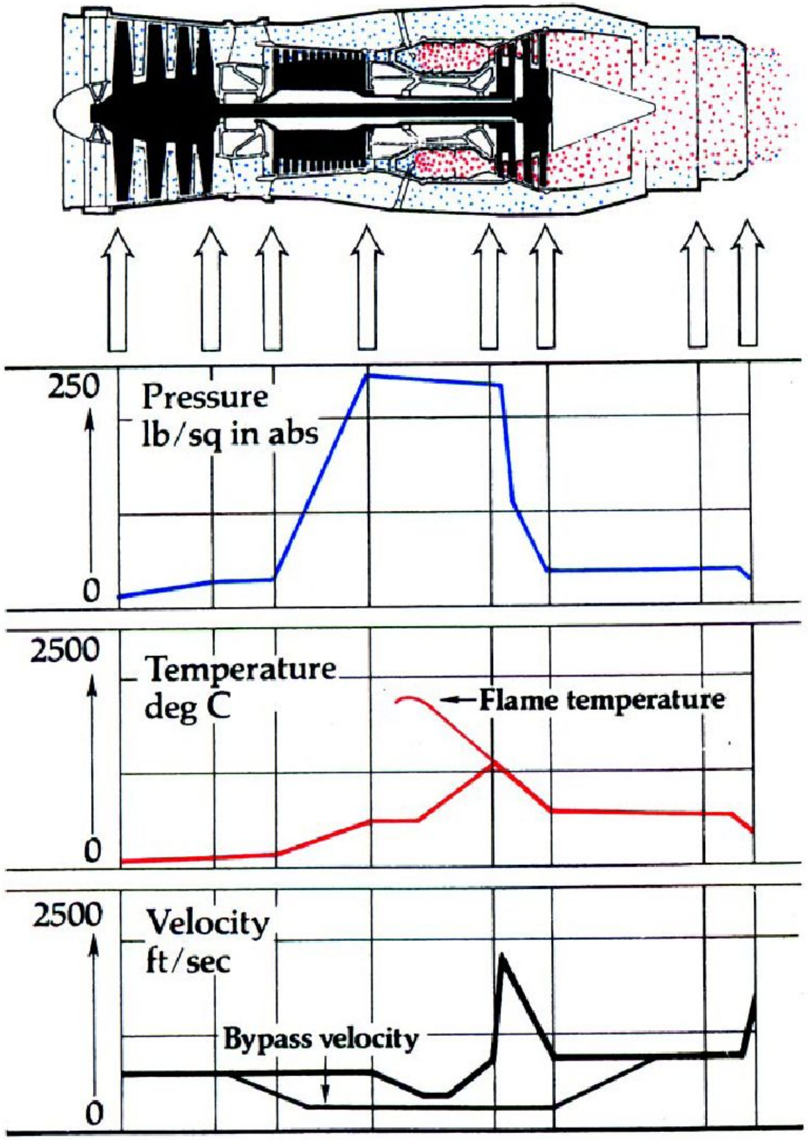
GAS TURBINE OPERATION



GAS TURBINE OPERATION



GAS TURBINE OPERATION



GAS TURBINE OPERATION

JET ENGINE TYPES

Different types of Jet Engines

Different types: -

Turbo Jet		Avon, Olympus 593
Bypass Engine	Small Bypass	Spey, BR700
	Medium Bypass	Pegasus, BR715, V2500
	Large Bypass	RB211, Trent Series
Turbo Shaft	Propeller	Dart, Tyne, BR715TP
	Helicopter	Gem
	RN Ships	Marine Spey
	Power Generation	Industrial Spey and Trent

To understand what is meant by ‘Turbo Jet’, ‘Bypass’, ‘Turbo Prop and ‘Turbo Shaft’

We need to look at the development of Gas Turbine Engines

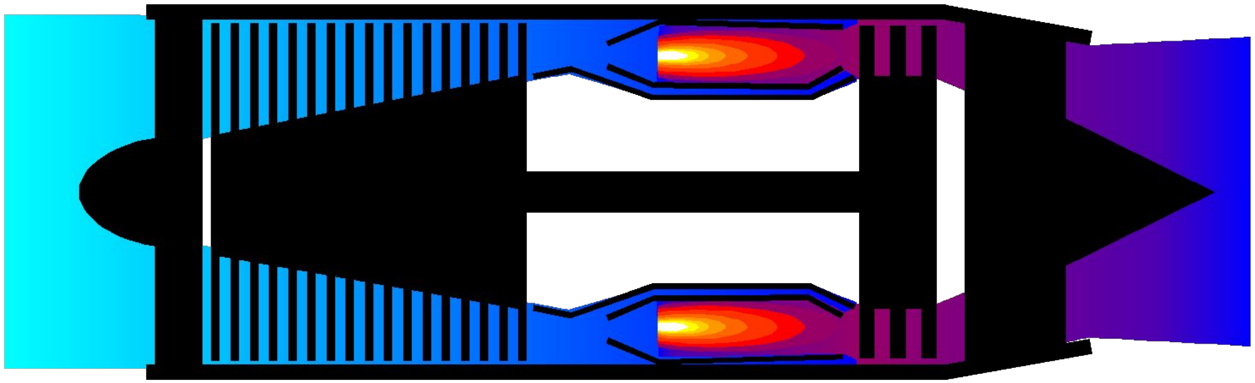
JET ENGINE TYPES

With RPM (I.e. Thrust) changes, the airflow velocity does not change in proportion to engine RPM

At low rpm – rear of compressor cannot get rid of all the air from the front of the compressor

Rolls-Royce AVON Basic Shape and Layout

Turbo Jet



17 Stage Compressor driven by: - a 3 Stage turbine

JET ENGINE TYPES

With RPM (I.e. Thrust) changes, the airflow velocity does not change in proportion to engine RPM

At low rpm – rear of compressor cannot get rid of all the air from the front of the compressor

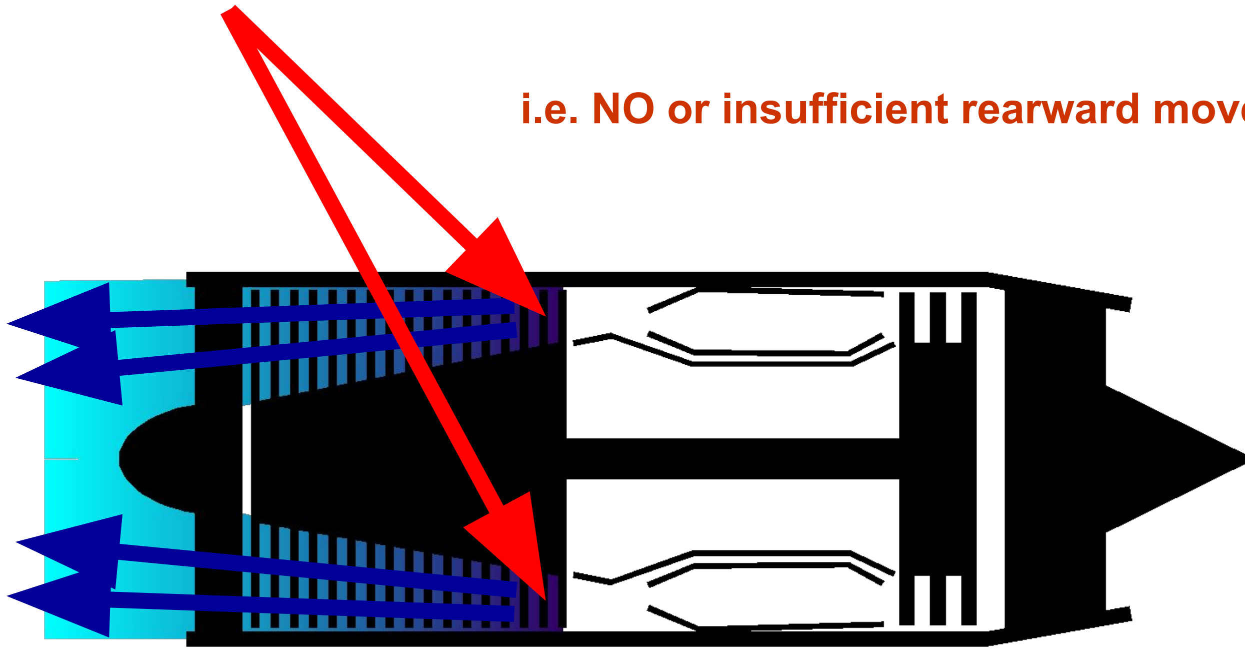
This can result in the rear end of compressor 'choking'

i.e. NO or insufficient rearward movement of air

So air

blasts

forwards



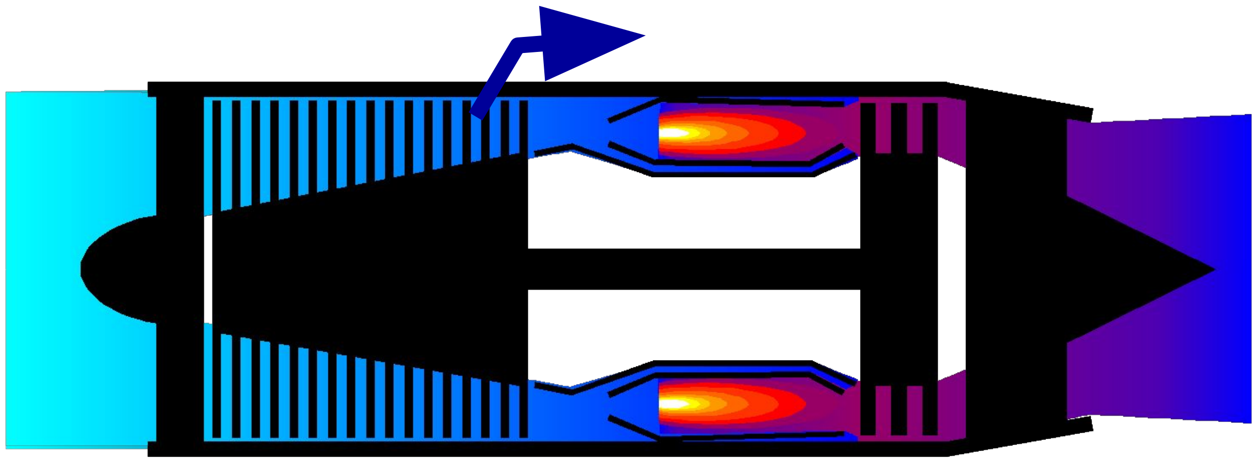
Flame almost goes out -
no power – no thrust

This is called: - Compressor SURGE

Rear end of compressor ‘unchoked’

Air dumped overboard

Rearward movement of air restored

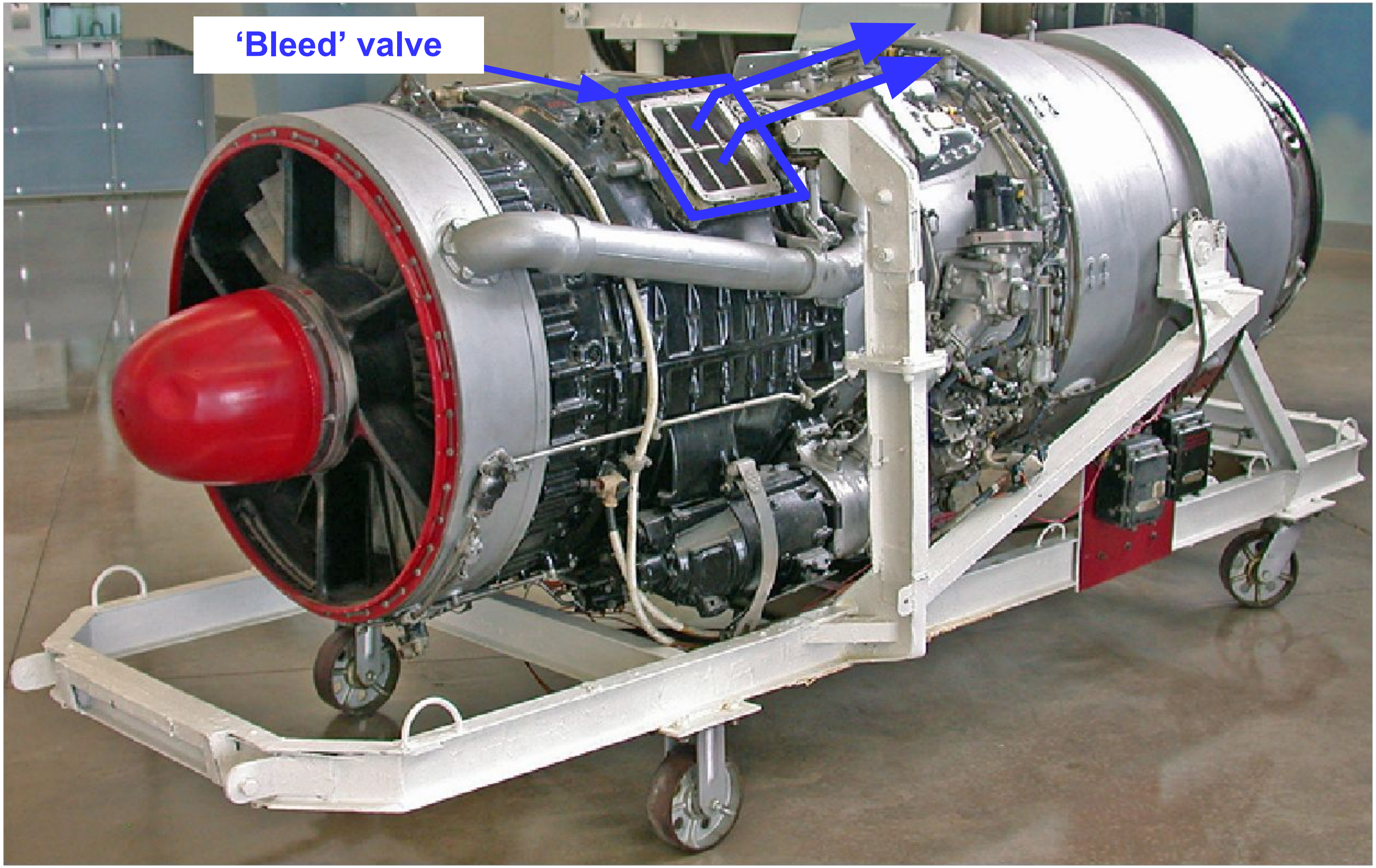


Power restored

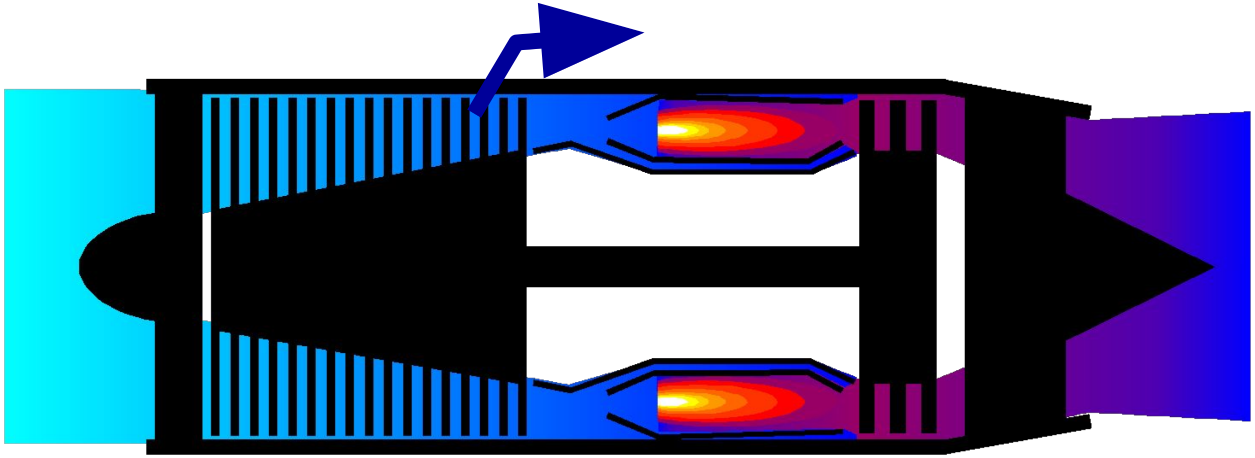
BUT: - air dumped sideways out of the engine (aircraft) produces no thrust

JET ENGINE TYPES

'Excess' air is dumped overboard through a valve



JET ENGINE TYPES



Air dumped overboard reduces thrust/wastes fuel

So a more efficient system was required

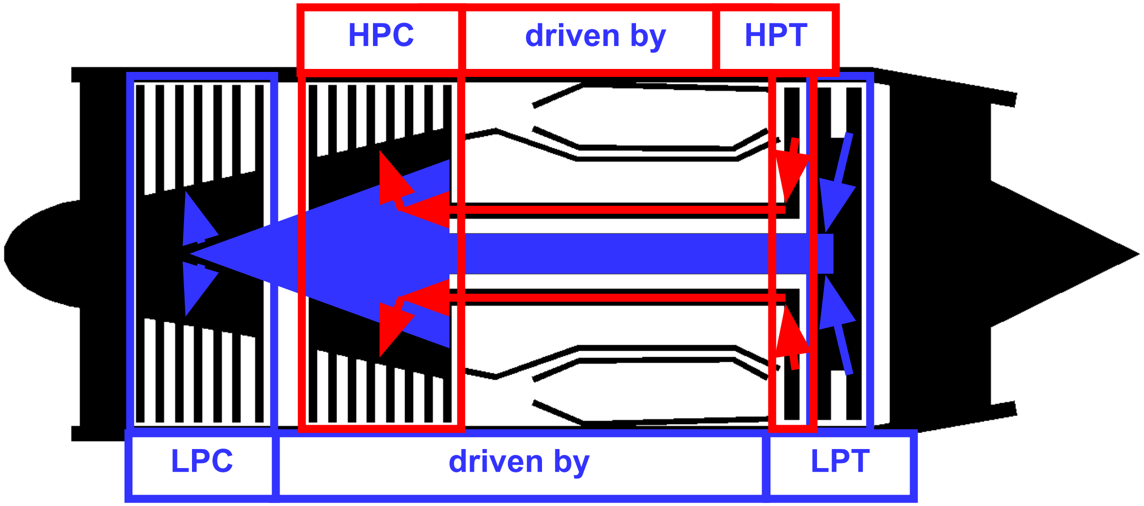
Enter - Multiple shaft engines and the Bypass system

JET ENGINE TYPES

Allows front end of compressor to slow down – move less air

AND

Allows rear end of compressor to speed up – move more air



Two shaft layout

Compressor surges lessened

No wasted energy/thrust

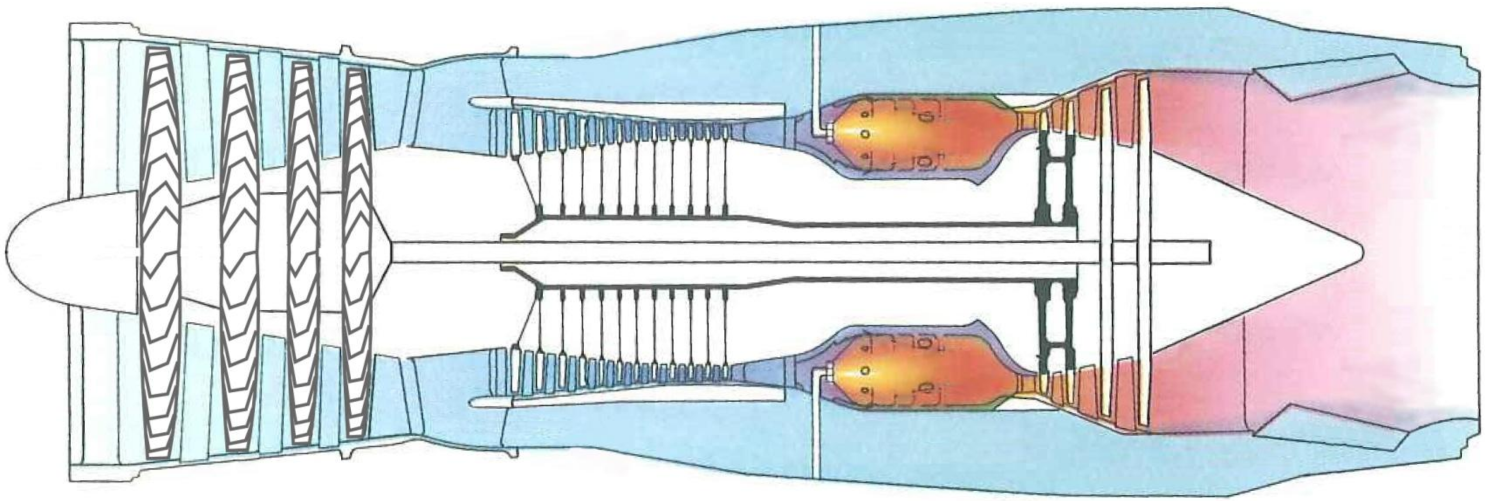
JET ENGINE TYPES

Bypass allows air not required in the HPC to flow around the outside of it

Rolls-Royce Spey

Adour

BR 710 series



Bypass Layout

Low Bypass

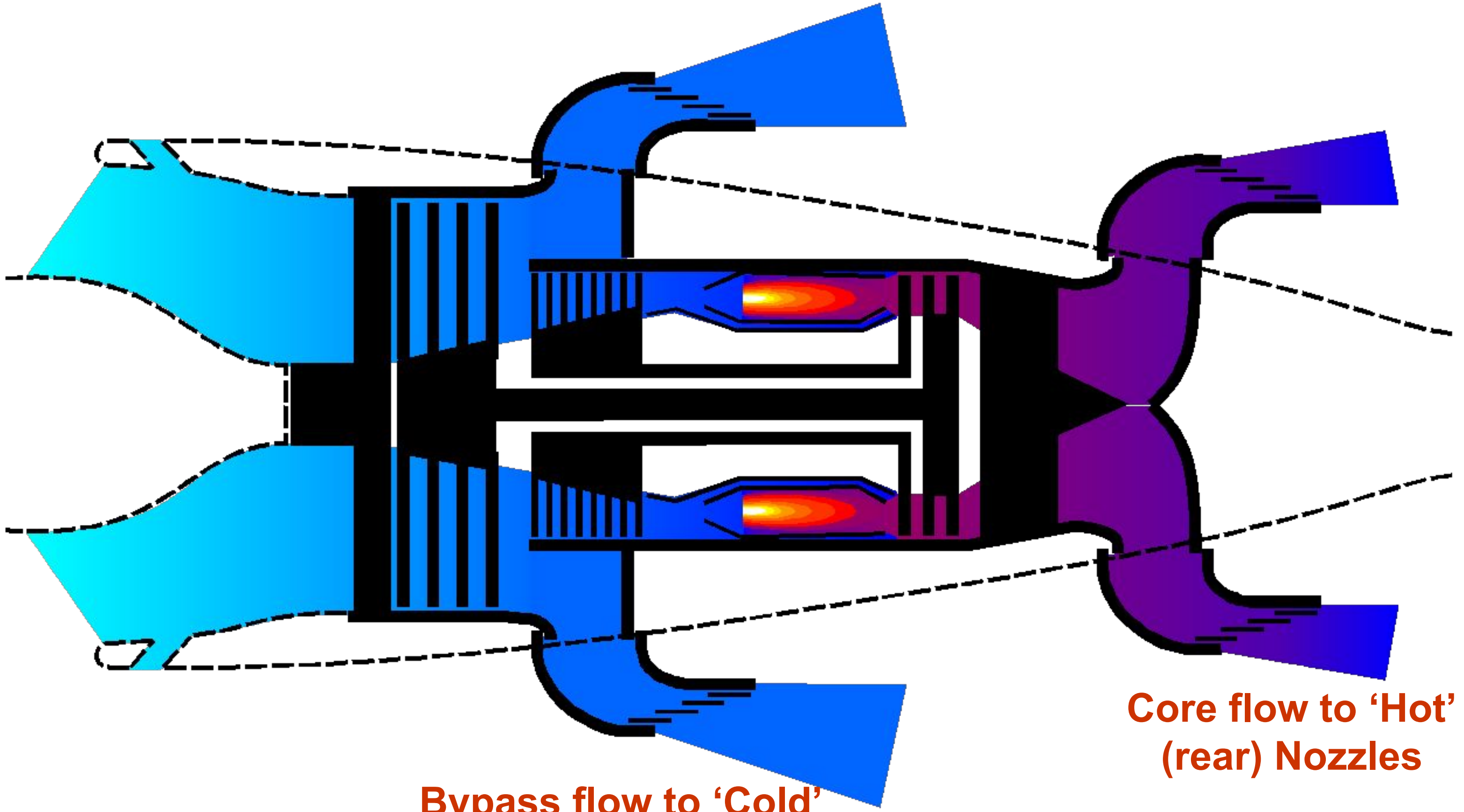
JET ENGINE TYPES

Pegasus

Two shaft layout – Contra-rotation – Medium Bypass

LP and HP AXIAL Flow Compressors

In RAF Service – Harrier series



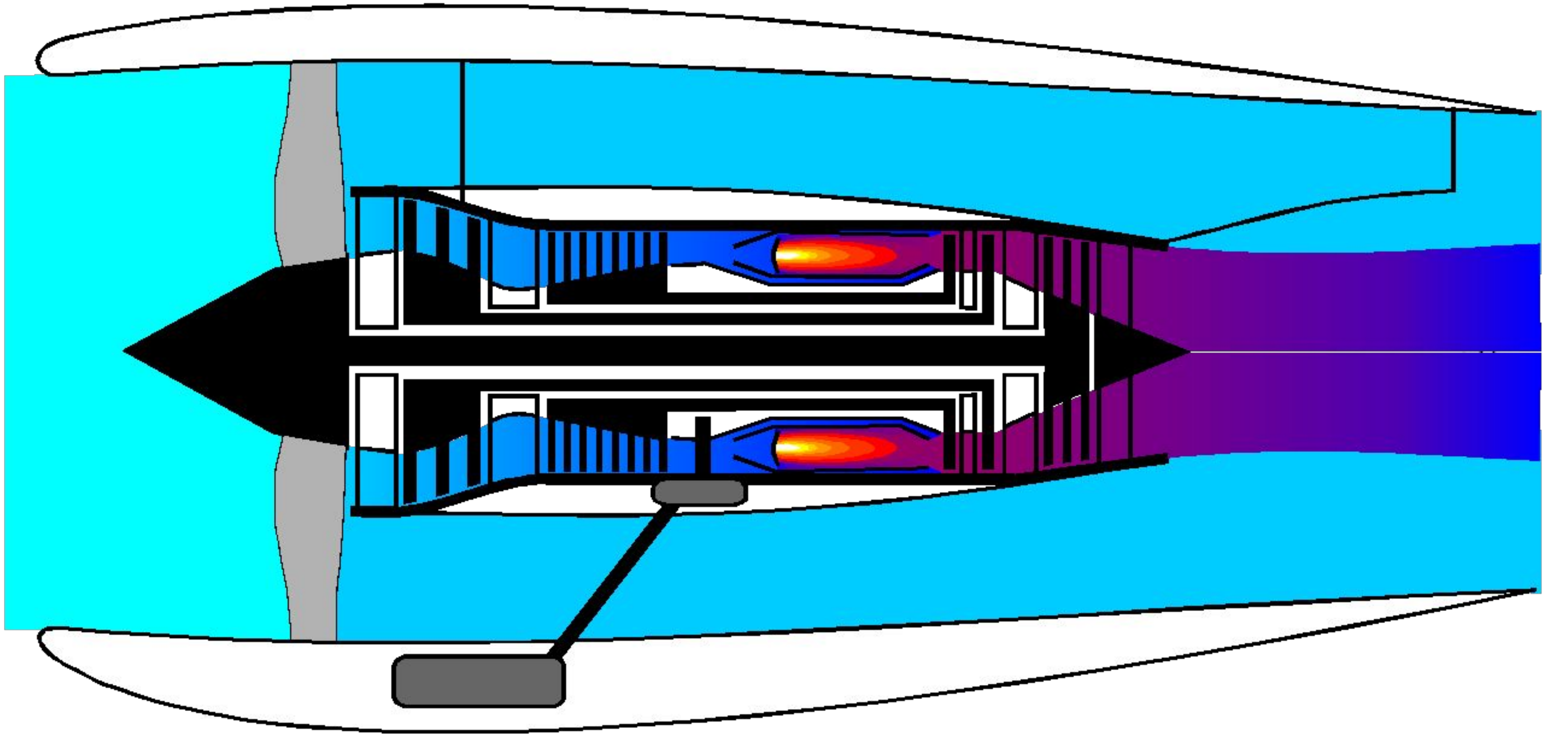
JET ENGINE TYPES

High Bypass Engine

RB211 Series (Trent)

Three shaft layout – all rotate same direction

LP(Fan) IP and HP AXIAL Flow Compressors



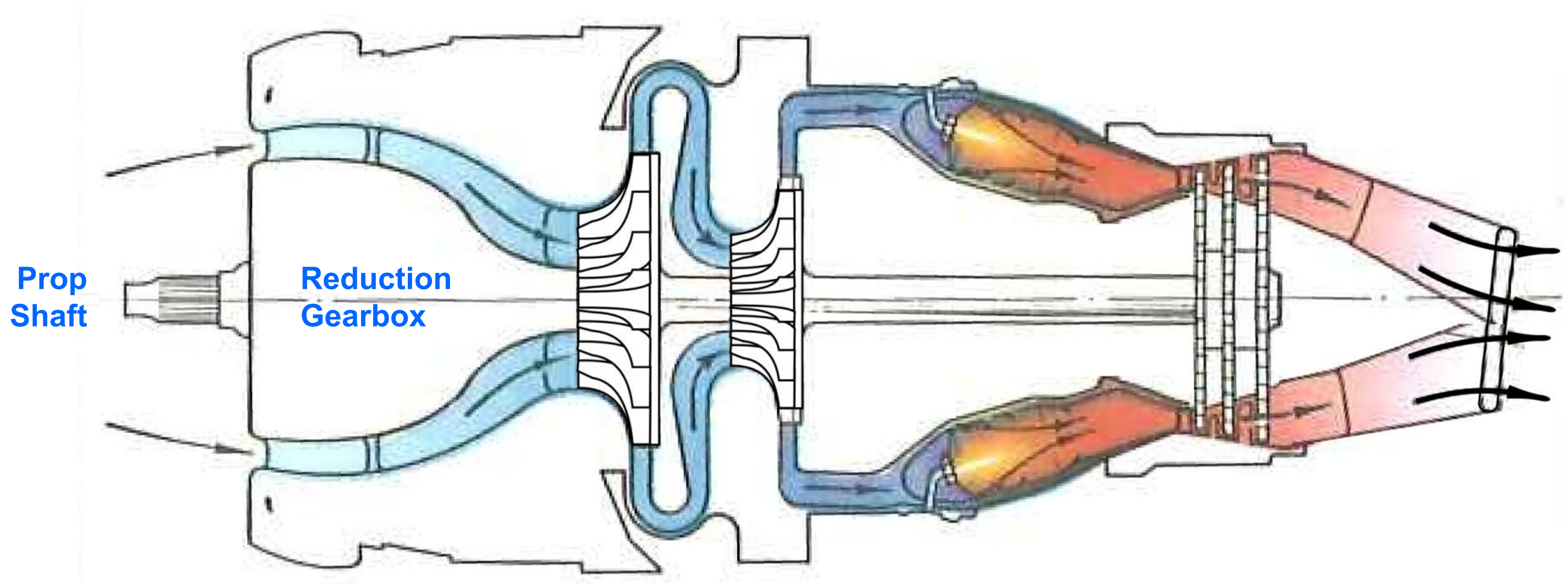
In service with RAF – Wide-body Tristar Tanker/Transport

Boeing 747 and later series, Airbus A330 and larger a/c

JET ENGINE TYPES

JET ENGINE TYPES

RR Dart Turbo Prop



Dart RDa6 = 2 stage turbine

Dart RDa7 = 3 stage turbine

Turbine drives 2 stage CENTRIFUGAL Compressor and Propeller

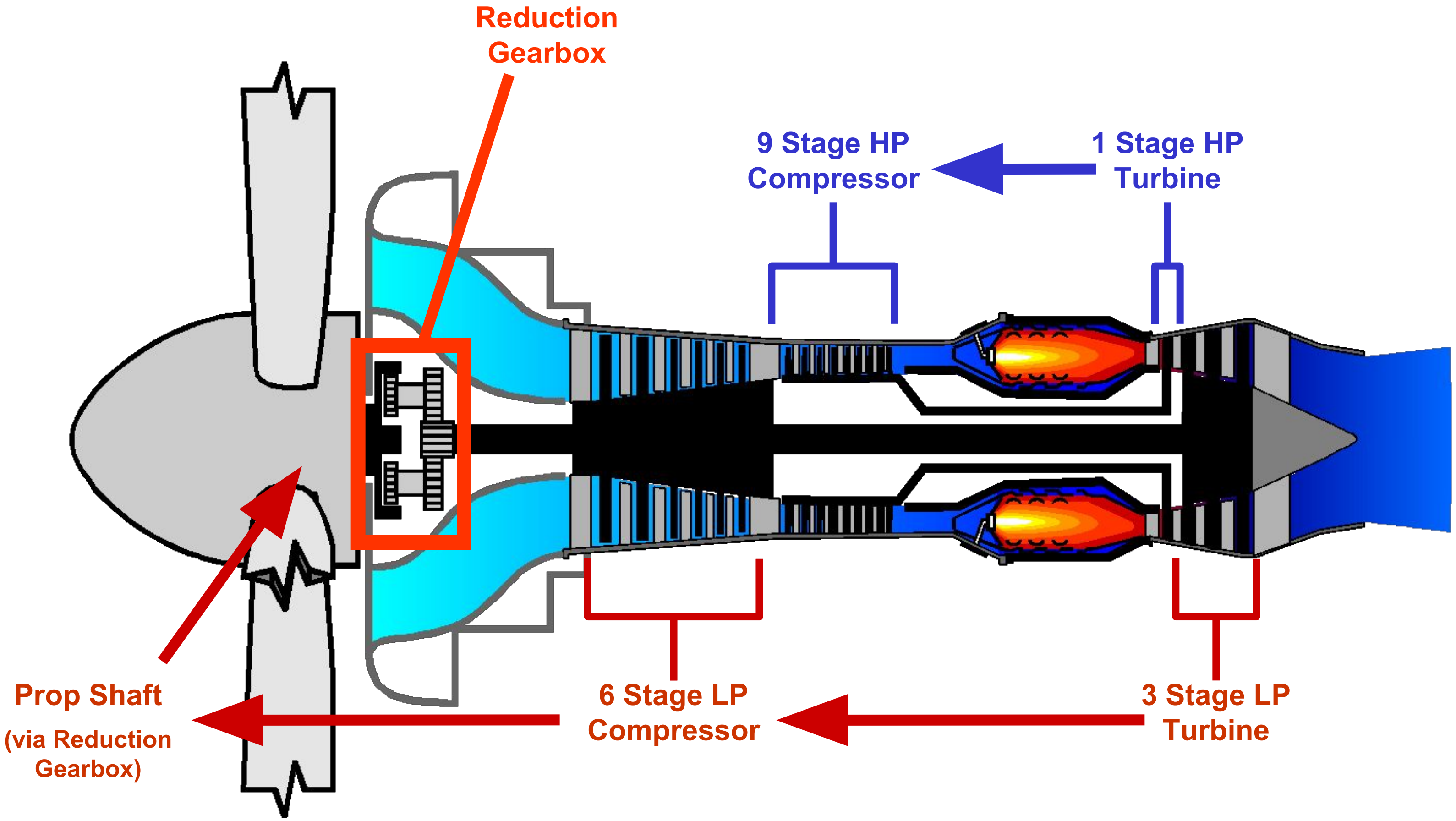
Over 70 different Marks of Engine – basically different power levels – 15 different aircraft

Was in service with RAF – 'Kneeling' Andover Transport (A BAe 748 with higher tail and rear loading ramp)

Fokker F27, Fairchild F27, Briguet Alize, (*and* P51 Mustang and Dakota!)

JET ENGINE TYPES

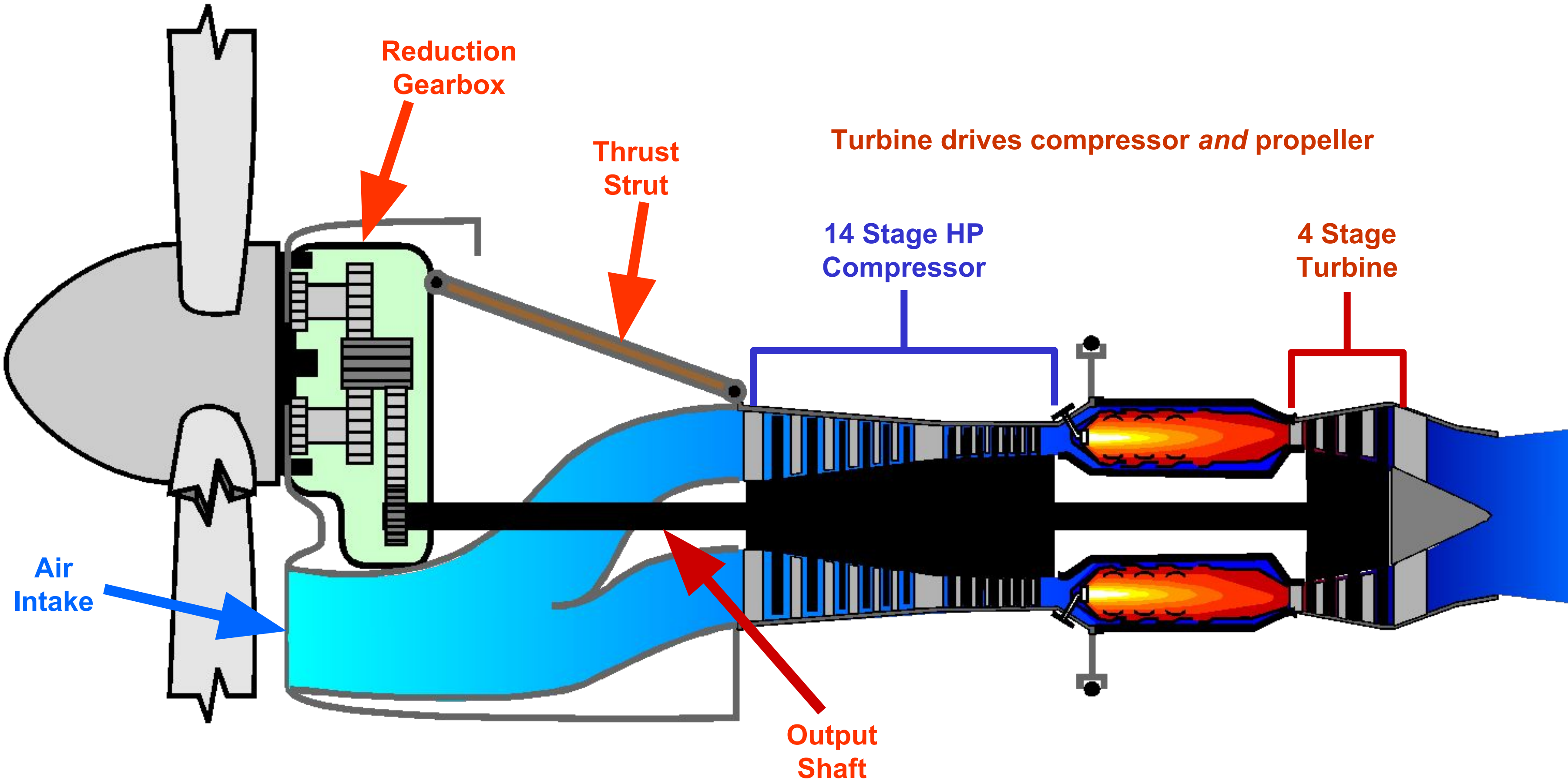
Tyne Turbo Prop



C160 Transall, Shorts Belfast, Brequet Atlantic, Avro Lincoln, Canadair CL44, Vickers Vanguard, Aeritalia 222.

JET ENGINE TYPES

RR Allison T56-A-15 Turbo Prop

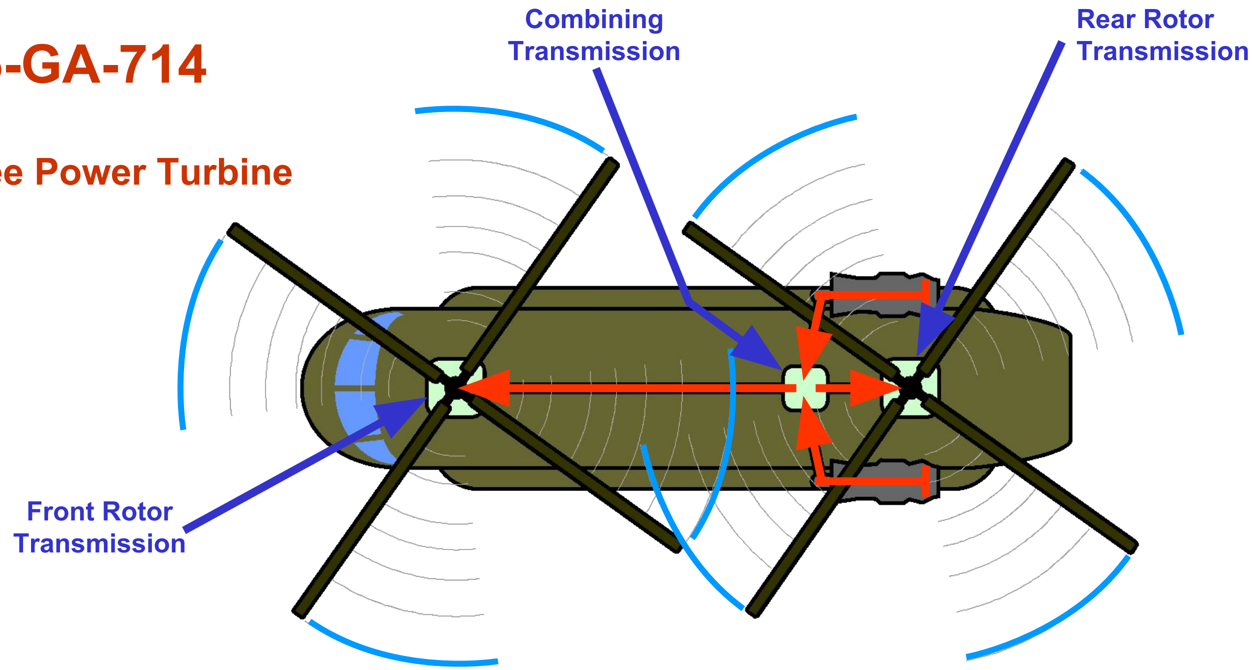


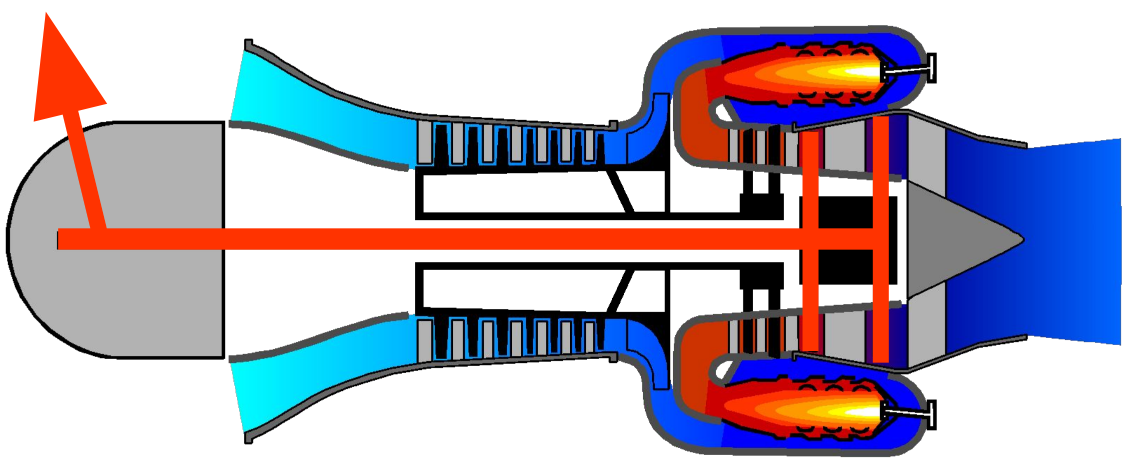
C130 Hercules.

JET ENGINE TYPES

Lycoming T55-GA-714

Turboshaft with Free Power Turbine





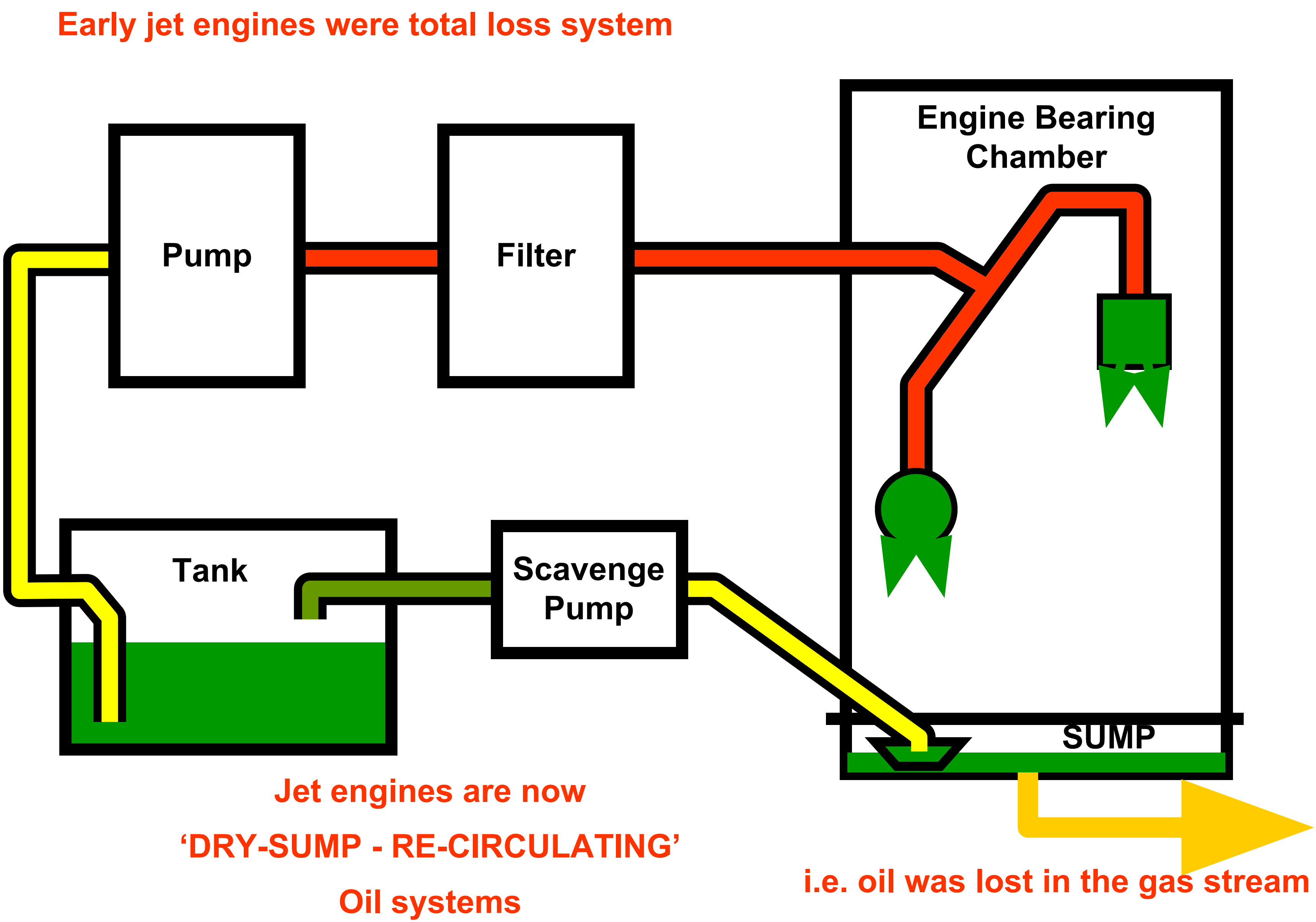
Boeing CH47 Chinook

JET ENGINE TYPES

TYPICAL OIL SYSTEMS

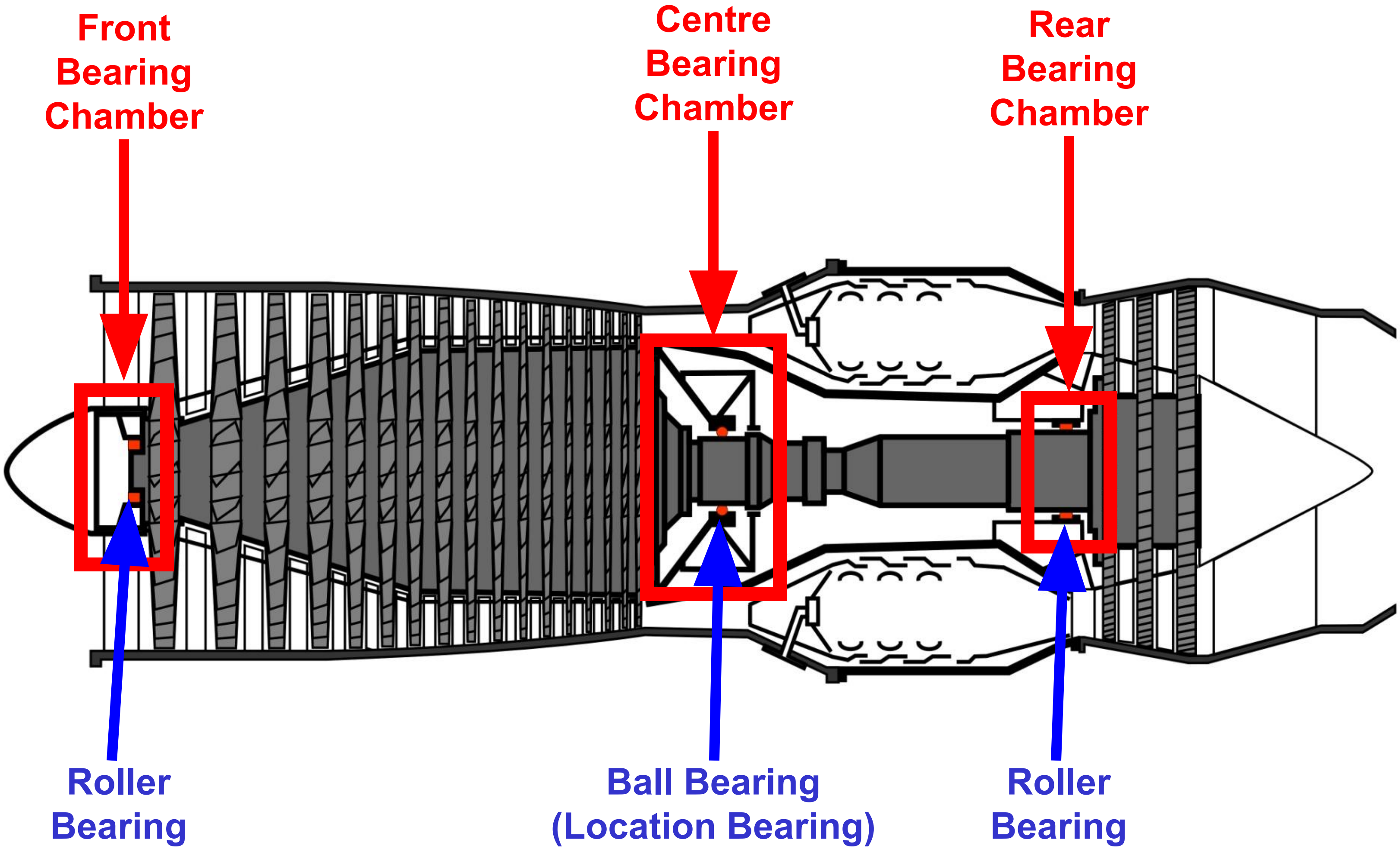
Jet Engines

Distribution and Lubrication



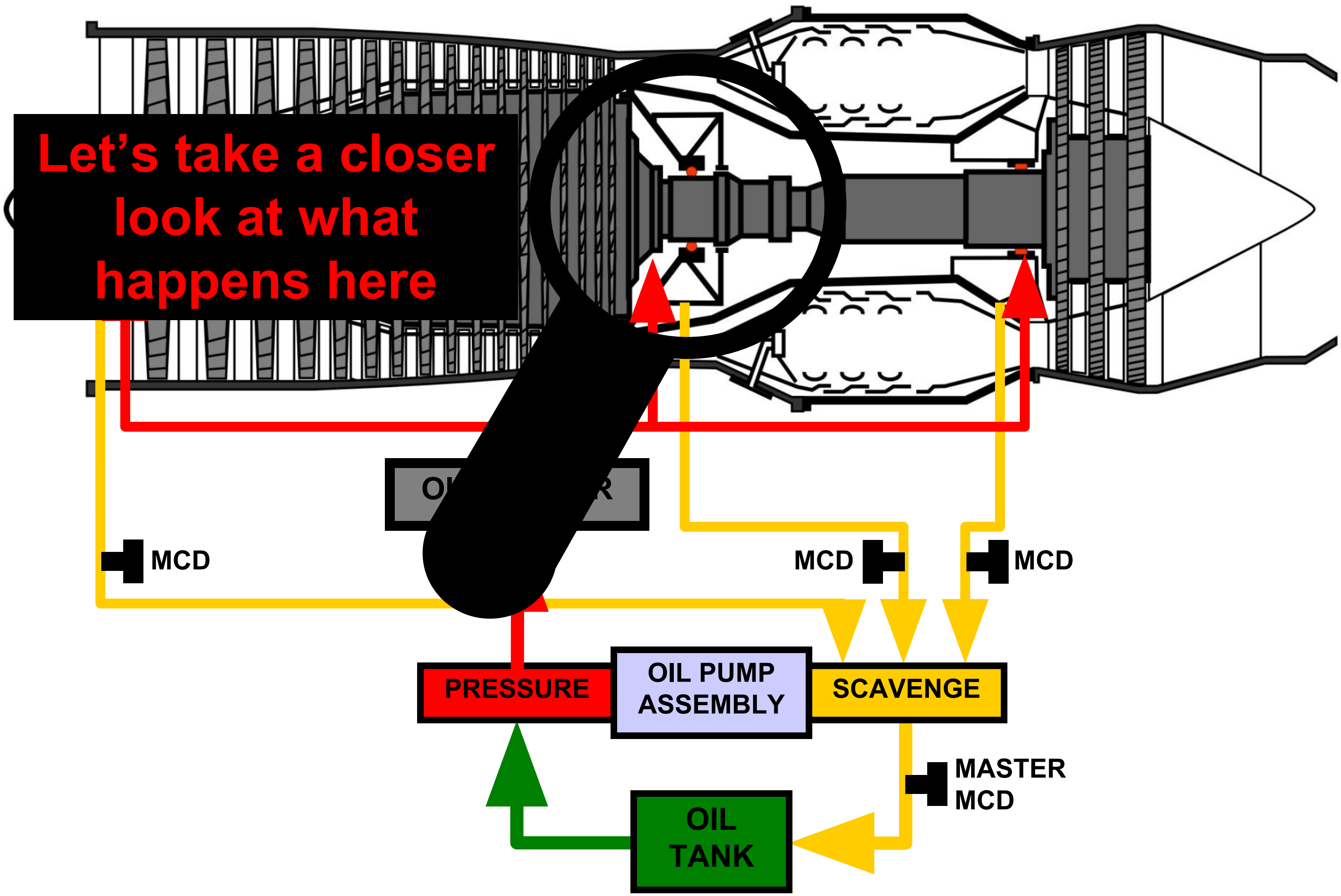
TYPICAL OIL SYSTEM - JET ENGINE

Bearing Chambers

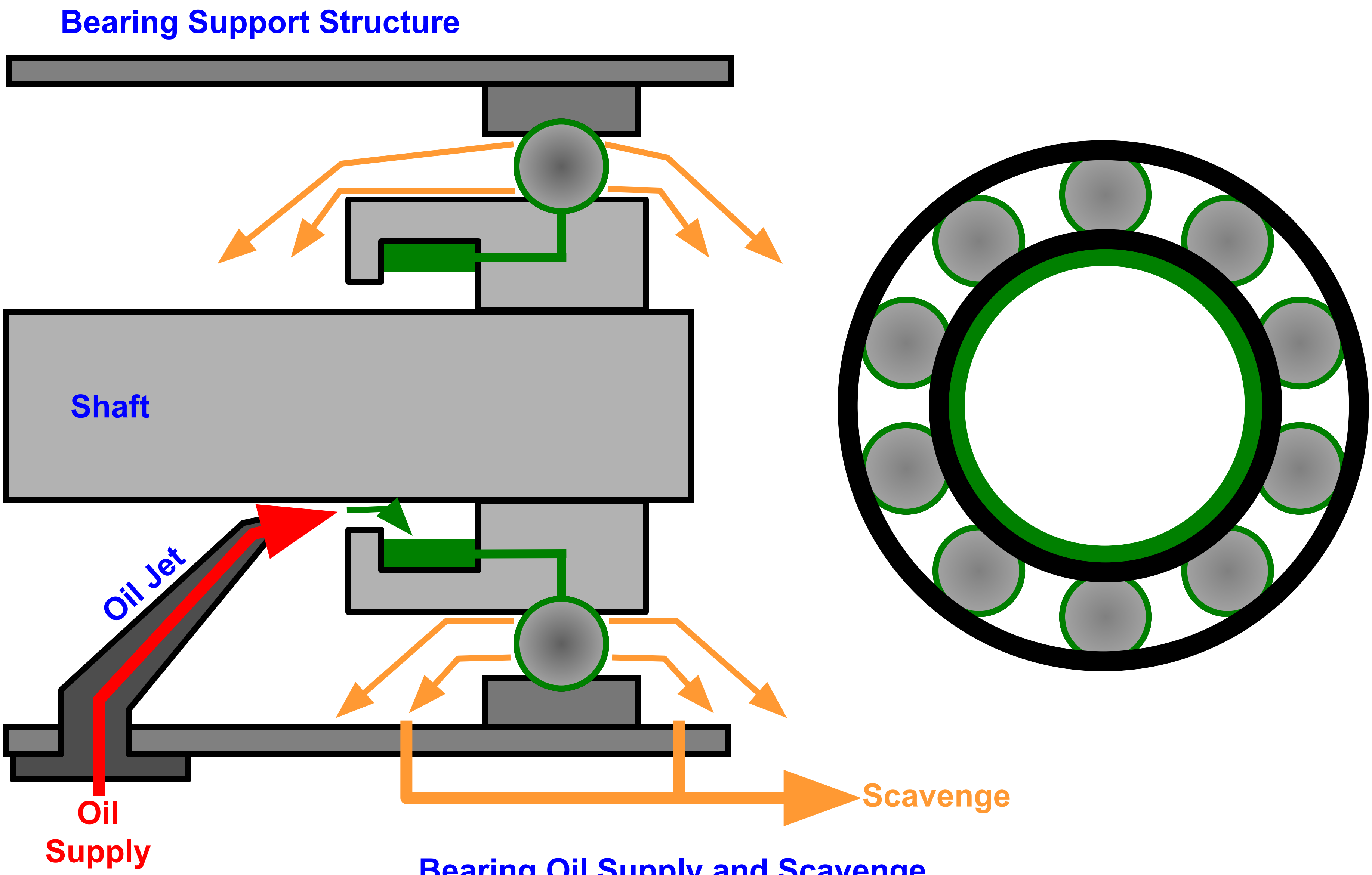


TYPICAL OIL SYSTEM - JET ENGINE

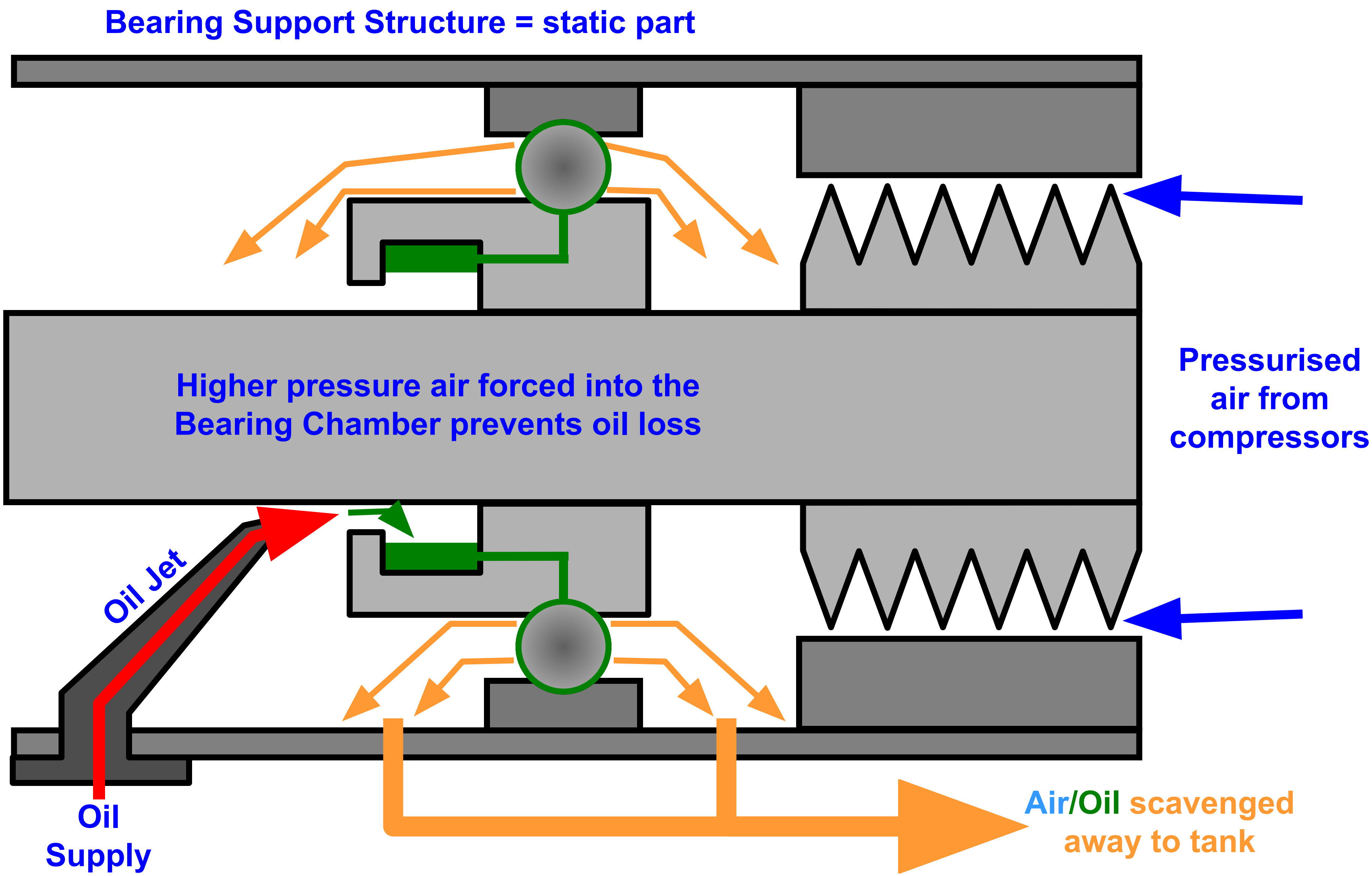
Notional oil system



TYPICAL OIL SYSTEM - JET ENGINE

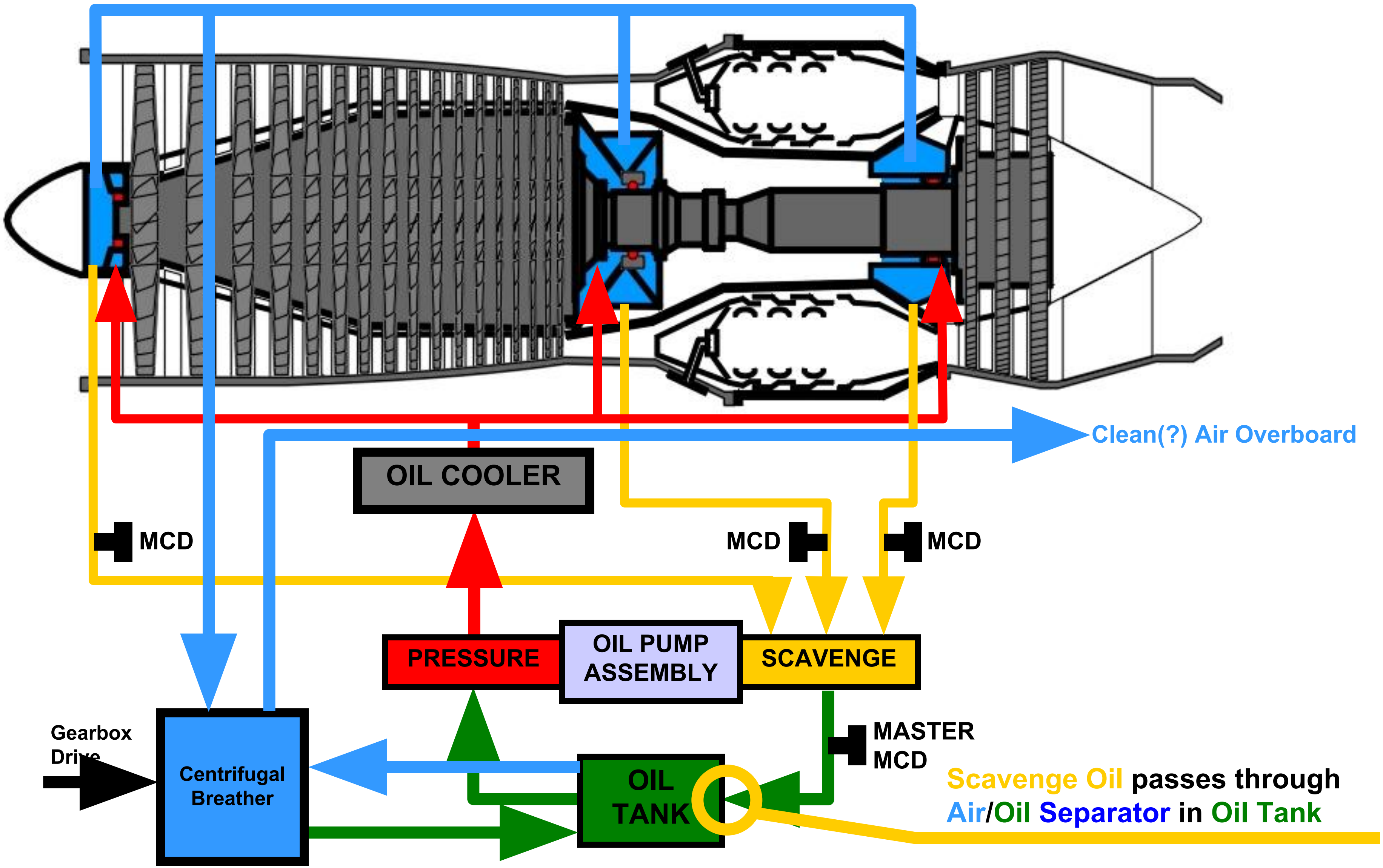


TYPICAL OIL SYSTEM - JET ENGINE



TYPICAL OIL SYSTEM - JET ENGINE

Notional oil system with Air Sealing

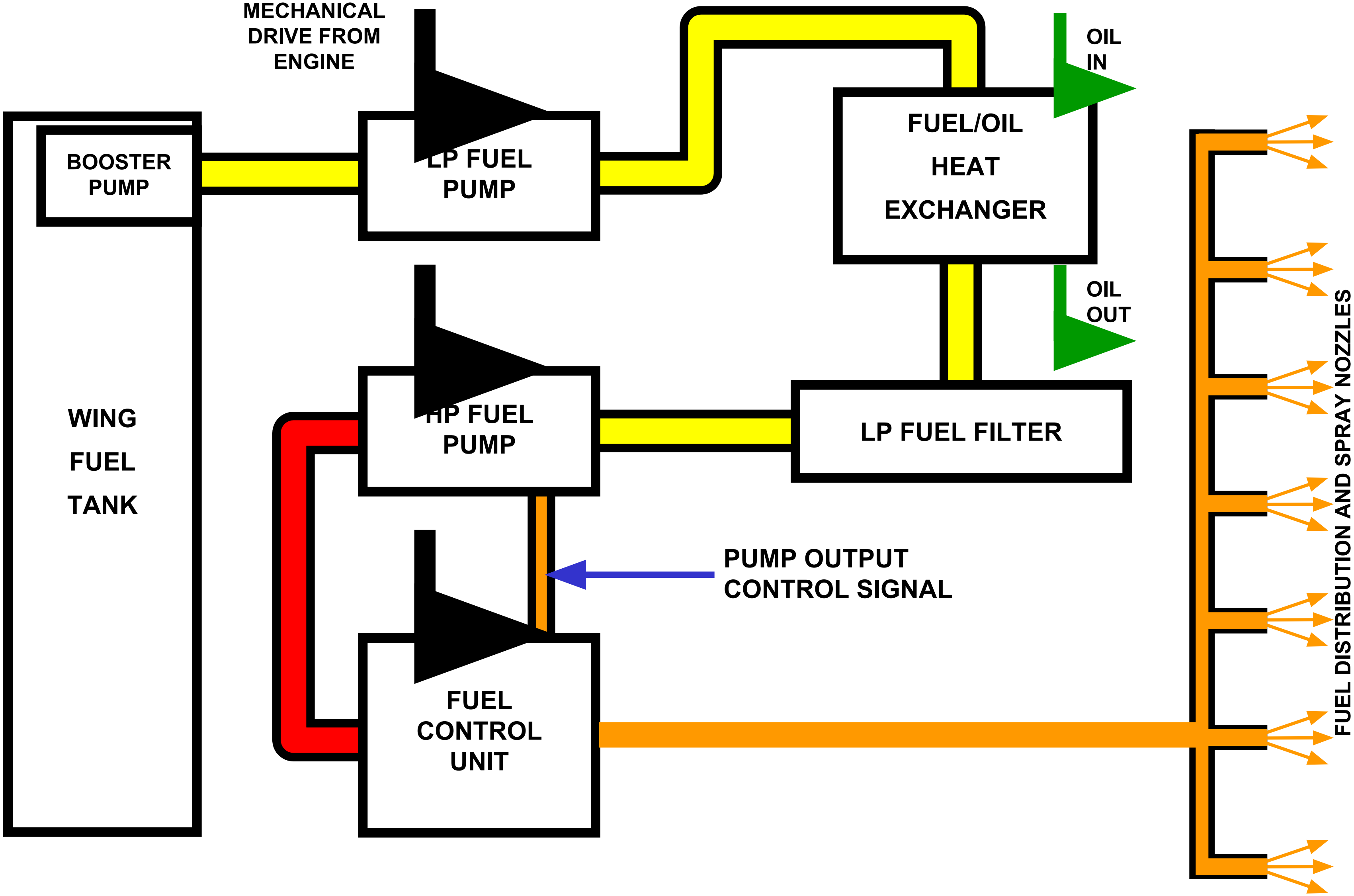


TYPICAL OIL SYSTEM - JET ENGINE

TYPICAL FUEL SYSTEM

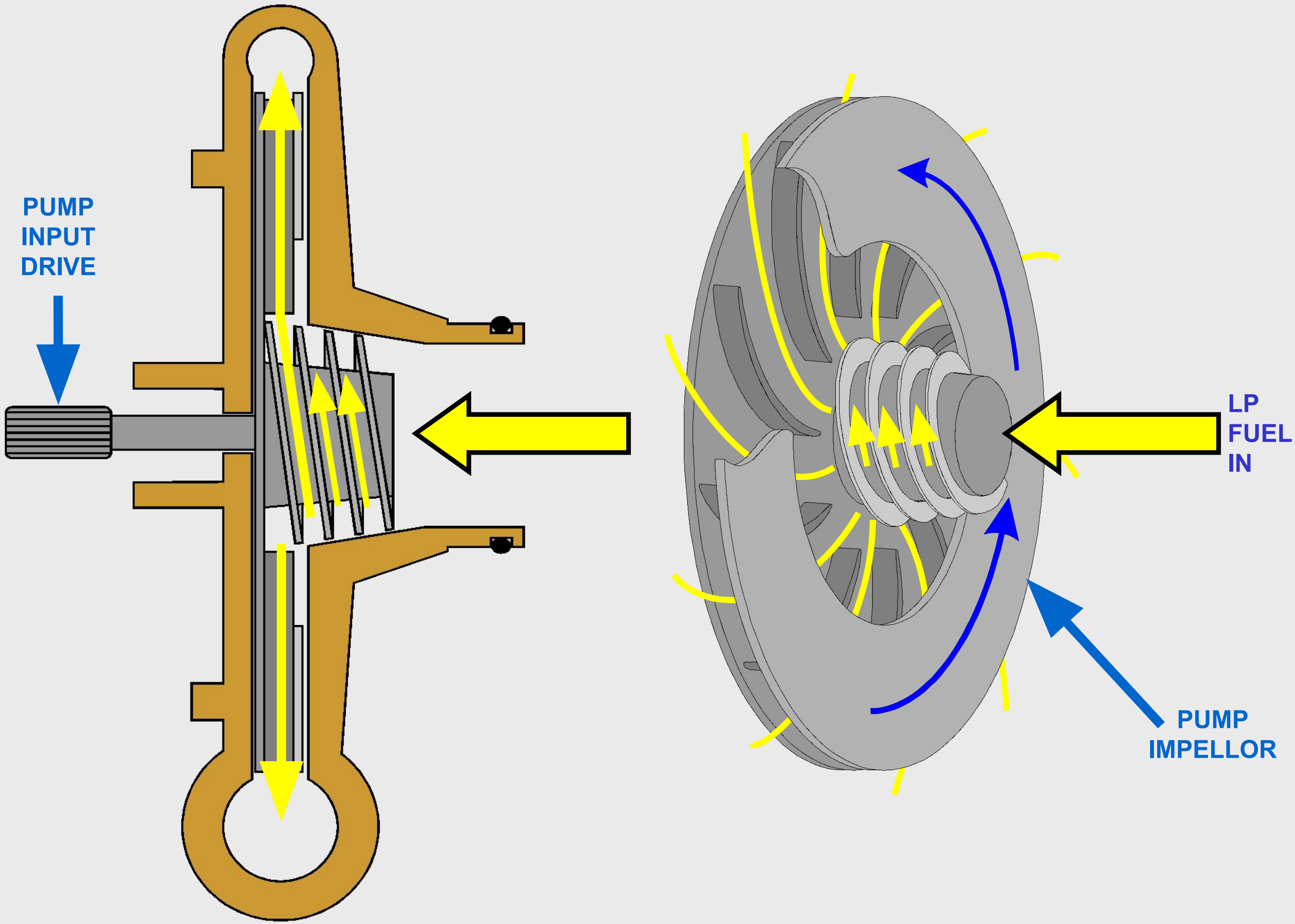
GAS TURBINE ENGINE

1ST – WE WILL LOOK AT HYDROMECHANICAL SYSTEMS



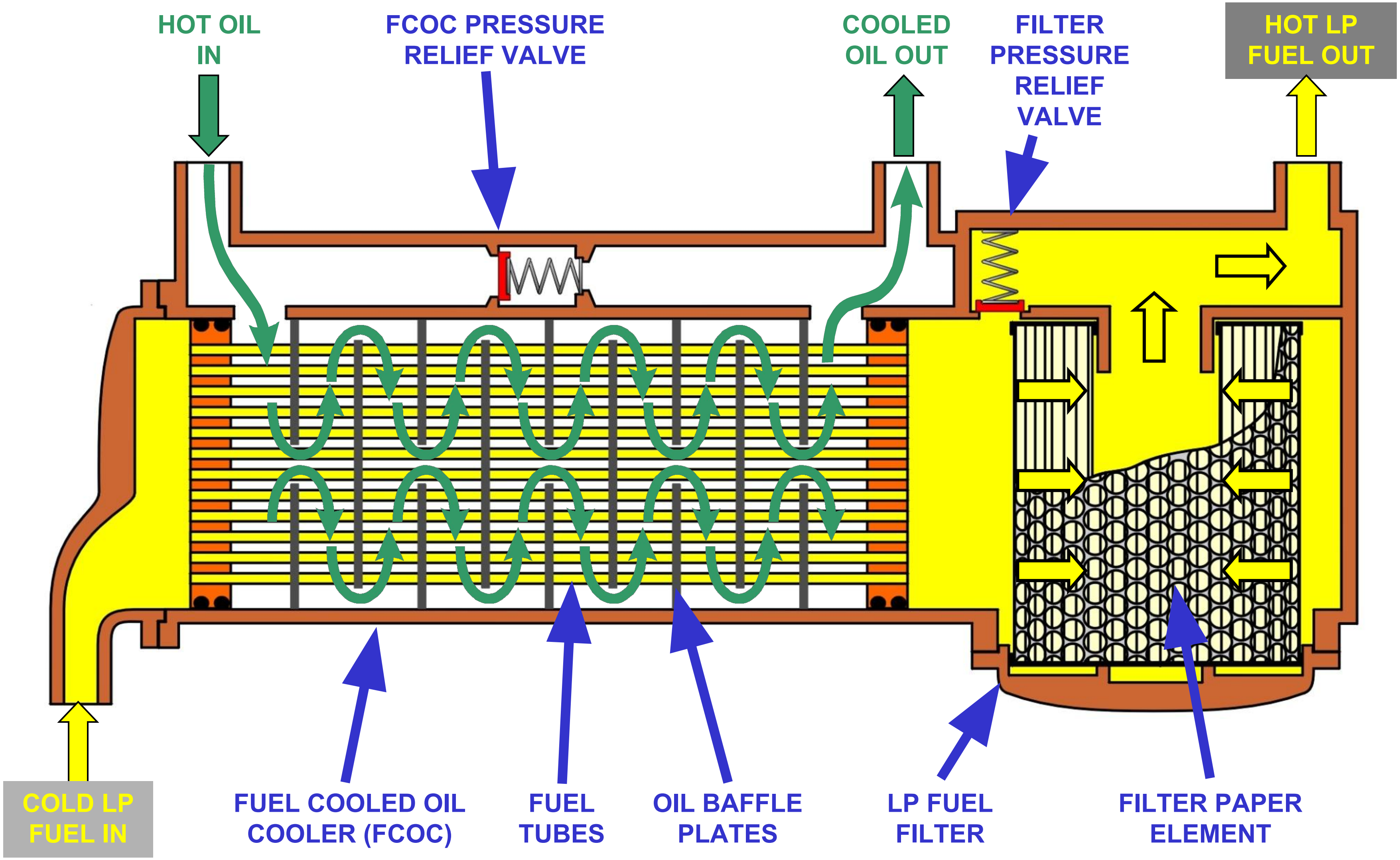
MULTI PLUNGER (SWASH-PLATE) PUMP

TYPICAL FUEL SYSTEM - GAS TURBINE ENGINE



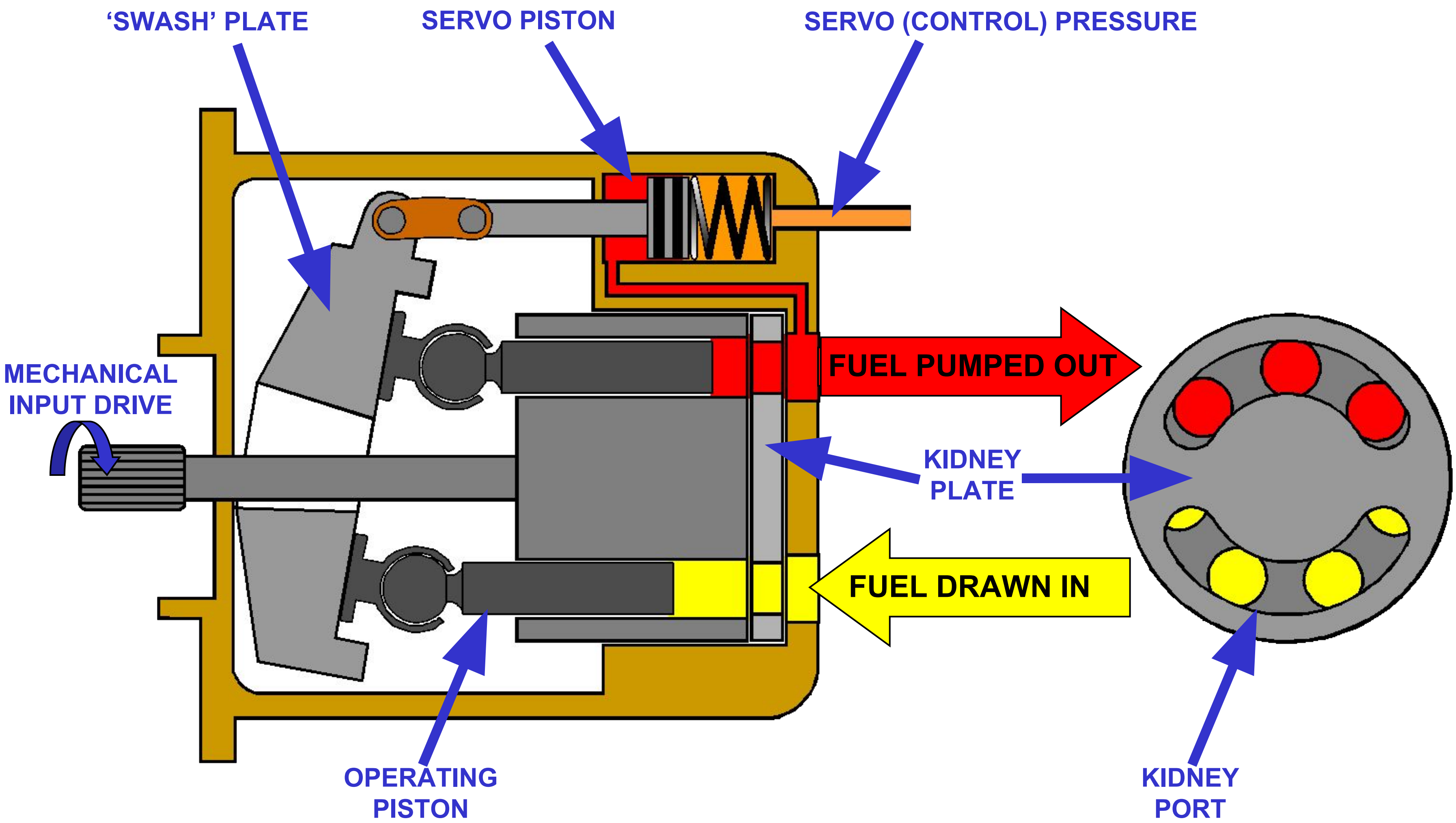
LOW PRESSURE PUMP

TYPICAL FUEL SYSTEM - GAS TURBINE ENGINE



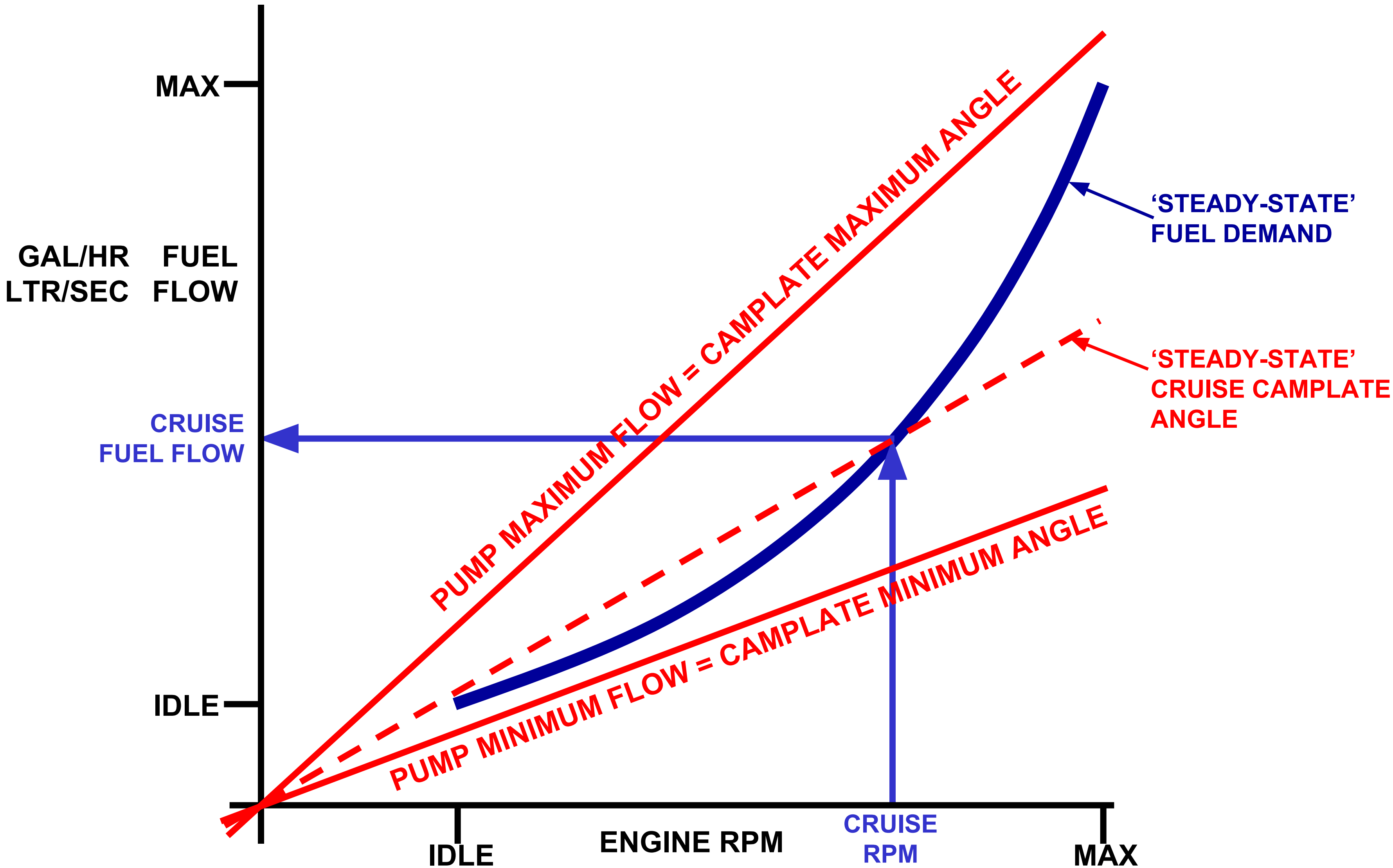
FUEL/OIL HEAT EXCHANGER AND FUEL FILTER

TYPICAL FUEL SYSTEM - GAS TURBINE ENGINE



MULTI PLUNGER (SWASH-PLATE) PUMP

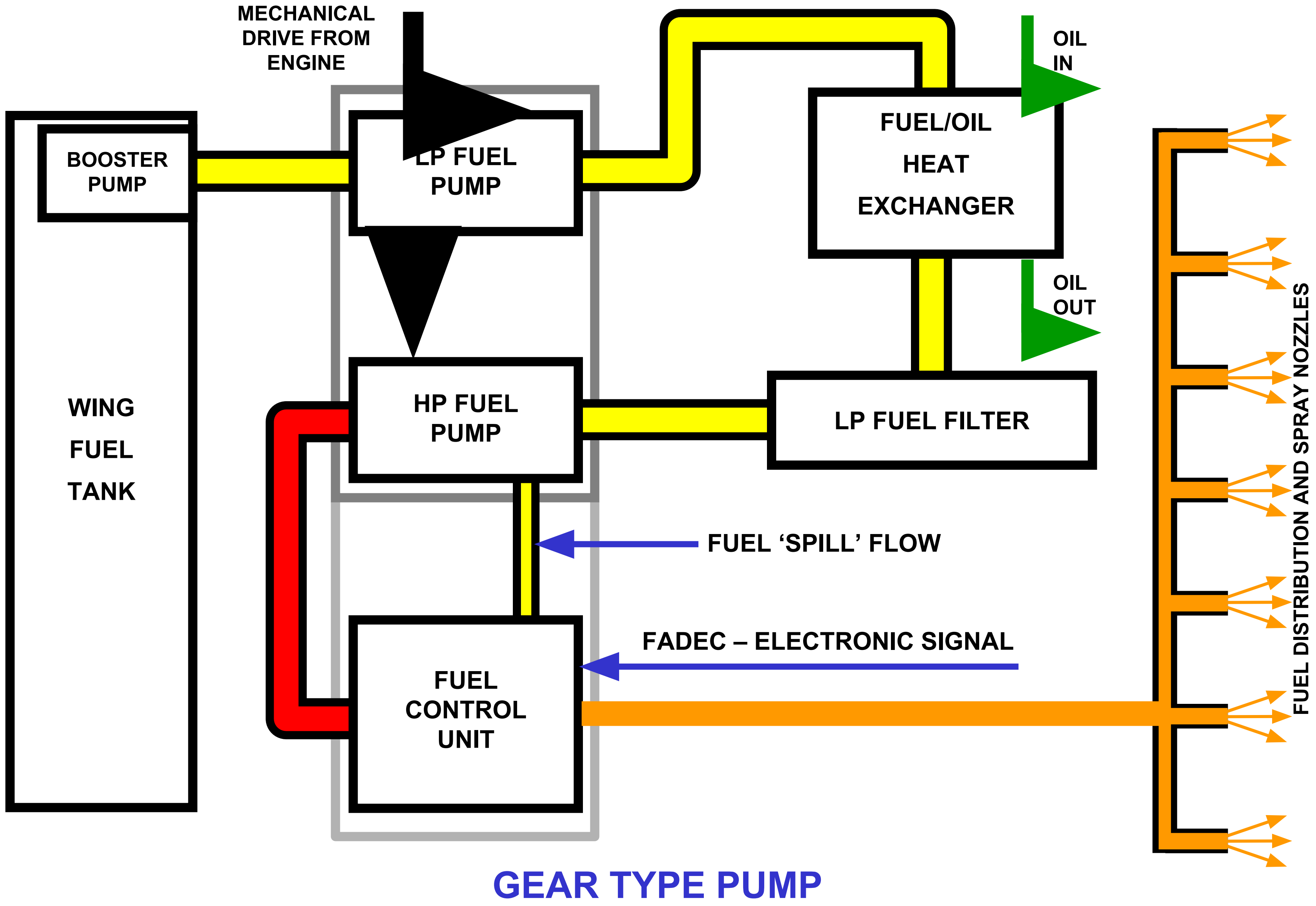
TYPICAL FUEL SYSTEM - GAS TURBINE ENGINE



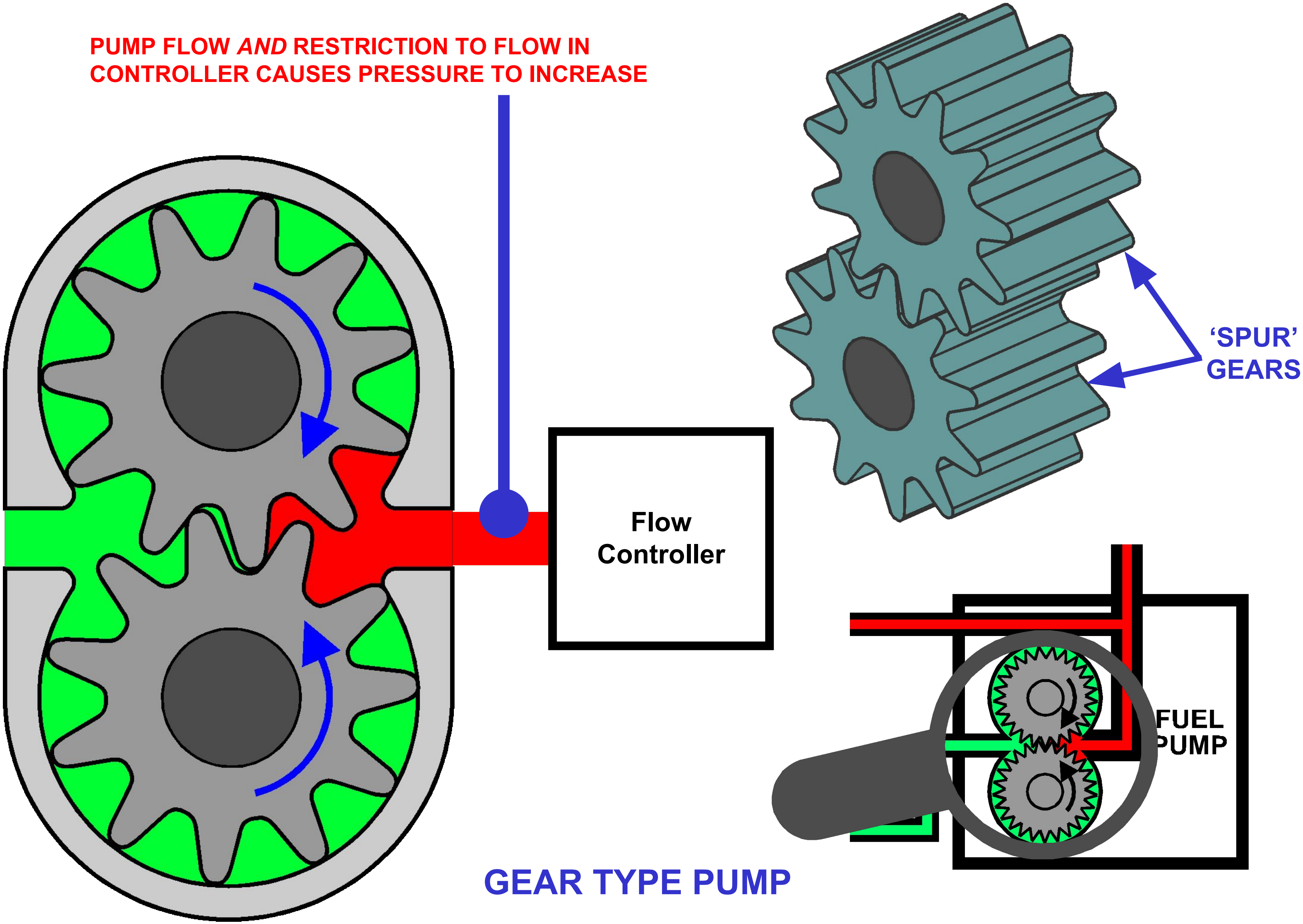
MULTI PLUNGER (SWASH-PLATE) PUMP

TYPICAL FUEL SYSTEM - GAS TURBINE ENGINE

NOW – WE WILL LOOK AT ELECTRONICALLY CONTROLLED SYSTEMS



TYPICAL FUEL SYSTEM - GAS TURBINE ENGINE



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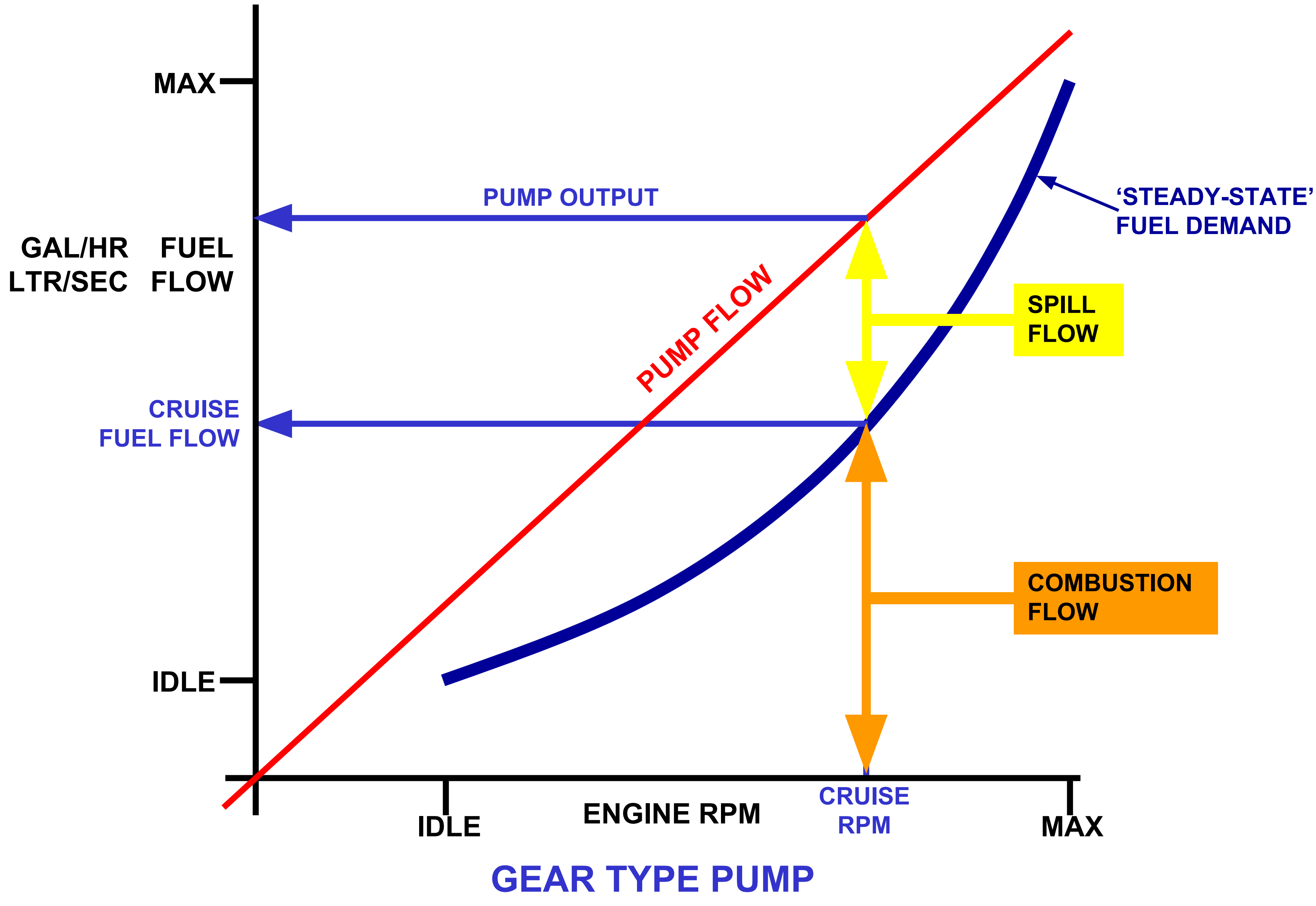
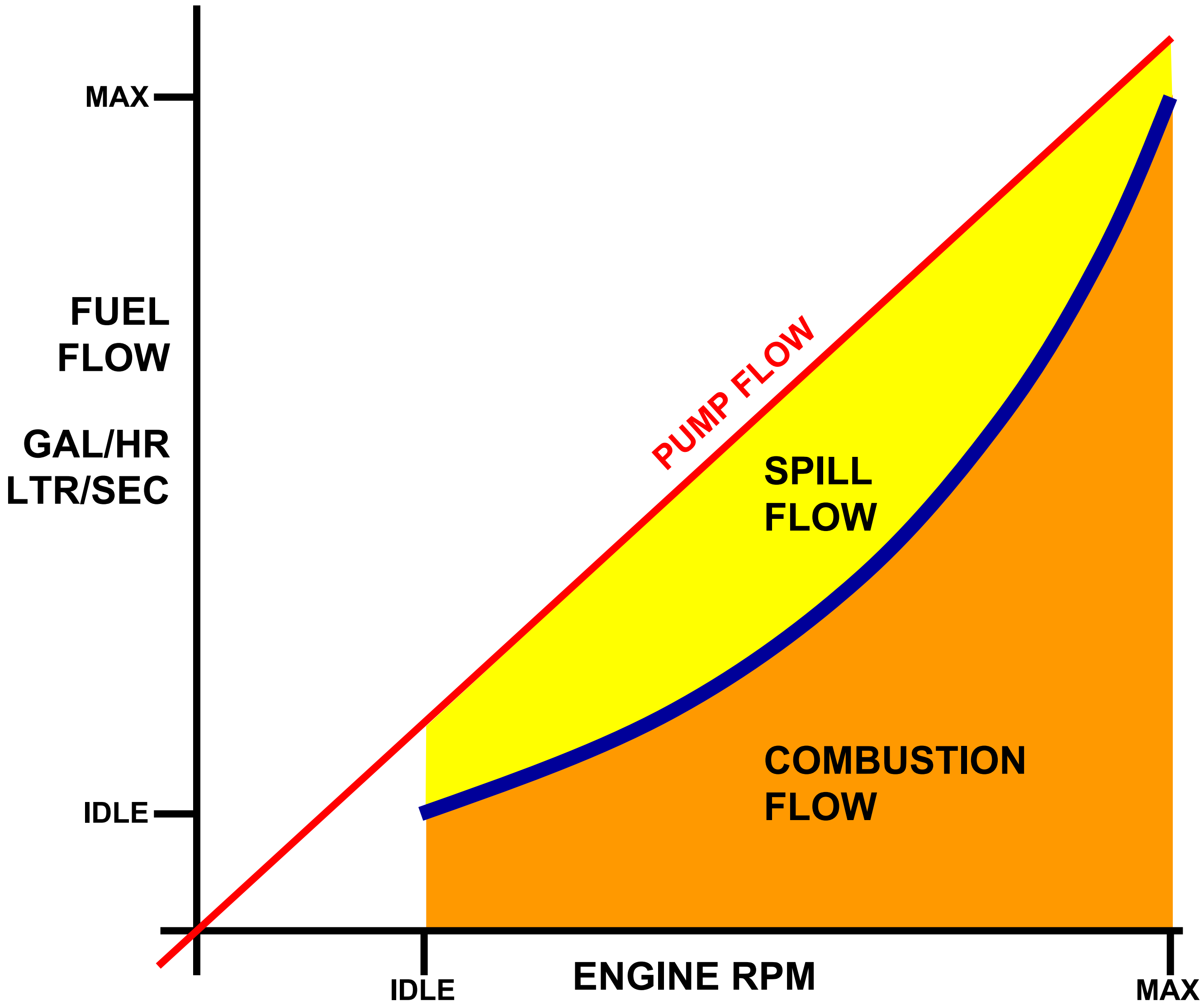


TYPICAL FUEL SYSTEM - GAS TURBINE ENGINE



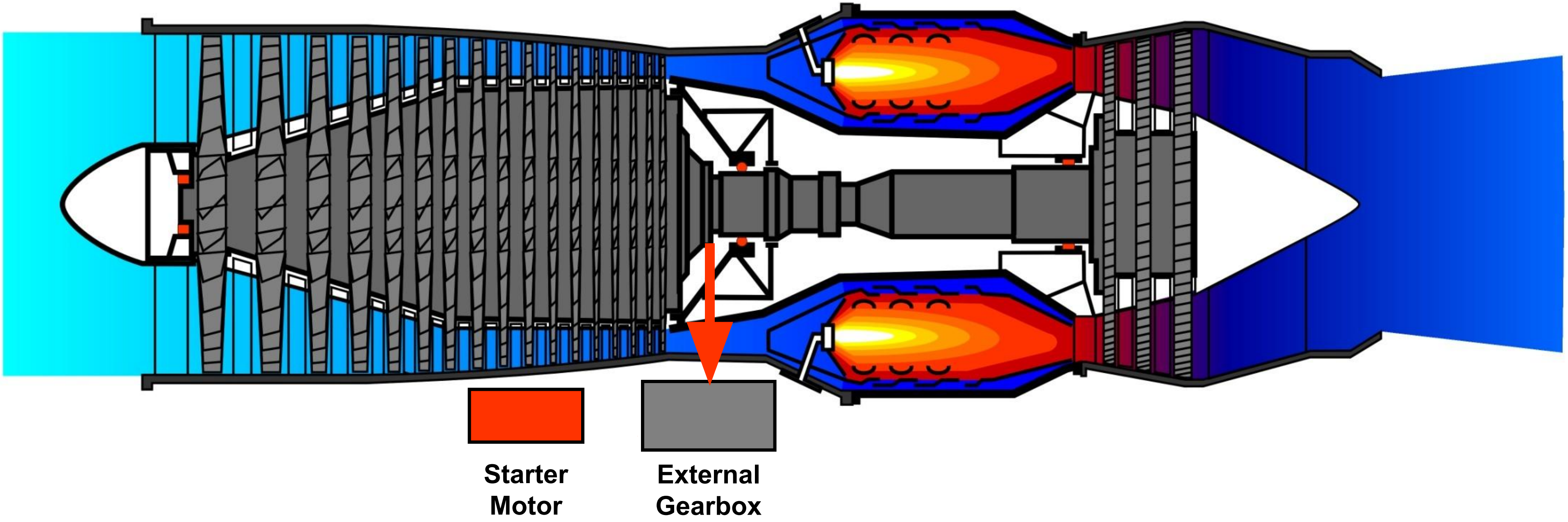
GEAR TYPE PUMP

TYPICAL FUEL SYSTEM - GAS TURBINE ENGINE

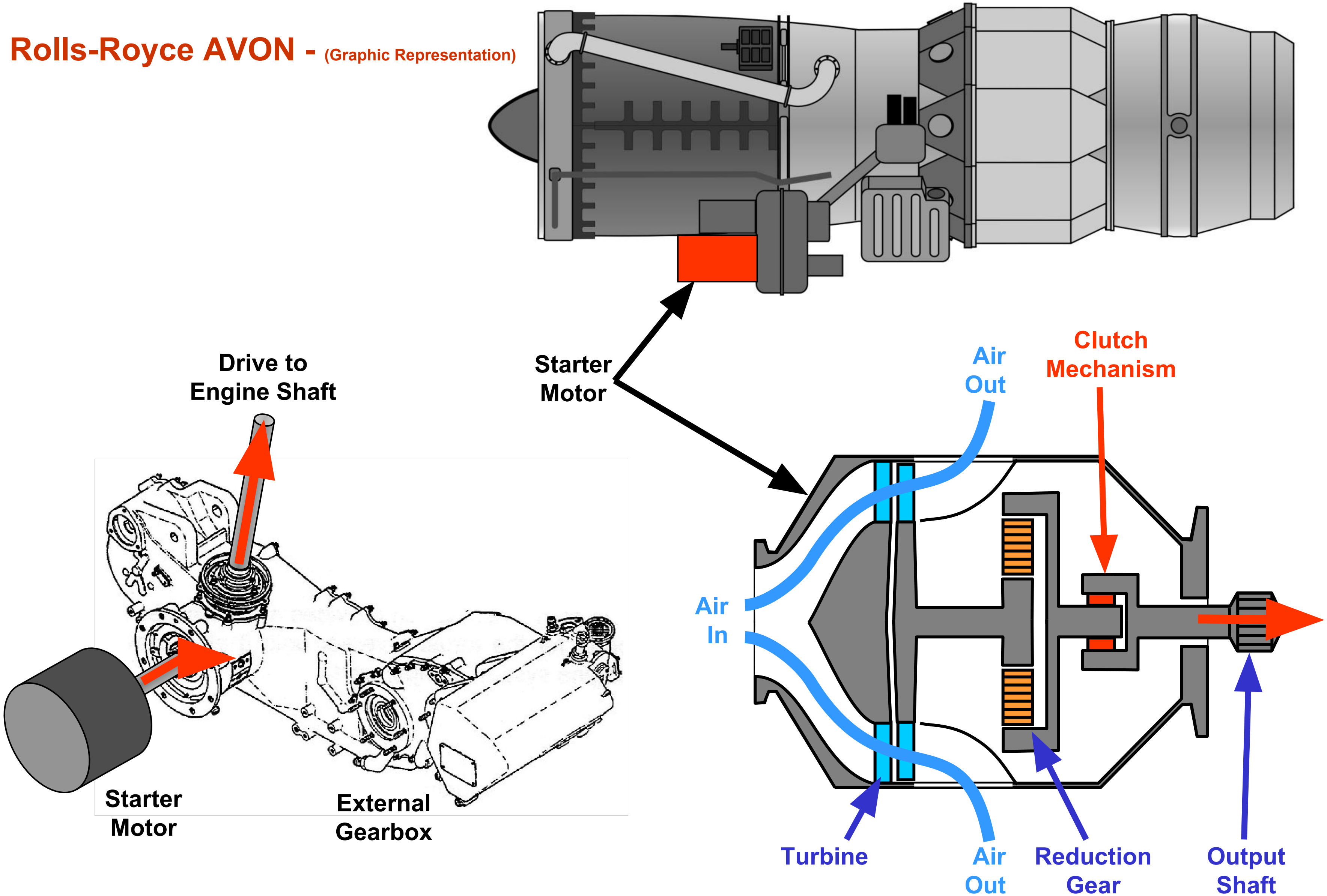
JET ENGINE STARTING AND IGNITION SYSTEM

GETTING A JET ENGINE GOING

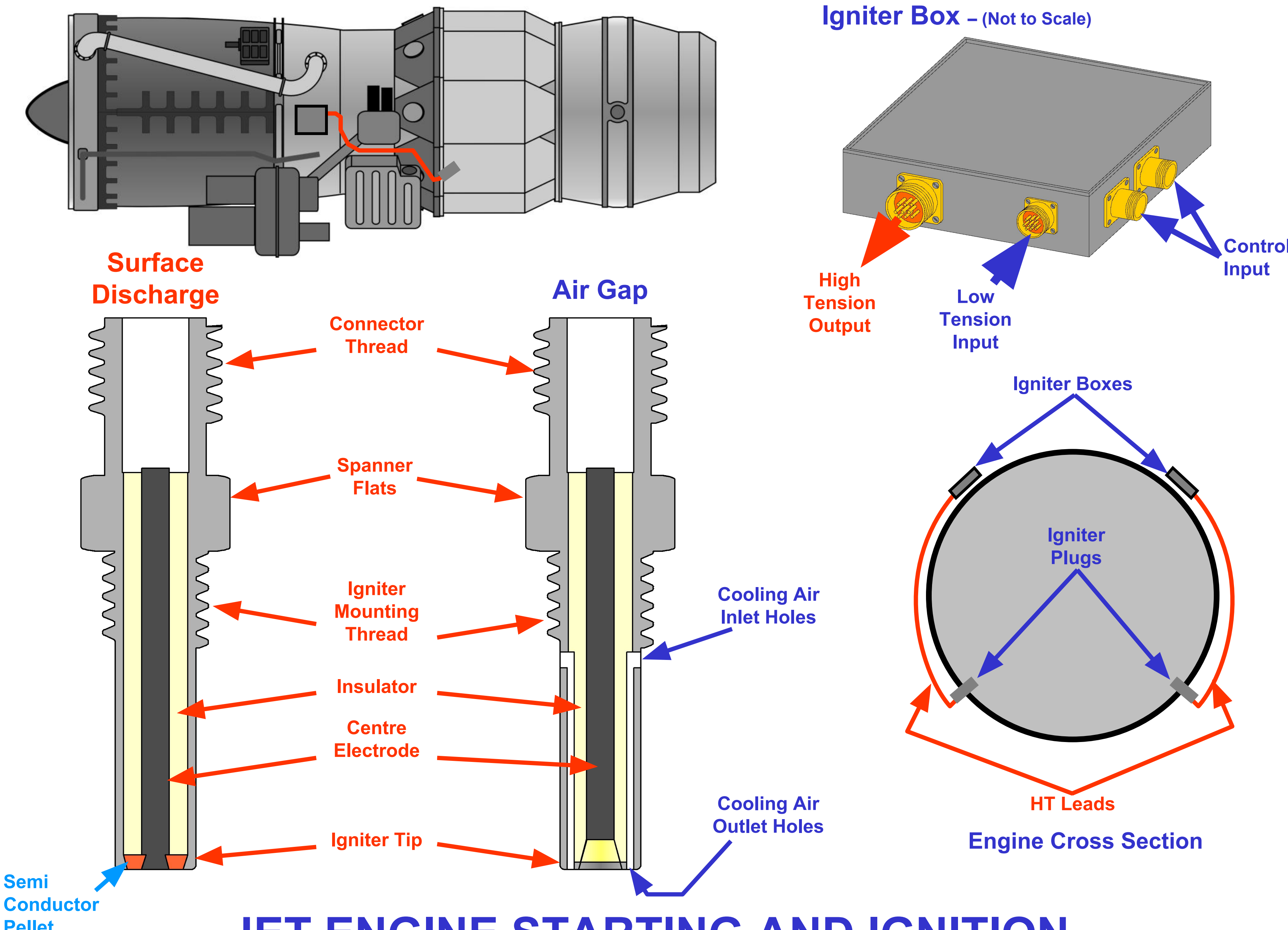
The basic sequence of the start cycle



JET ENGINE STARTING AND IGNITION



JET ENGINE STARTING AND IGNITION



JET ENGINE STARTING AND IGNITION

Thrust Augmentation

What is it?

A method of extracting more power from Internal Combustion Engines

Piston engines:-

Supercharging or turbo charging	Forced air aspiration
Higher Octane fuels	More power per bang

Gas turbines engines:-

Booster engines	HS121 Trident and early V/STOL a/c
Water injection + more fuel	Methanol
Water injection	
Afterburning	Mainly military but also Concorde

Other methods

Rocket boosters RATO – Rocket Assisted Take-Off Single use only

Thrust Augmentation

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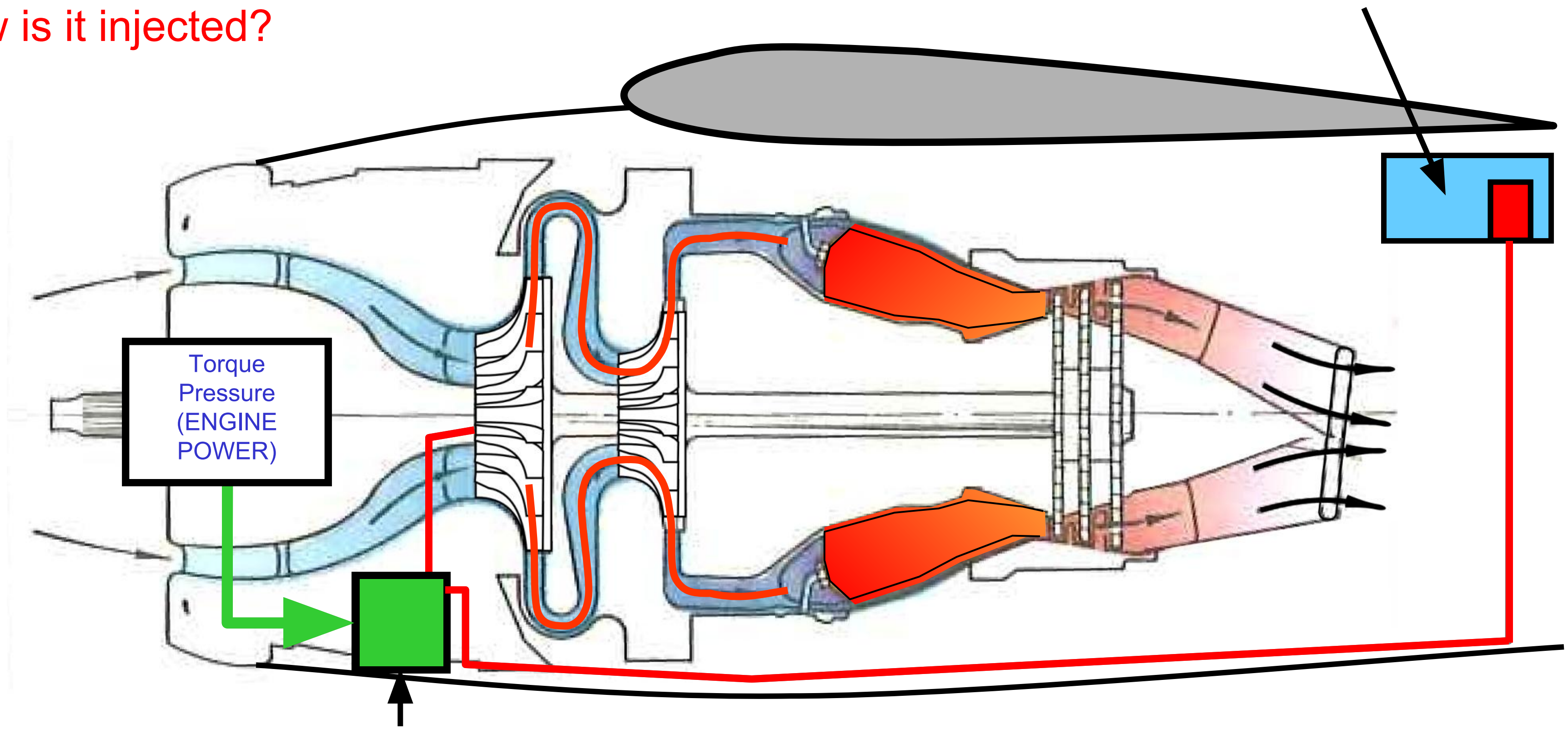
Thrust Augmentation

Water Methanol Injection

How is it injected?

Dart Engine Series



Water cools the turbine and increases pressure and therefore velocity = more power.

Cooler turbine means more fuel (methanol) can be added = more power.

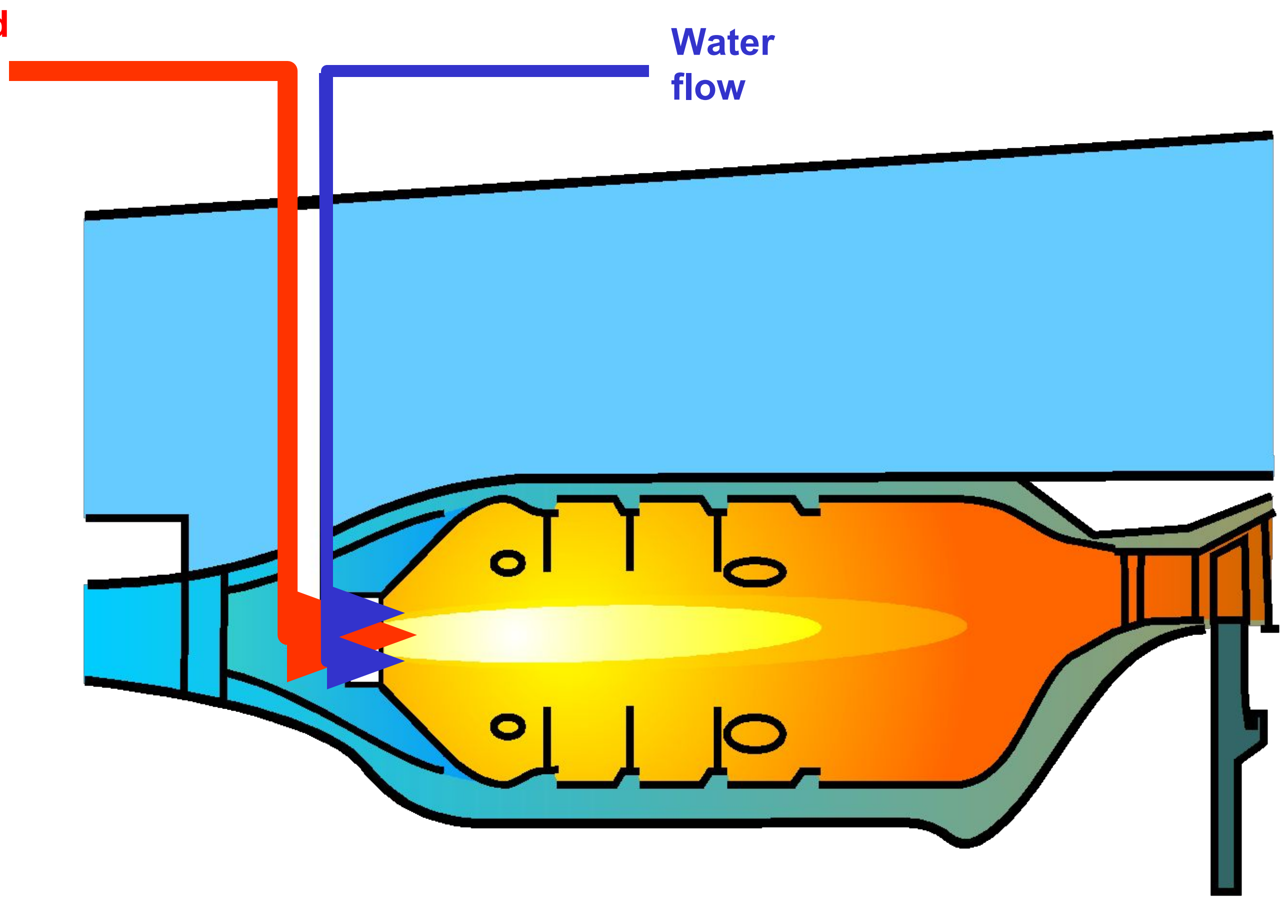
In the Dart engine, more power means coarser propeller pitch = more thrust.

Use limited because of combustion characteristics

Thrust Augmentation

Water Injection

Rolls-Royce Spey Series



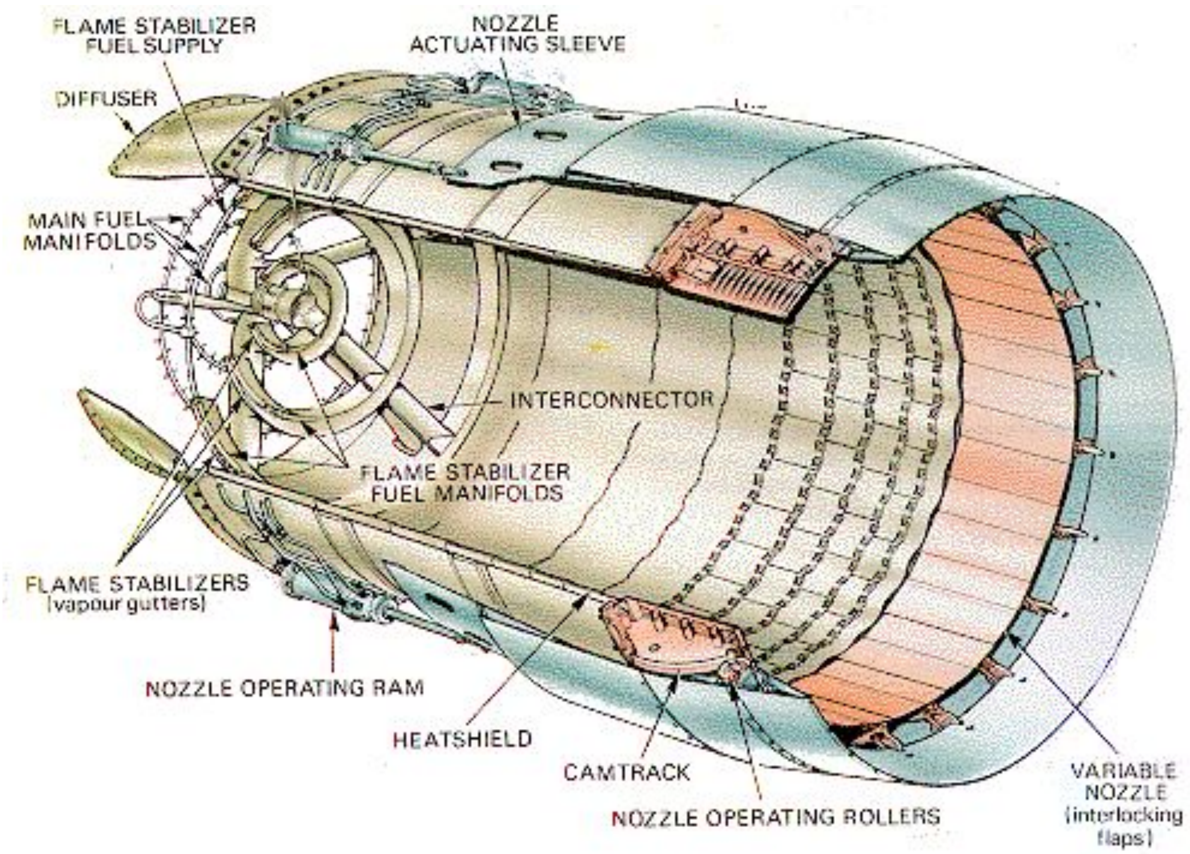
Water cools the turbine and increases pressure and therefore velocity = more power.

Cooler turbine means more fuel can be added = more power.

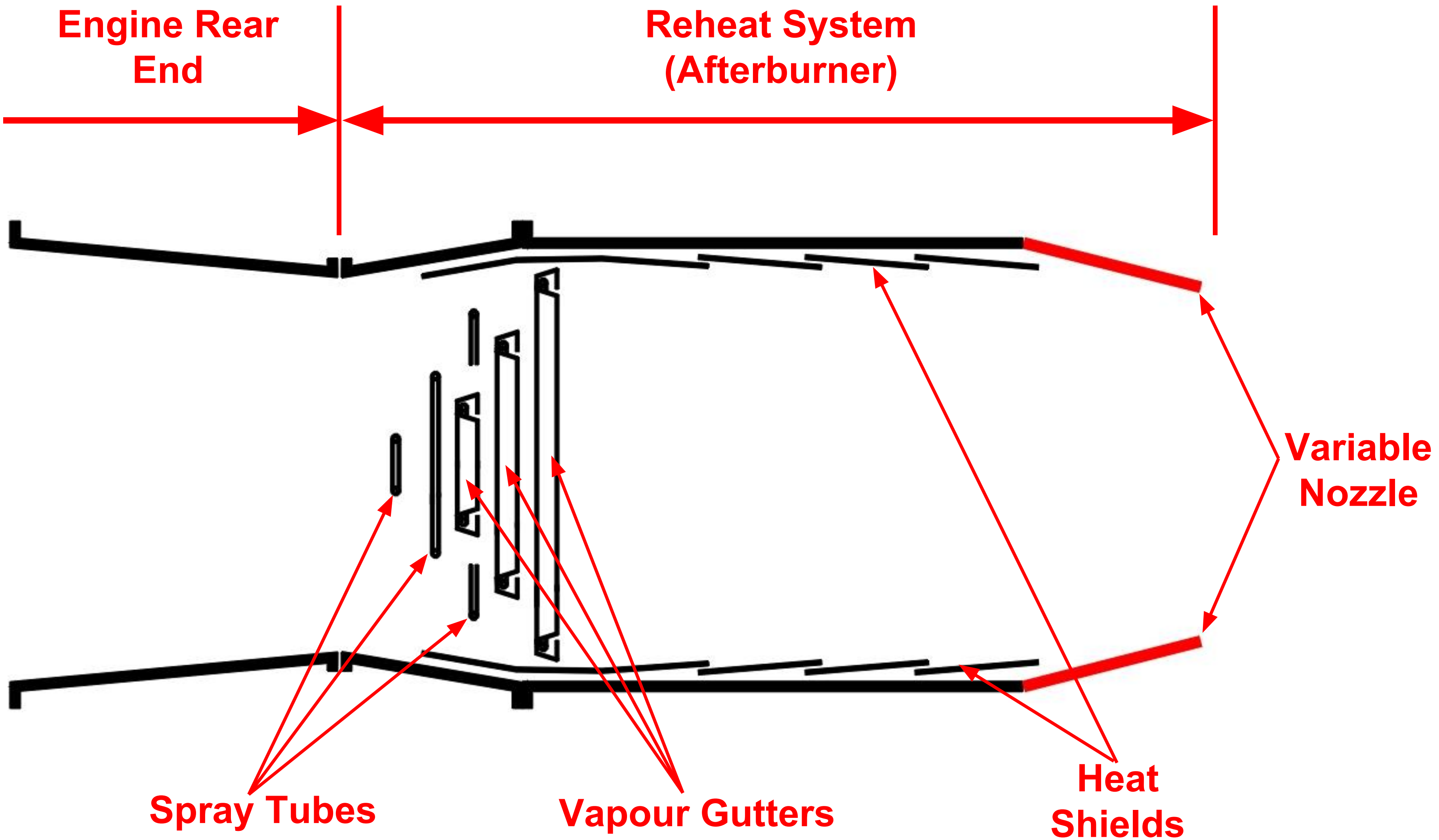
Thrust Augmentation

Typical Reheat System

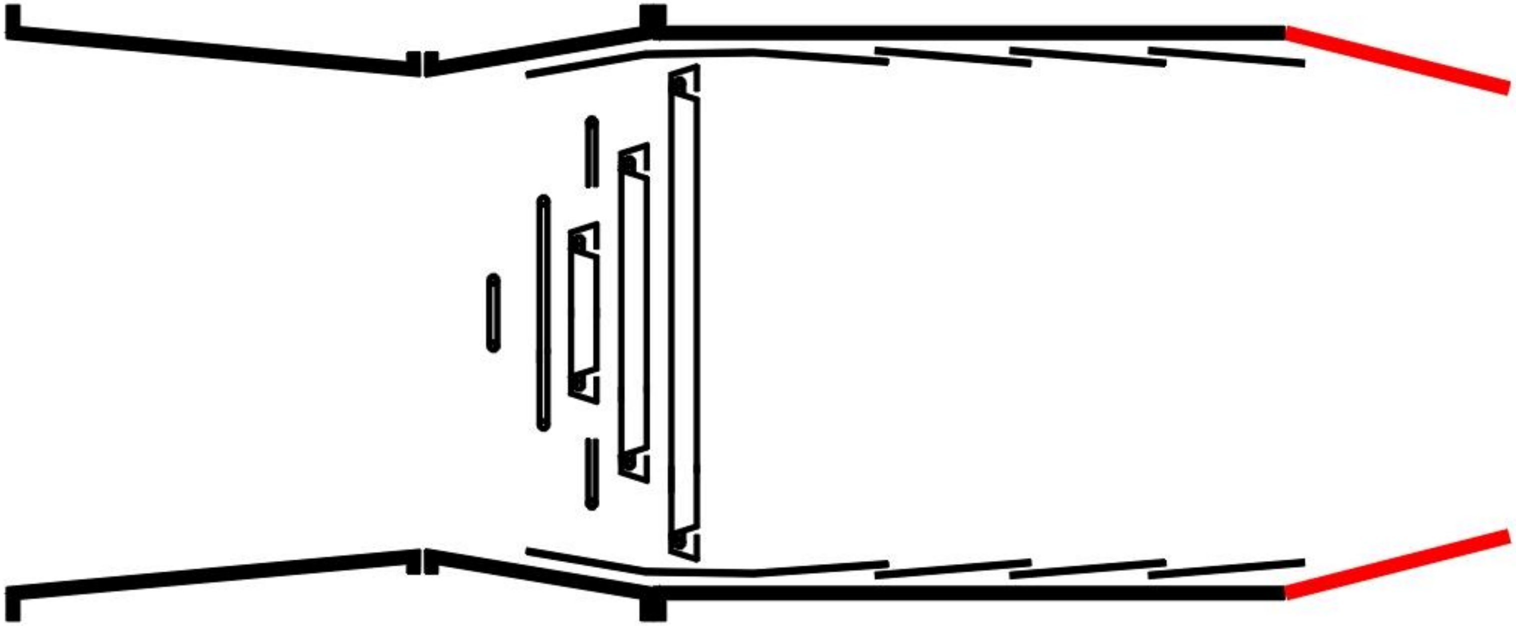
Rolls-Royce Phantom Spey and Jaguar Adour series



Thrust Augmentation

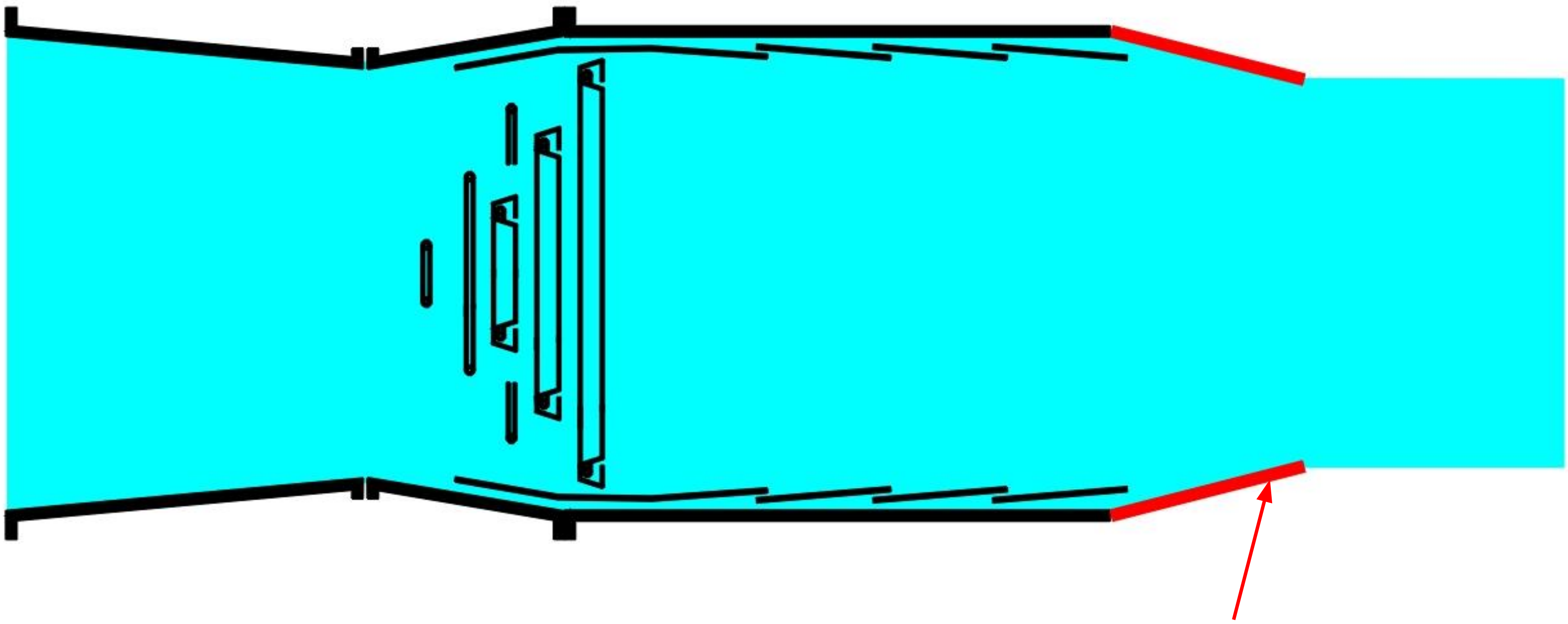


Thrust Augmentation



Thrust Augmentation

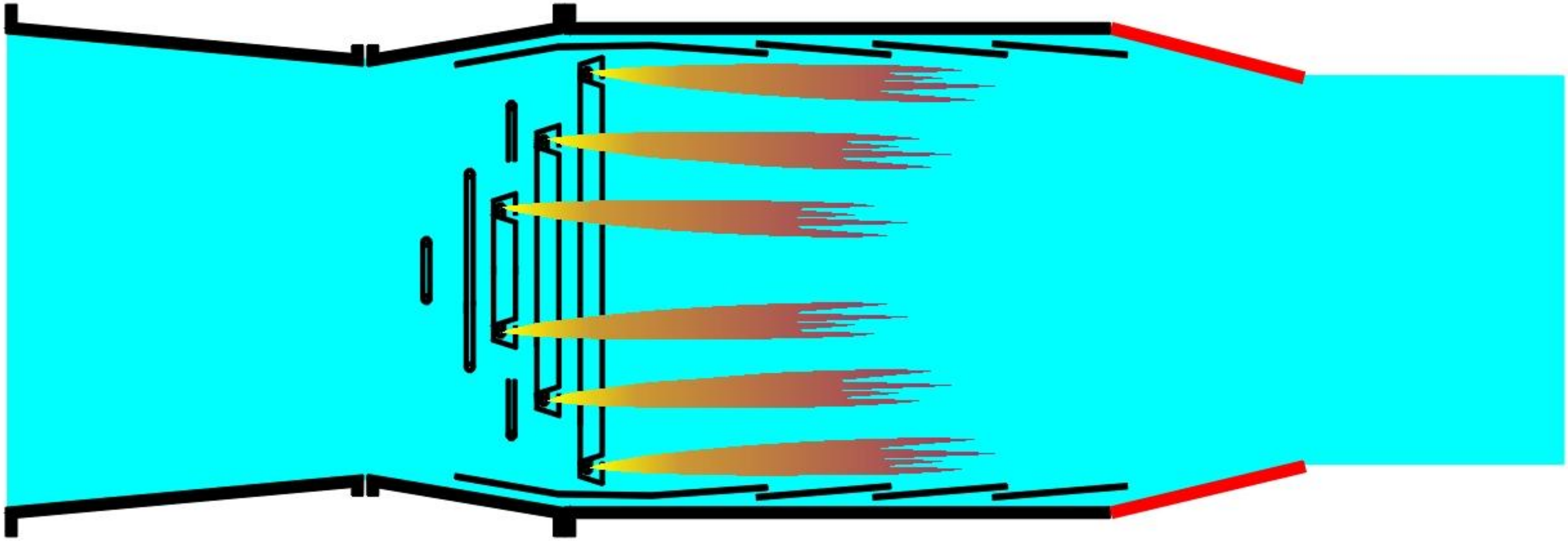
Engine Gas Stream *without* Reheat



Variable Nozzle ‘Closed’

Thrust Augmentation

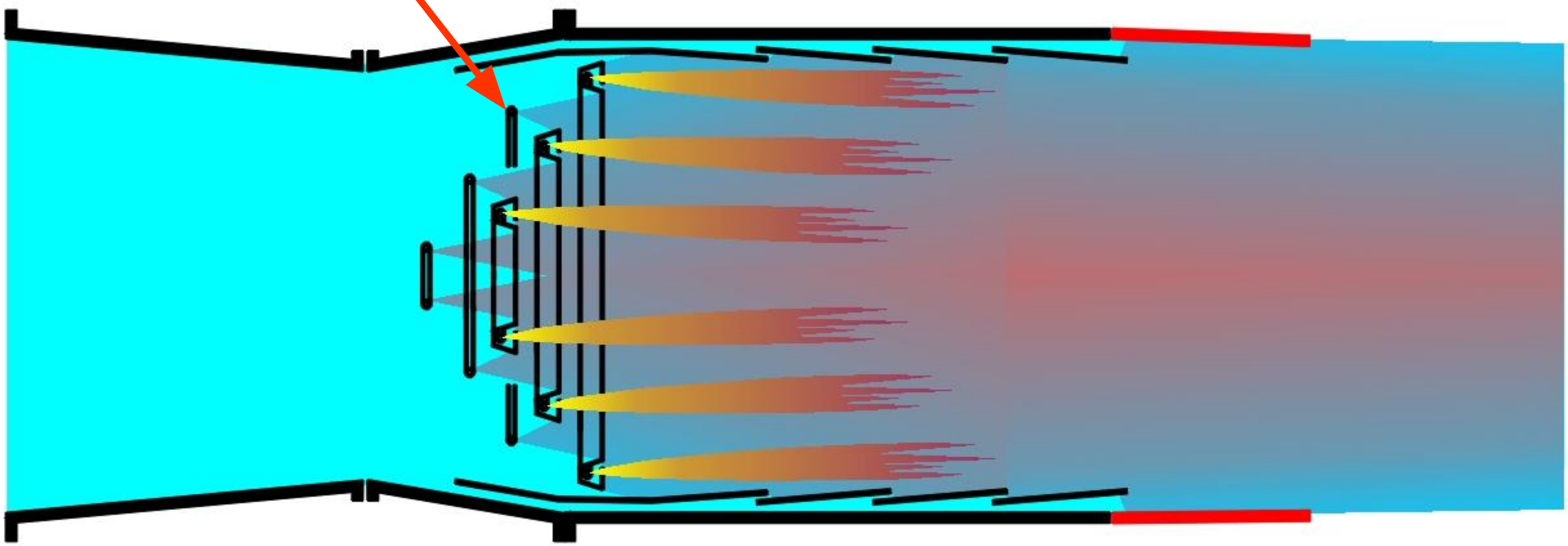
Reheat Starts with Vapour Gutters Spraying Fuel



Thrust Augmentation

Then Spray Tubes add more
fuel to combustion process

And Variable
Nozzle ‘Opens’

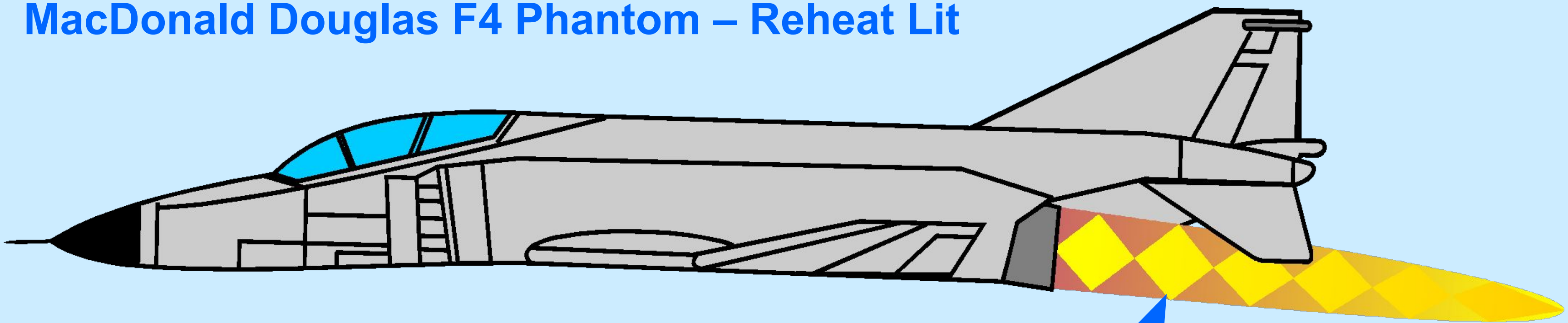


This is to prevent higher jet pipe pressure

to ensure that reheat has no effect on jet engine

Thrust Augmentation

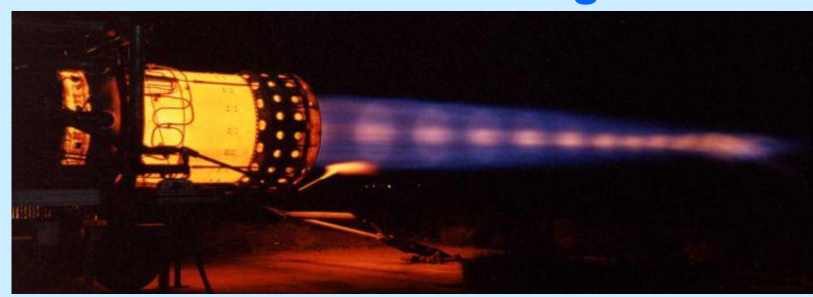
MacDonald Douglas F4 Phantom – Reheat Lit



Visible ‘Shock’ waves appear in exhaust plume!

FA18 Hornet on Carrier Take-off – Reheat Lit

Does the Afterburner get hot?



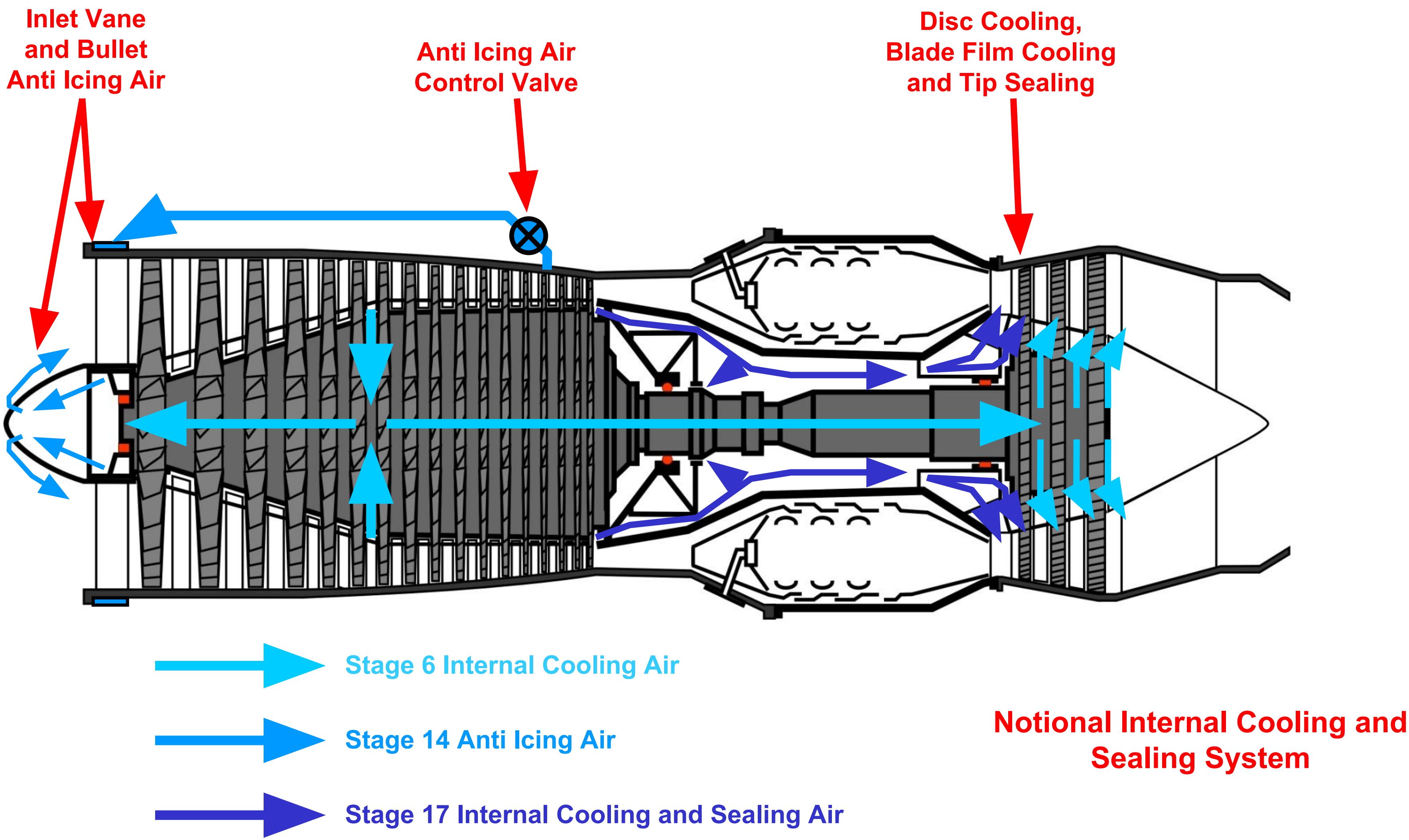
Just a little bit!!

Use of the afterburner is restricted to take-off and combat only (except Concorde of course) due to the extremely high fuel consumption rate

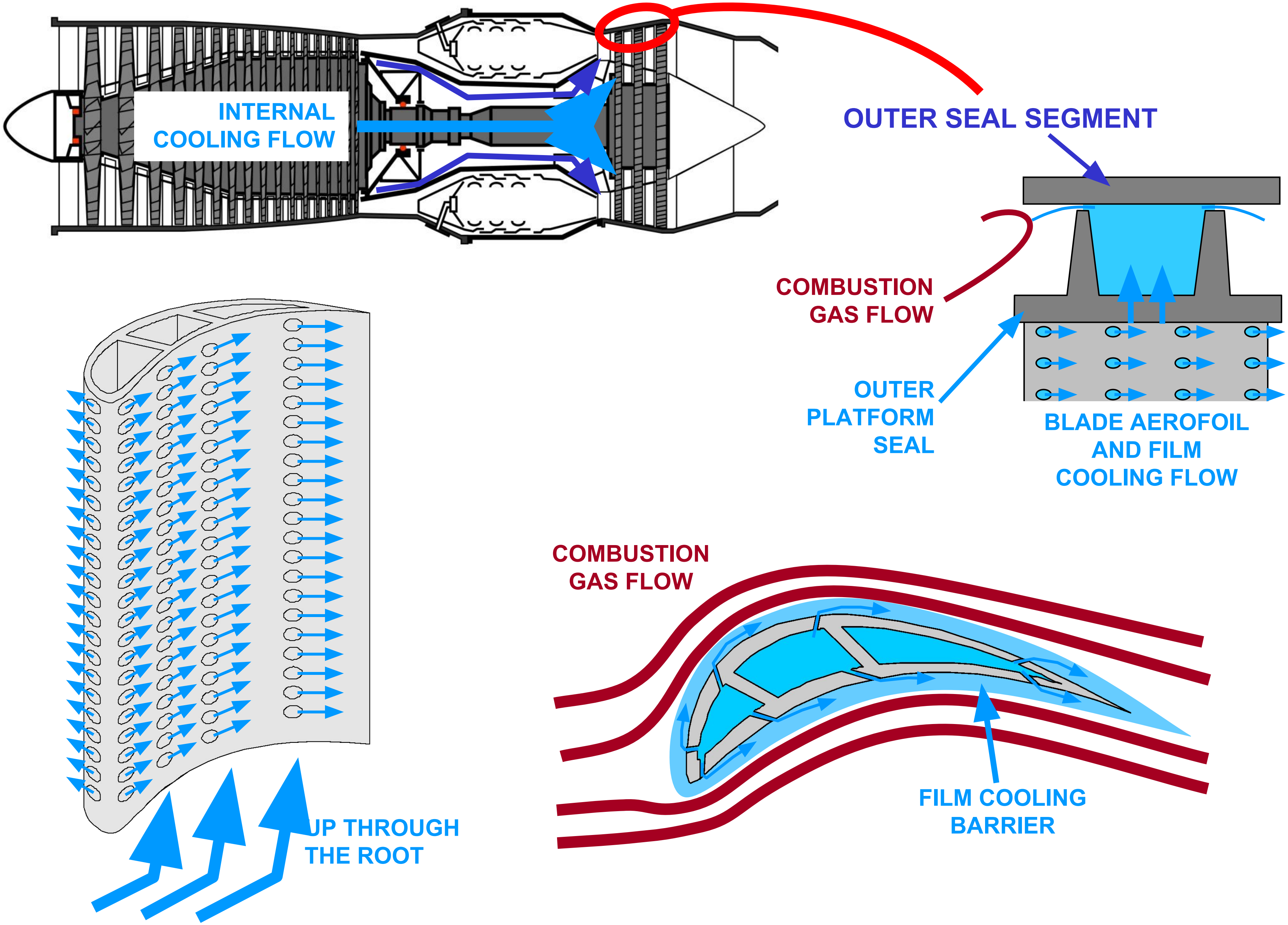
Thrust Augmentation

JET ENGINE INTERNAL COOLING AND SEALING

PREVENTING BURN OUT OF THE HOT SECTION



JET ENGINE INTERNAL COOLING AND SEALING

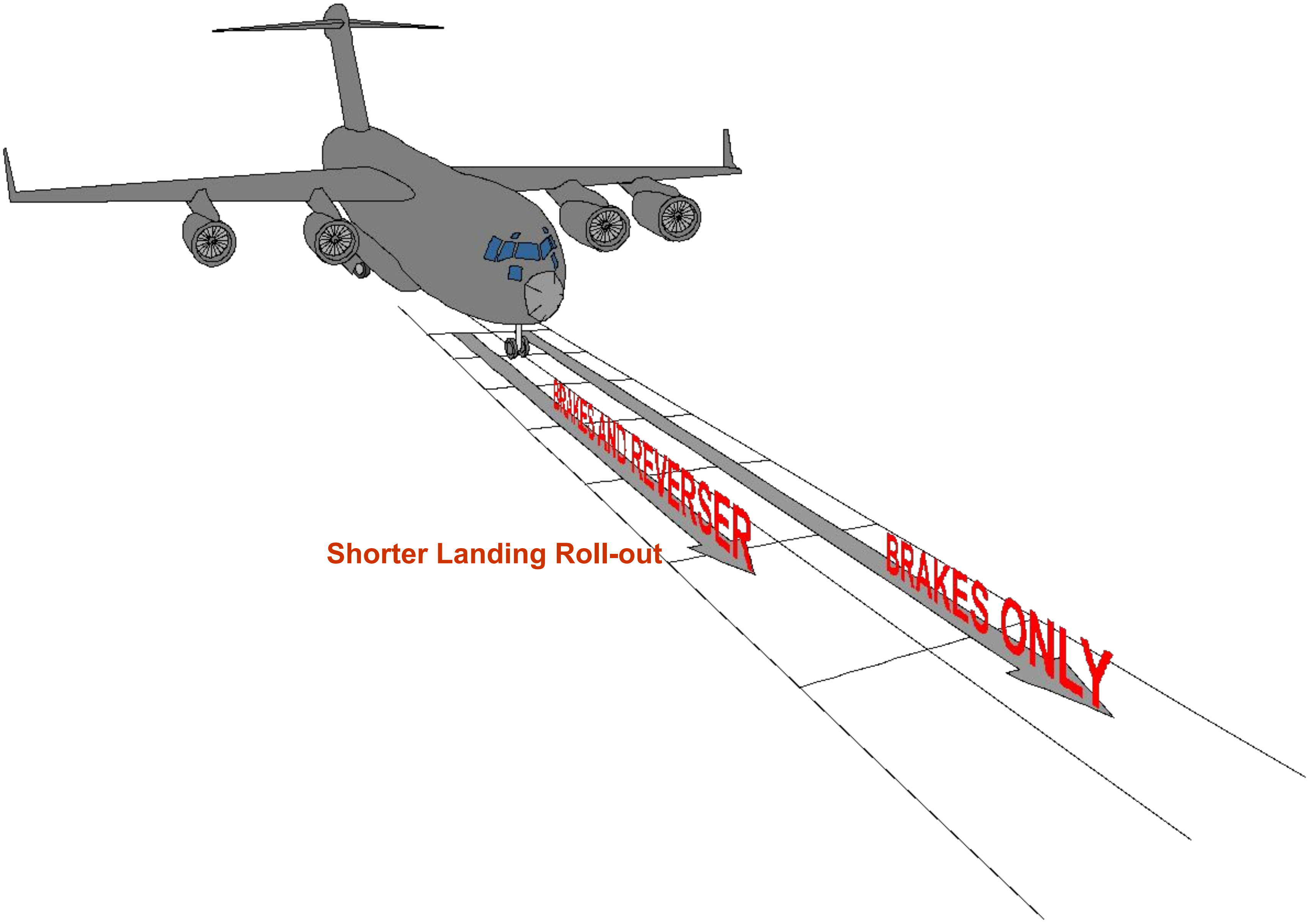


JET ENGINE INTERNAL COOLING AND SEALING

JET ENGINE THRUST REVERSERS

Putting the Brakes On

Thrust Reverser Effect



Shorter Landing Roll-out

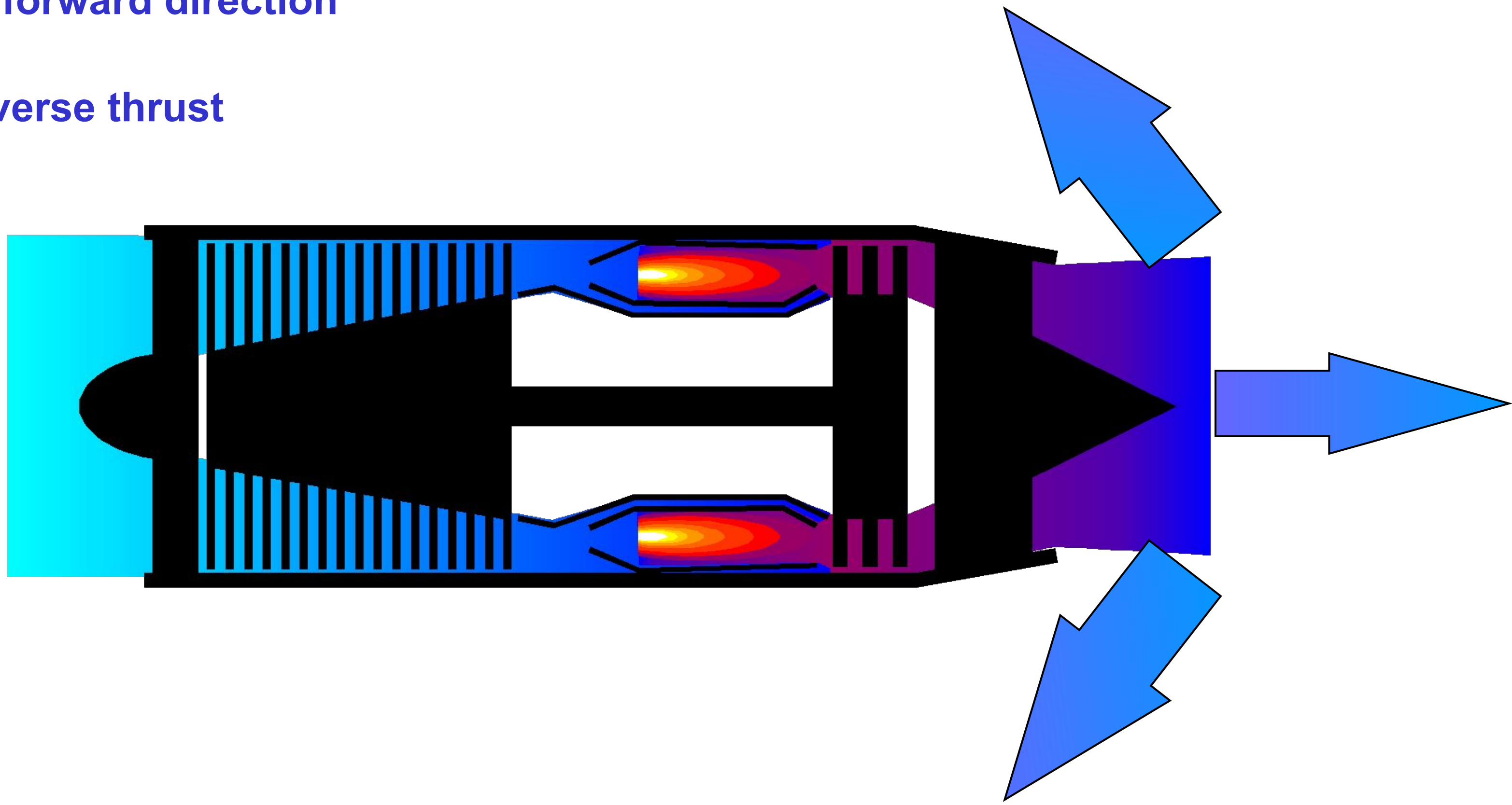
JET ENGINE THRUST REVERSERS

BASIC PRINCIPAL

Divert some or all of the rearward directed jet

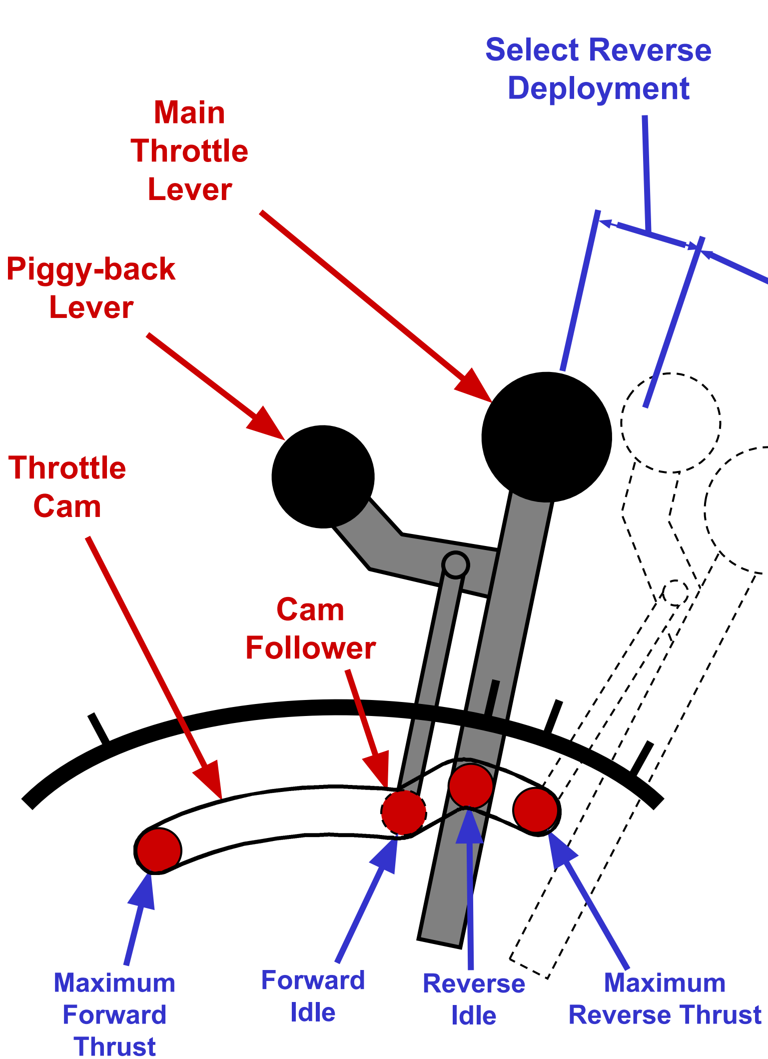
in an almost forward direction

providing reverse thrust

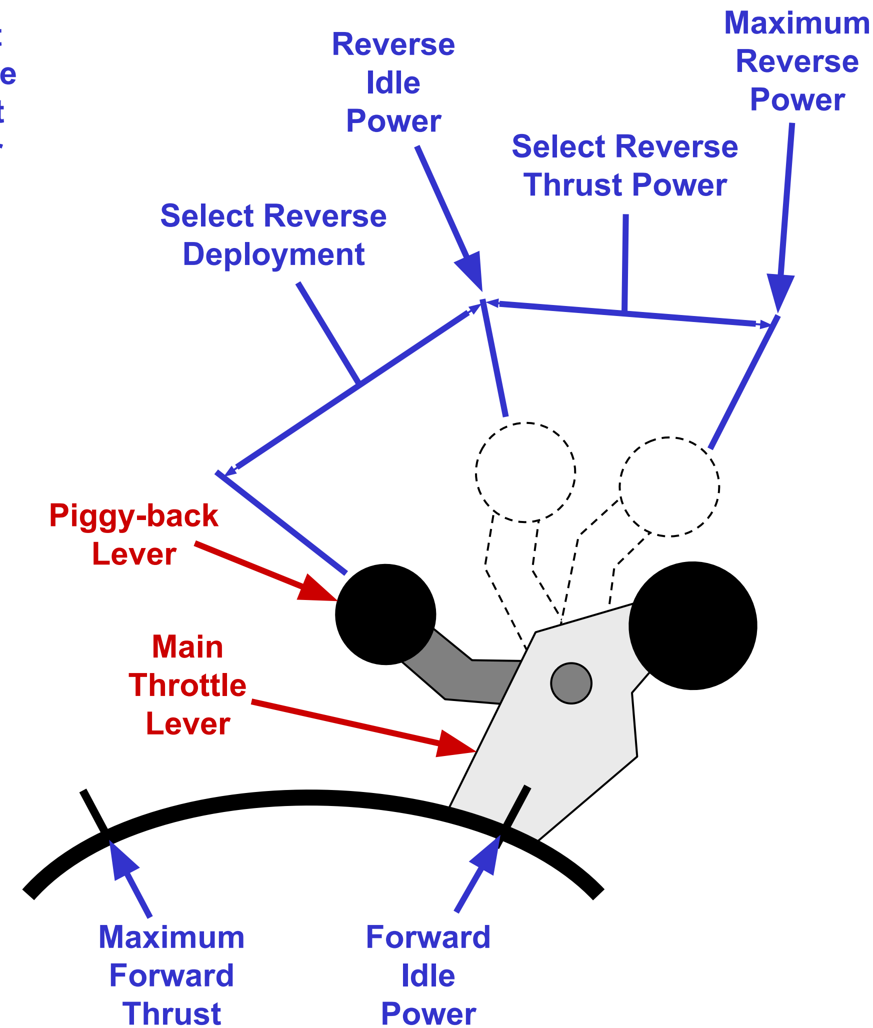


TRANSLATING COWL TYPE

JET ENGINE THRUST REVERSERS



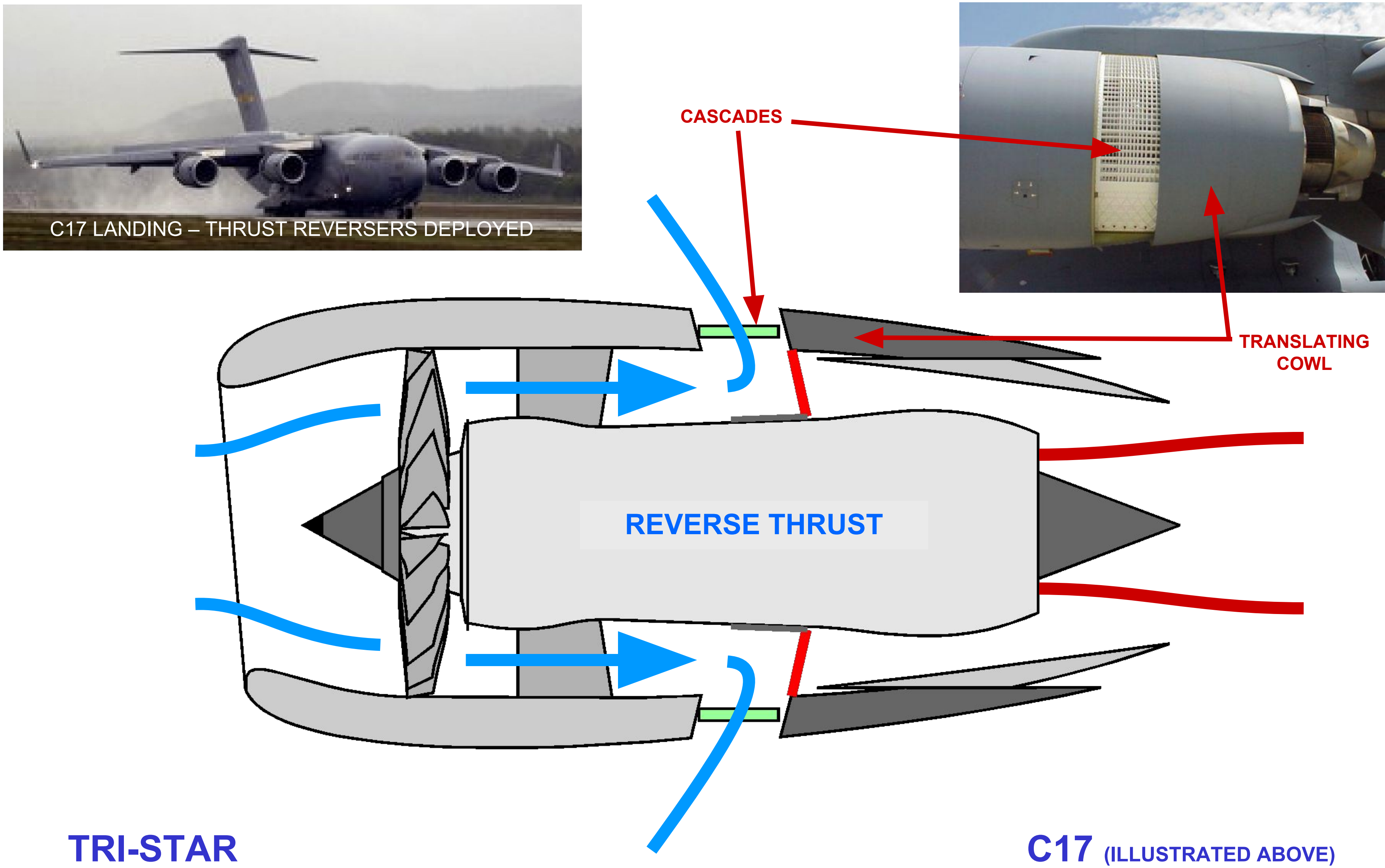
Electro/Hydro Mechanical Control System



FADEC Control System

Selection, Sequencing and Safety Features

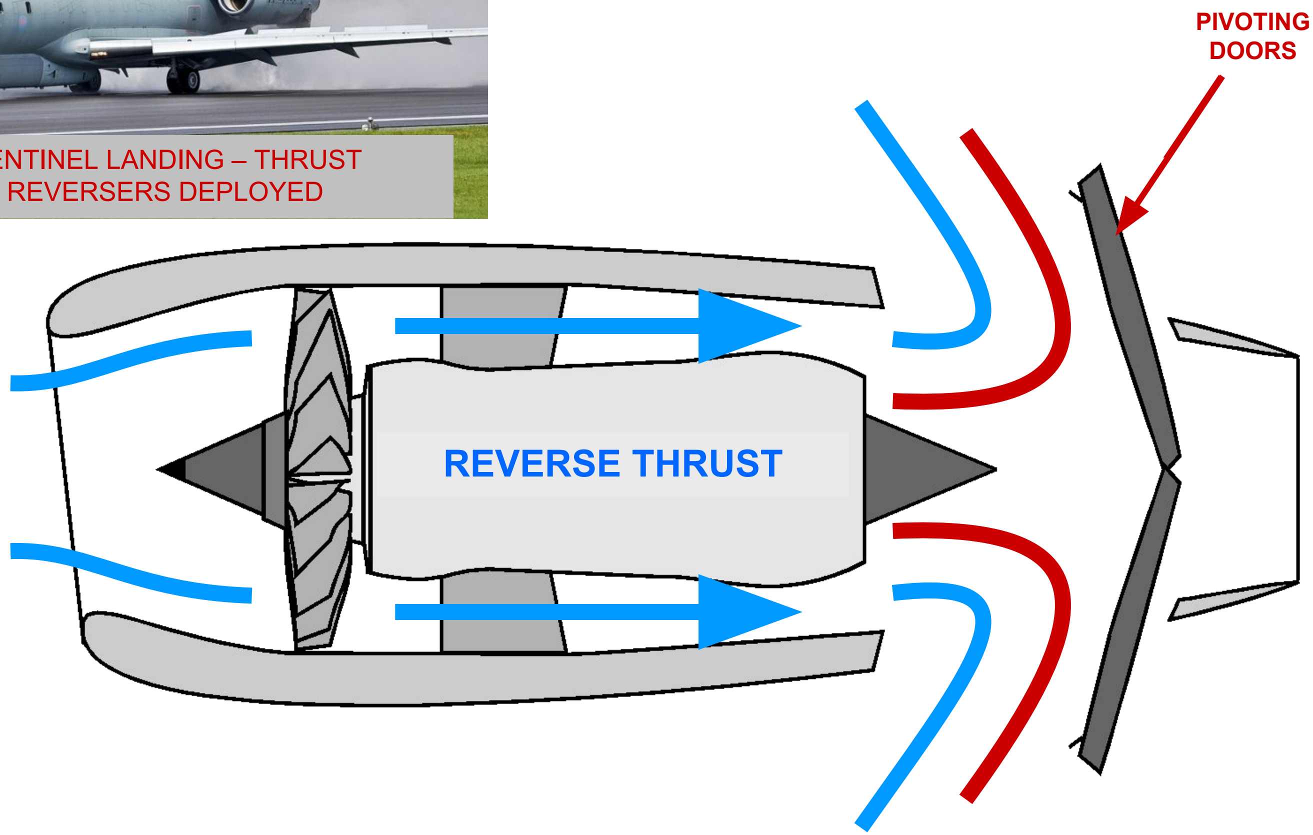
JET ENGINE THRUST REVERSERS



TRANSLATING COWL TYPE

JET ENGINE THRUST REVERSERS

SENTINEL LANDING – THRUST REVERSERS DEPLOYED

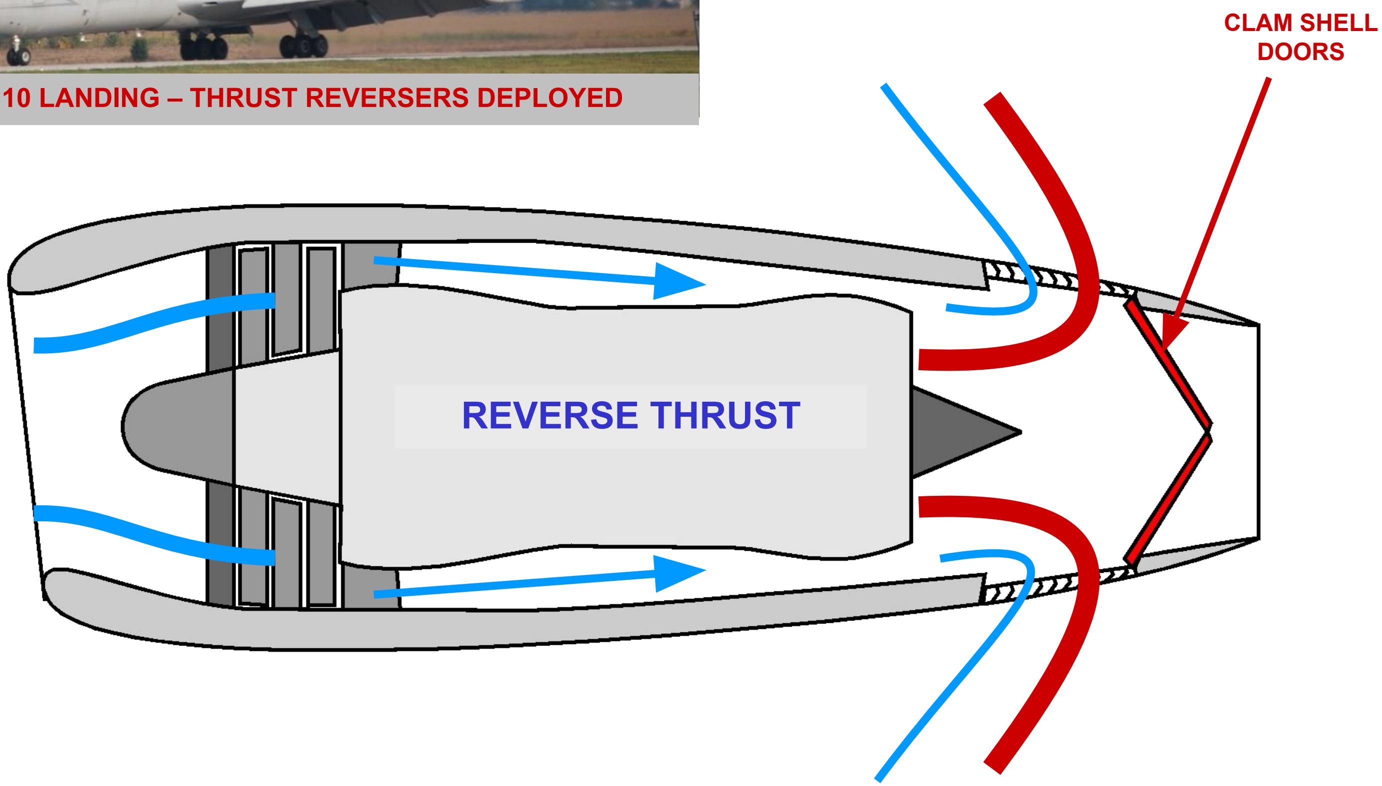


SENTINEL (SHOWN ABOVE)

PIVOTING DOOR TYPE

JET ENGINE THRUST REVERSERS

VC10 LANDING – THRUST REVERSERS DEPLOYED

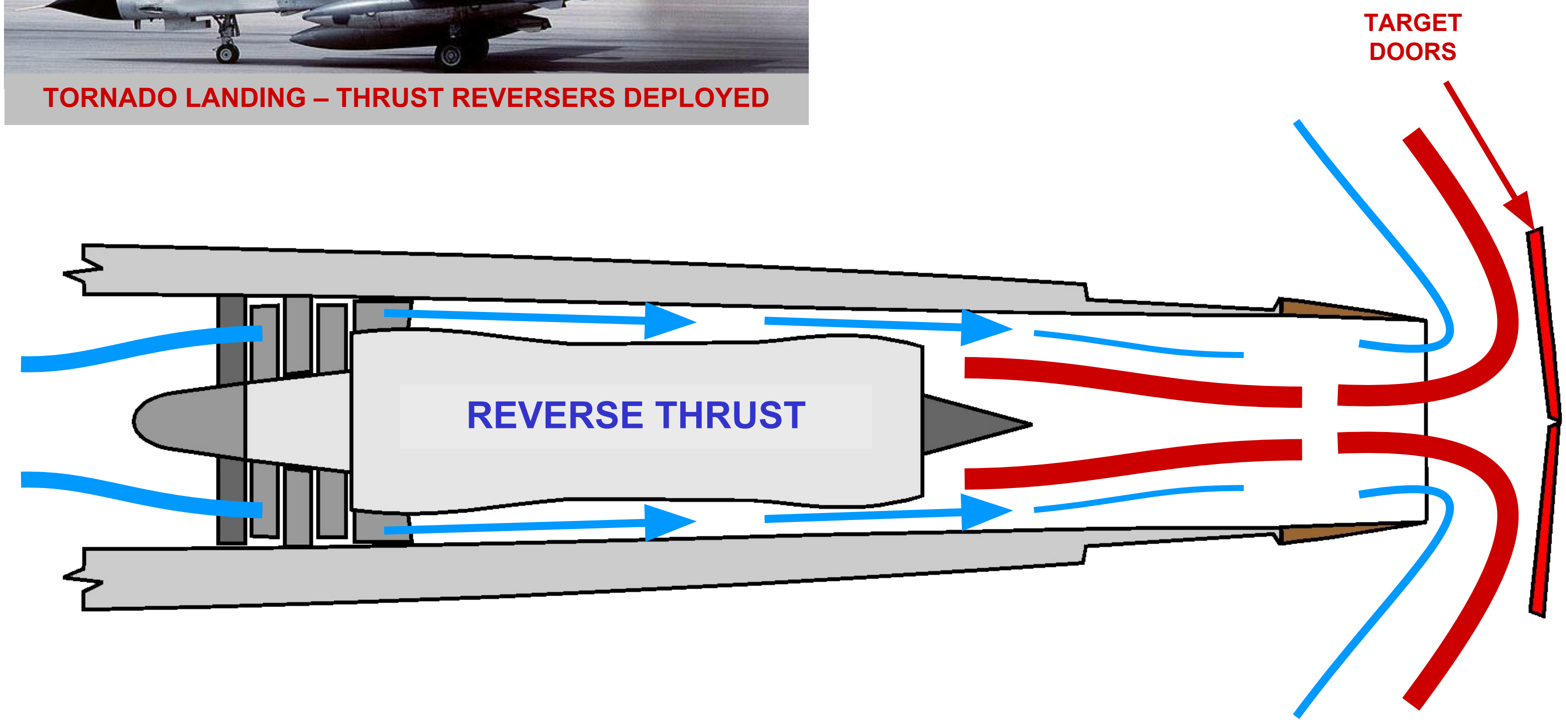


VC10 (SHOWN ABOVE)

‘CLAM SHELL’ DOOR TYPE

JET ENGINE THRUST REVERSERS

TORNADO LANDING – THRUST REVERSERS DEPLOYED



TORNADO (SHOWN ABOVE)

TARGET DOOR TYPE

JET ENGINE THRUST REVERSERS

HERCULES

REVERSE PITCH PROPELLER

SEE PROPELLER SECTION FOR DETAILS

VULCAN

DROGUE PARACHUTE

OTHER METHODS OF BRAKE ASSIST

JET ENGINE THRUST REVERSERS